CRANFIELD UNIVERSITY

YUHUI SUN

CAPTURING THE CHEMICAL MILLING PROCESS CAPABILITY

SCHOOL OF APPLIED SCIENCE
Msc By Research

Master of Science
Academic Year: 2010 - 2011

Supervisor: Dr Yuchun Xu
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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science

ABSTRACT

In order to support the chemical milling process decision making on the new product producing, a process capability model is developed. The model uses process factors, capability measures and the assessing methods to capture the present chemical milling process capability on the new products. The inputs for this model implementation include a set of common product and production information. This model covers a wide range of capability measures, which are recommended by the manufacturing engineers.

Despite of traditional statistical capability indices such as Cp/Cpk, this research assesses the chemical milling process capability within the manufacturing system which consists of process, product and resource. The estimations about chemical milling process capacity and process efficiency are covered in the model's implementation.

Keywords:

Process Factors, Capability Measures, Capability Modelling, Chemical Milling Productivity, Aircraft Manufacturing.

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1 INTRODUCTION

1.1 Background

Aircraft manufacturing is migrating from metallic materials primary to composite materials primary. The composites in A320, one of the most popular commercial aircraft families, take about 10% of the structural weight. In new generation aircraft design and manufacturing, such as A350, composite materials have been applied to fuselage skin, fin and some other structural parts, see Figure 1-1 (Buckley, 2009) and Figure 1-2 (Vogelar, 2010). The total composite material in A350 takes more than 50% of the weight. B787 introduced composites at 50% by weight as well, see Figure 1-3(Hawk, 2005). It means that the demand on metal materials manufacturing goes down and demands on composite materials rise up. Composites are becoming the primary materials on fuselage skin, wing panels and other parts where used to be aluminium alloys.

It is well known that modern manufacturing industry is challenged by strict requirements of environment regulations and increasing cost of waste disposal, especially for chemical processes such as chemical milling, chrome acid anodizing and electroplating (PPRC,1997)(Morris, 2000). Meanwhile, the traditional chemical milling (CHM) process will face the challenges of decreasing production demand, average chemical waste processing cost increasing, and the new numeric control machine milling techniques' competing, see Figure 1-4(AEROLIA, 2010).

One of the impacts of the reduction of chemical milling parts is excess capacity of present production line, i.e. see Figure 1-5. There would be two options for taking reaction. First, introducing more products; second, processing the remained parts with outside cooperated resources. The airframe manufacturers may introduce more products into their existing chemical milling product line to deal with the excess capacity. In this case more customers' demands have to be satisfied, such as product specifications, delivery schedules and prices.

Otherwise airframe manufacturers perhaps find out subcontractor for low scaled chemical milling parts. Then the sub contractors' capabilities should be captured. However, the criteria are not limited to the product specifications, delivery schedules and prices during the sub contractors' selection. The three are mentioned as examples. In this research, questionnaires are used to capture measures for assessing the process capability.

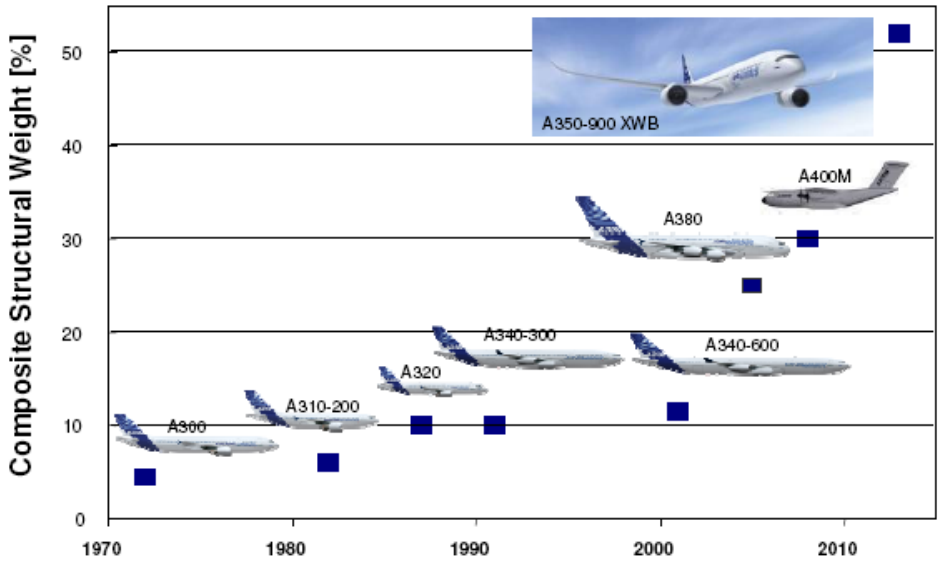


Figure 1-1 Composite structural weight developments in Airbus

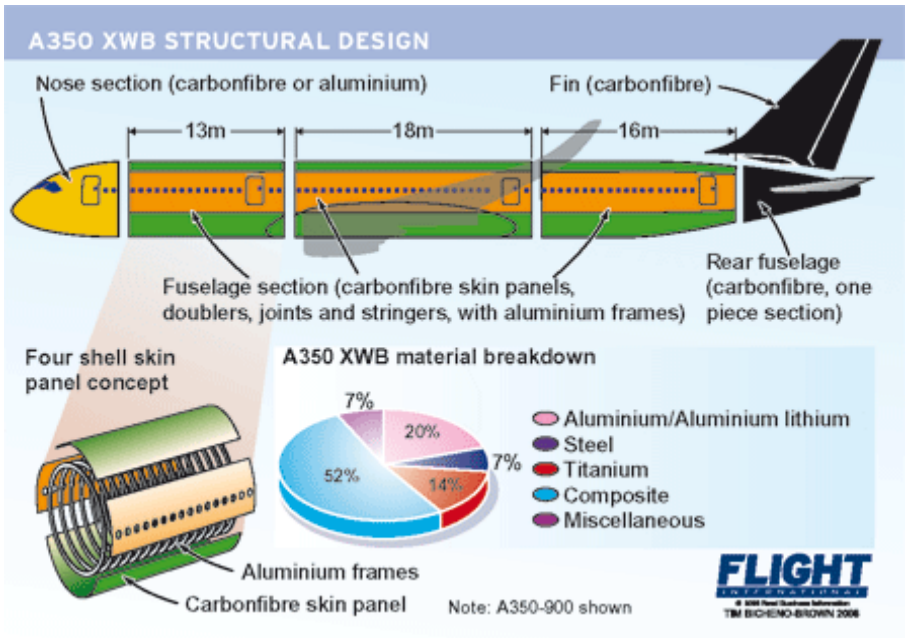


Figure 1-2 A350 Materials breakdown

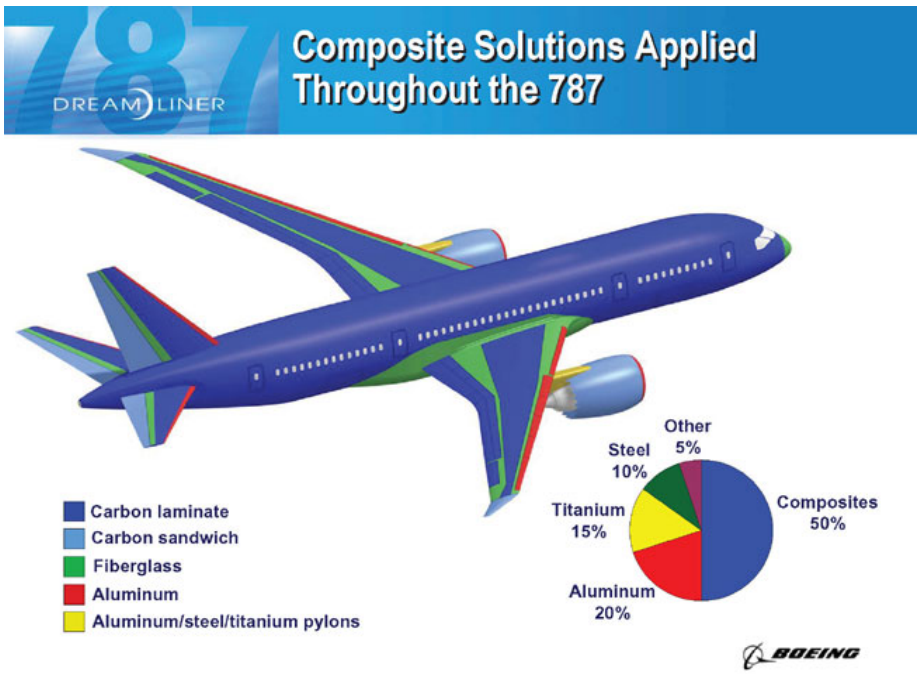


Figure 1-3 B787 Materials breakdown

Figure 1-4 Mechanical milling for 3D fuselage skin

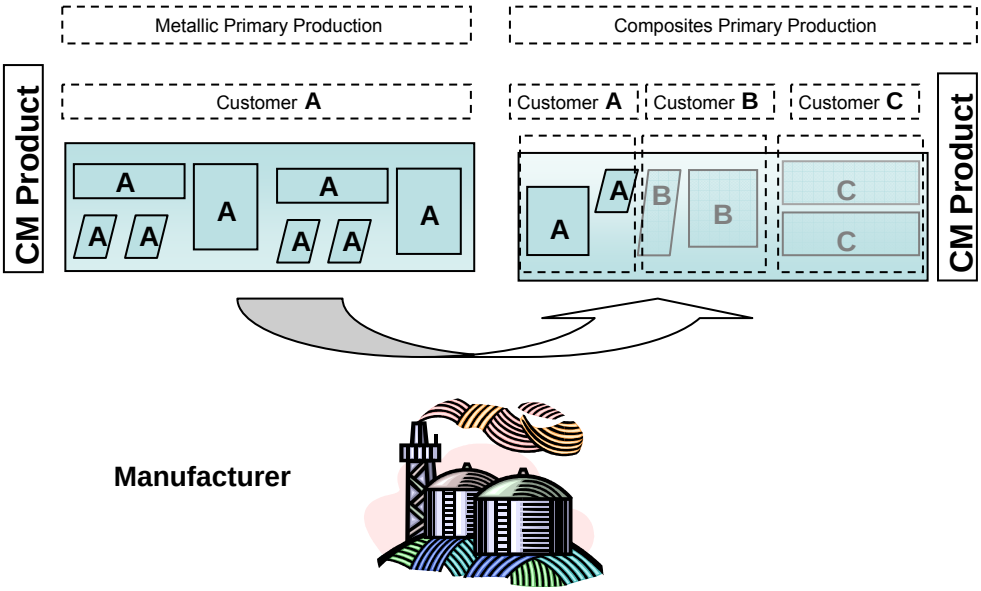


Figure 1-5 Impacts on chemical milling production line

1.2 Motivation and problem profile

In aerospace industry, the manufacturers of chemical milling process products very often need to decide whether launch specific product. However, there is no significant systematic tool to assess process flow, process feasibility and stability, manufacturing capacity and process economic with one integrated model.

Therefore this research is to develop a capability model to sufficiently support the decision making on whether launch the specific product, particulay the capability in this scenario means the achievements of existing proccess on the concerning producrt engineering requirements, product specifications, product demands.

1.3 Aim and objectives

The aim of this research is to develop a computer model for capturing and assessing the chemical milling process capability, so that the manufacturers can decide whether reasonable to take the order of specific products from customer based on their existing CHM process.

The project objectives are:

- Capture the measures for chemical milling process capability
- Identify the factors related to the CHM process capability measures.
- Develop assessment methods for the CHM process capability measures using the factors.
- Develop the chemical milling process capability model;
- Validate the model by using case study and experts' judgement.

1.4 Research scope

In Scope

- Chemical milling process capability on producing.
- Chemical milling process capability for parts made of aluminium alloy sheet.
- Process factors directly linking to product realization in accordance with specifications.

Out of Scope

- Chemical milling process capability for the design of aircraft parts.
- The impacts on environment.
- Capability of Operation design, capability of template design and fabrication.
- Process control factors for chemical milling process.
- Measures in project management (including labour capacity), quality management and administration performance.

2 METHODOLOGY

The methodology adopted in this research is shown as following:

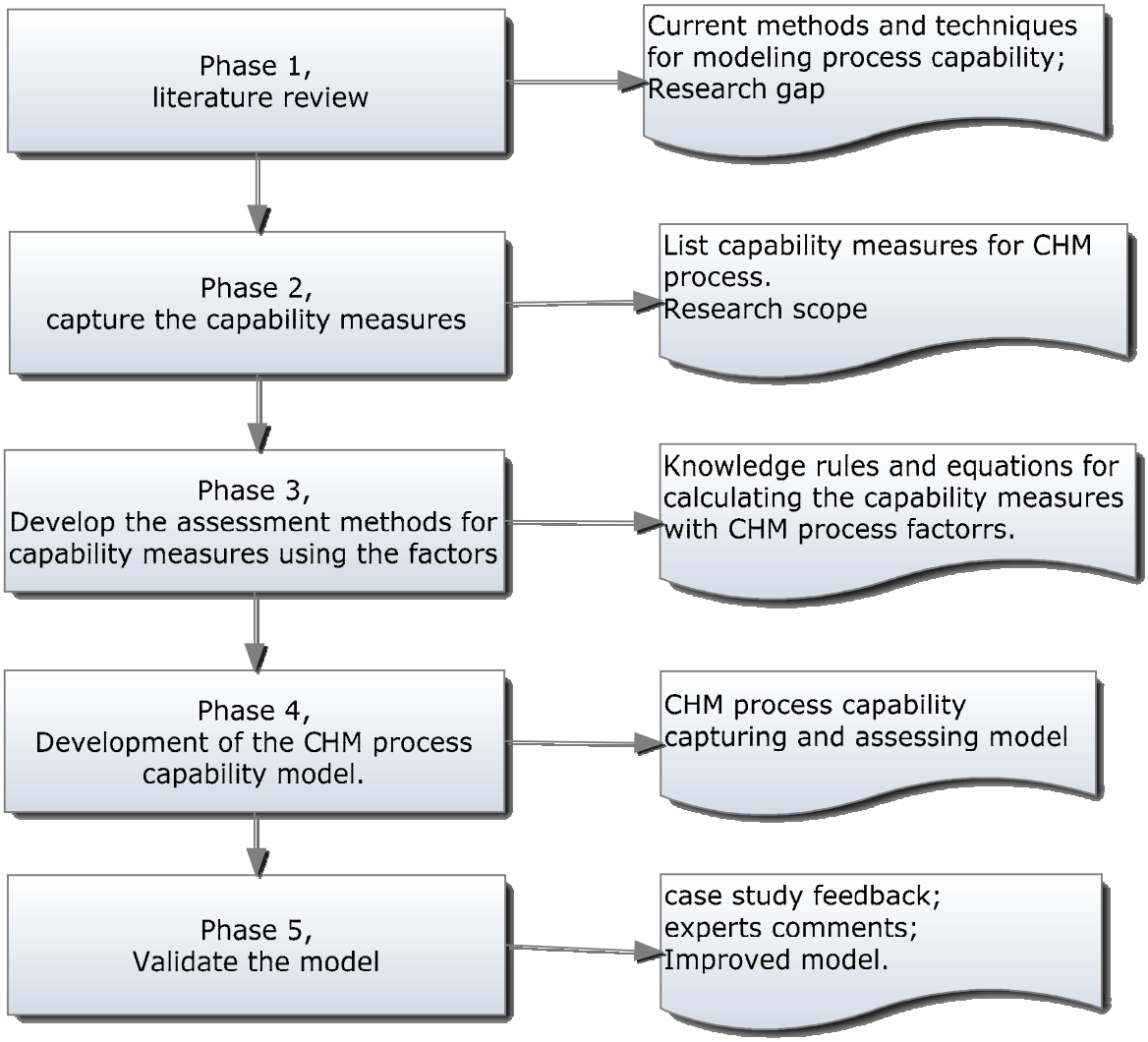


Figure 2-1 Methodology Introduction

The detailed tasks are conducted in each phase as below:

Phase 1, literature review

Review literatures in the fields of chemical milling process in aerospace industry, principles, capability capturing methods and manufacturing process presentation methods.

Phase 2, capture capability measures.

In this phase, send out questionnaires to understand industrial application measures during the process capability assessing.

The questionnaire answers need to be analyzed.

Classify the measures mapping in the research scope for modelling.

Phase 3, Develop the assessment methods for measures using the factors.

Identify the key process factors in each major chemical milling flow step by the knowledge reusing. The knowledge sources include publications and the industry practice experience.Map these factors to the capability measures captured in phase 2.

Transfer the knowledge of chemical milling process into application rules.Formulate the rules to the equations of calculating capability measures with processing factors.

Phase 4, Model development.

Define the inputs and outputs needed in the model

Implement the calculations of capability measures by using database in the formation of MS Excel®.

Implement the interface in MS Excel®.

Document the model development process.

Phase 5, Validate the model by actual example and case study.

Collect the actual product data of chemical milling process from industry, and input them to the model; and use them to validate the model.

Collect industry experts' comments about the capability assessing methodmodel and improve the model based on the comments.

3 LITERATURE REVIEW

3.1 Chemical milling process

Chemical milling process is a non-conventional machining process, which achieves the milling depth by controlling etching parameters in chemical solution processing tanks. The chemical milling process is widely used on ferrous, nickel, titanium, magnesium and copper alloys, and silicon (Swift and Booker, 2003). Despite of numeric control machining, chemical milling process removes material from the substrate by chemical etching. The capable processing material depends on the selected etchants.

Harris (1976), Griffin (2003) and Çakir (2007) classify the main processing activities to five steps: Cleaning, Masking, Scribing, Etching and De-masking.

Griffin (2003) listed four measures to assess processing quality including etching depth, pocket dimensions, surface finish and free of surface defects. The tolerance requirements of depth, pocket dimensions and surface finish are usually specified by product's engineering drawings. By controlling etching time, the required depth is achieved under a given etching rate. The pocket dimensions accuracy is determined by template tolerance and etch ratio. The etch ratio, which affects the chemical milling accuracy on the width direction, is considered during the templates' design. Surface finish is measured with roughness. Usually the surface defects measure is a visual inspection item to control surface defects during the production rather than chemical milling process performance itself.

Bralla (1998) recommended the depth tolerance ranges (Table 3-1) and pocket dimensions tolerance ranges (Table 3-2) for chemical milling product design. The surface finish could achieve 0.5 to 1.3μm by applying proper etchant. The general surface finish range for parts cutting to 6.3mm is 1.75 to 3.13 μm.

Table 3-1 Recommended Depth Tolerance

Depth of Cut, mm(in)	Tolerance, mm(in)
Up to 2.15 (0.085)	±0.025 (0.001)
2.16–3.05 (0.086–0.120)	±0.038 (0.0015)
3.06–3.94 (0.121–0.155)	±0.050 (0.002)
3.95–4.84 (0.156–0.190)	±0.064 (0.0025)
4.85–5.84 (0.191–0.230)	±0.076 (0.003)
5.85–7.10 (0.231–0.280)	±0.089 (0.0035)
7.11–8.65 (0.281–0.340)	±0.102 (0.004)
8.66–10.16 (0.341–0.400)	±0.114 (0.0045)

Table 3-2 Recommended Pocket dimension Tolerance

Depth of Cut, mm(in)	Tolerance, mm(in)*
Up to 1.3 (0.050)	±0.38 (0.015)
Over 1.3 (0.050)	±0.64 (0.030)

*Apply to the scribe-and-peel maskants.

However, the measures for chemical milling process are more than the allowable tolerance. The interference between the chemical milled surface and the assembling part surface may cause the unexpected grinding work in the subsequent assembly; see Figure 3-1(Griffin, 2003).

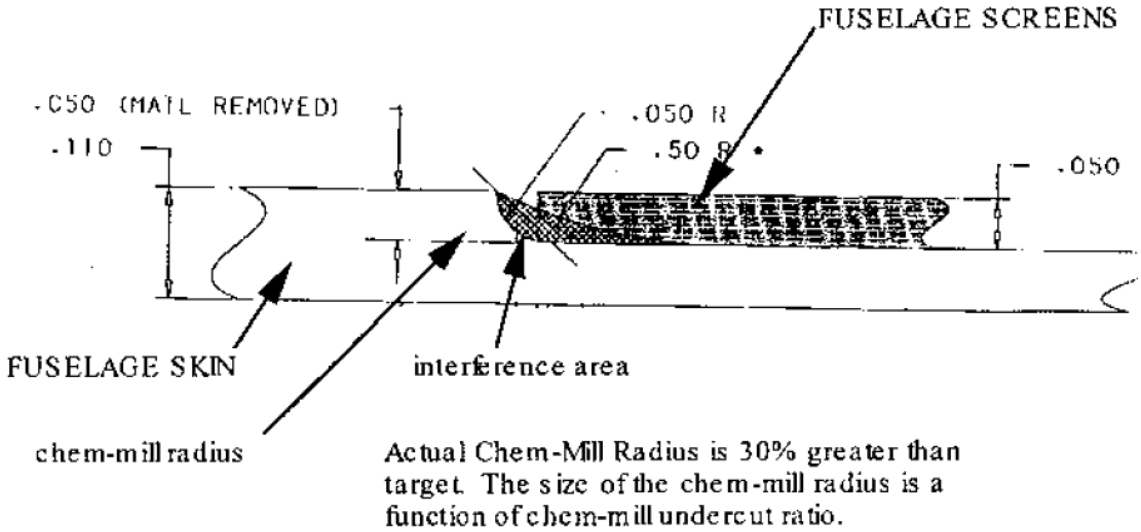


Figure 3-1 Fillet interference in chemical milling surface

The chemical milling process capability is also combined with former process and material characters. Chemical milling fabricates parts with selective surface areas etching. The capability indices such as dimension tolerance, stress deforming and roughness are significantly influenced by factors from process control, former panel metal forming and material selections during design. This should be aware of in capturing process capability.

Narisaranukul (1997) detailed the steps of chemical milling process, stress distribution, simulated the residual stress of material with finite factor analysis. The “Springback” effects after forming and chemical milling should be considered during design, process plan and fabrications. The Springback in stretch forming was illustrated with a Moment-Curvature diagram.

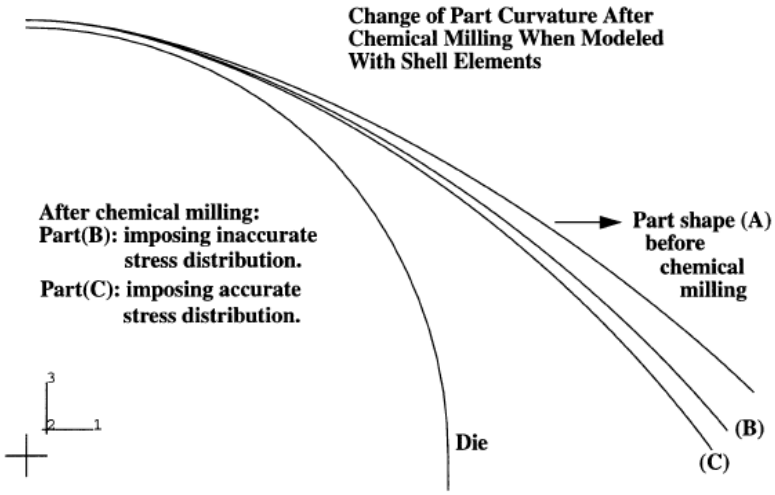


Figure 3-2 Springback effects after chemical milling
(Narisaranukul, 1997)

Francis (1966) spot the typical issues on certain aluminium alloys, which are non-uniform stock removal, stretch marks and rough etching. The causes of these issues and the effects of process factors were studied by the experiments. According to different aluminium alloys experiments results chemical milling process appears variety process performances for different material temper and former heat treatments. The majority structural material selections involved with chemical milling in now days aircrafts design does differ from these Howard's report studied. But the leads linking to material type, material tempers and former heat treatment in his study open a window of process capability factors.

Knowledge summary

- Chemical milling process includes five major steps,
- Chemical process capabilities are influenced by material characters, subsequent processes and former process.
- Chemical milling process accuracy on pocket dimensions is influenced by template design.

Comparing to conventional machining processes, one of the most obvious benefits of this process is weight reduction on the large panel parts and complex shape parts (Swift and Booker, 2003). Another one is lower cost level on equipments than conventional machining process on tools (Bralla, 1998).

Contract to the manually processing, Nof et al. (2009) mentioned the chemical milling application in the automated part fabrication system. Groover (2006) illustrated the chemical process capability on the “work part” geometric features.

Apparently, chemical milling is not the only process which achieves the weight reduction on large structural parts. NASA (1985) established a study about pre-machining plus stretch forming process method on the large external tank parts of an aerospace vehicle. Comparing the processing route of stretching plus chemical milling, the proposed processing route reduces near 50% cost on estimated man-hours. The actual man-hours, which base on the part size and complexity, are proposed as cost index for the present stretching and chemical milling. The labour standard data collected from Boeing are used for the cost estimation of pre-machining and stretch forming. The cost level depends on the total man-hours and rates. The set up time and run time consist of the total man-hours of each part. The man-hours cost index could be explained from above as:

Equation 3-1 Man-hours Cost

$$C_m = R \times \sum_{i=1}^{n} (ST_i + RT_i)$$

Where Cm stands for man-hours cost level, Dollars;

R stands for man-hours’ rate, Dollars per hour;

STi stands for set up time of part i, hours;

RTi stands for run time of part I, hours;

i stands for 1, 2, 3… n;

n stands for the part quantity.

In practical way, Harris (1976) introduced the chemical milling process economics with the capital costs and operating costs. The capital costs are fixed that could not clearly reflect the chemical milling different cost level on different products. The operating costs are sensitive to products and processing methods. It consists of man-hours and materials cost.

The man hours cost is estimated according to the part features, process methods, and an operation time allowances data see Figure 3-3(Harris, 1976).

The material cost is estimated with part surface area, weight reduction, process methods and a group of material usage-cost data, see Figure 3-4(Harris, 1976)

Both of the operation time data and material cost estimation data are based on process methods level. For particular operating cost estimation, the data need to be verified and modified according the actual application.

<u>Knowledge</u>

Etching flow includes De-masking and etching.

Etching method includes alkaline base and acid base.

Etchant constituents and temperatures determine the performance of surface finish and pocket dimensions.

The operating cost could be used as cost index of chemical milling process.

The following literature review consists of several major parts related to capturing process capability, which are SPC, process modelling, combined processes capability and the delivery of captured process capability.

TABLE 10.3

Time allowances (minutes) for operations involved in chemical milling most materials†

	Flat about 1 m^2	Flat about 5 m^2	Formed <1 m^2	Formed >5 m^2
(a) Degrease and pickle (min m^{-2} surface area)	7	2	7·5	2·25
(b) Apply maskant plus handling (min m^{-2} surface)	18 8	3 3	18 8	3 3
(c) Check maskant/repair (min m^{-2} surface)	5	5	5	5
(d) Template handling (min per template)	4	8	5	10
(e) Scribing (m min^{-1})	2	4	1·5	3
(f) Maskant peeling (min m^{-2} removed)	20	20	20	20
(g) Etching				
handling	3	6	3	6
rotating (min m^{-2} surface)	—	0·5	—	0·5
(h) Thickness check (min per step)	1	3	1	3
(i) Maskant stripping				
handling (min per part)	4	20	5	24
peeling (min m^{-2} removed)	4	4	5	5

(† For one step depth, low tolerance on remaining metal thickness.)

Figure 3-3 Operation time allowances estimation

TABLE 10.4

Approximate materials costs for aluminium chemical milling

Stage in process	Rate at which material used	Cost per unit quantity of material (1974 prices) (£)	Cost related to part dimensions (£)
Alkaline degrease	0·045 kg m^{-2}	0·28 per kg	0·013 per m^2
Pickle (alternative to de-oxidize)	0·045 kg m^{-2}	0·028 per kg	0·0013 per m^2
Maskant	0·91 m^{-2}‡	0·65 per l	0·58 per m^2
Toluene	0.31 m^{-2}	0·175 per l	0·053 per m^2
Etchant (NaOH)	3 kg per kg Al dissolved	0·08 per kg	0·24 per kg Al dissolved
De-smut	0·045 kg m^{-2}	0·094 per kg	0·0042 per m^2
Demask solution	0·42 l m^{-2}	0·244 per l	0·103 per m^2

‡ For coating 0·25 mm (0·010 in) in thickness.

Figure 3-4 Material cost estimation data

3.2 Capturing the process capability.

There are three domains in manufacturing system, which are product, process and resource. The process resource includes such as machine, facilities, working shop and labour. The corresponding processes realize product through resource.

Algeo (1994) reviewed the main representing methodologies of manufacturing process capability and capability information before 1994, most of which focus on the resources than product and process. These representations are based on the structure of "domain models plus database". The model structures could be summarized as Table 3-3.

Table 3-3 The domain model frameworks

Domains of model applications	Representing methodology	Techniques
Process planning system	Consists of three models: Manufacturing Resource Model Plan Formulation Model Process Specifications Model	ALPS Machine Capability Language L_m
Functional and Information Modelling	Consists of two models: Implementation model Information model (product, process and factory)	IDEF0 EXPRESS(1) Two-stage process model

(1) EXPRESS is a standard data modelling language for product data, called out by ISO10303-11.

Molina and Bell (1999) presented a flexible high performance machining line with an object oriented information model. What consist of its framework are manufacturing processes, manufacturing resources and manufacturing

strategies. This model does not only have general applicability but also provision of reliable manufacturing information and necessary knowledge. The information enquiries of process planning, scheduling, selection and related decisions are supported by manufacturing model in production life cycle wide. These functions are achieved by four levels modelling configuration, which are factory level, shop level, cell level and station level. In order to capture and represent manufacturing information related to process and resource, the description on each level includes strategic decisions, operational rules and performance measures. Process capability at station level is defined as the set of processes which can be done by target machines, see Figure 3-5(Molina and Bell, 1999), and the process performance measures are *cost, lead time* and *tolerances*. At the implementation stage, an object-oriented database was developed and used to represent capabilities of the modelling objects. The results demonstrated that prototype manufacturing information model could respond users' querying at any required level.

The advantages of Molina and Bell's process model are generic application and synthetic expression of manufacturing facility. However, there are disadvantages, where knowledge is delivered to users in pieces of information more than applying in the presenting.

In order to build up well communication between different disciplines, Nielsen (2003) identified and defined the framework of information requirements for process planning in the concurrent engineering environment. Nielsen's information model bases on the product, process and resource domains. Both the links and interfaces were represented among the product model, manufacturing process model and manufacturing resource model. One important concept in Nielsen's thesis is the modularization of process information, which aims to support general application, see Figure 3-6(Nielsen, 2003).

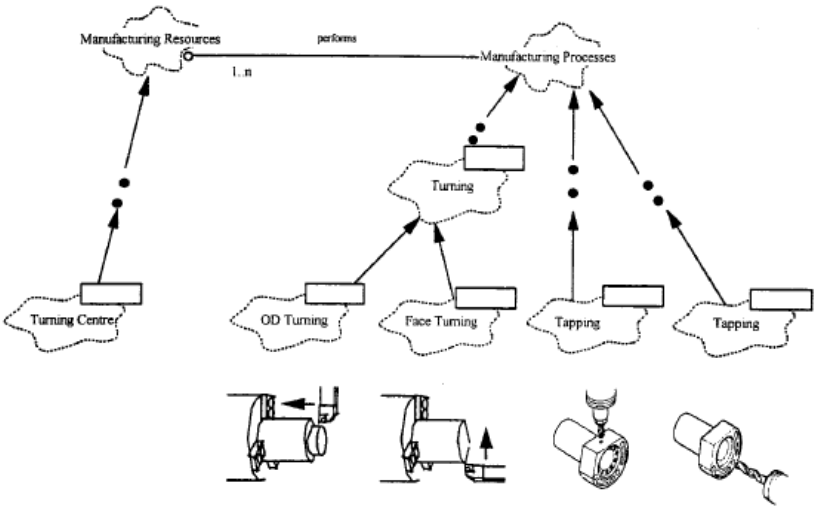


Figure 3-5 Modelling the process capability of a turning centre

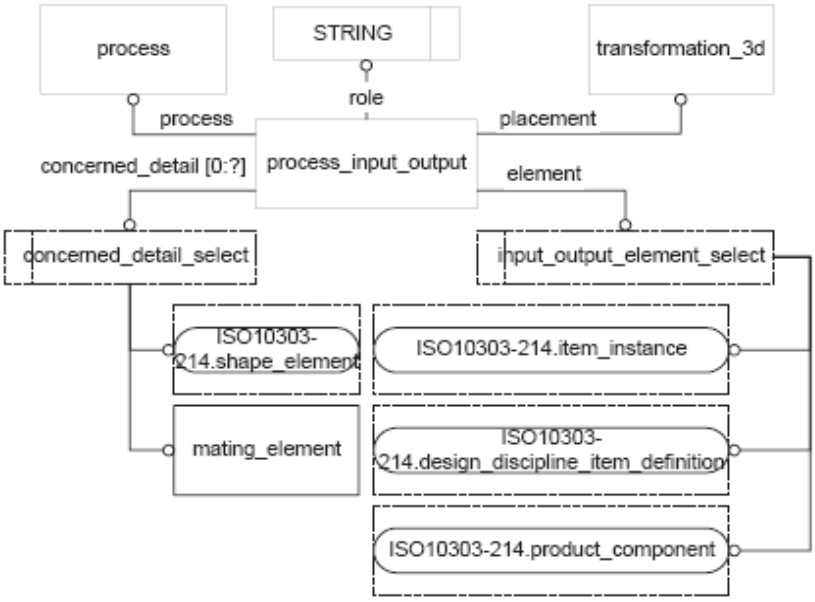


Figure 3-6 Modelling input and output of a process

Summary of this sub section:

- The process capabilities could not be isolated from process resources. They have to be captured from the physical measurable.
- The process capabilities vary due to different operational strategies of process resources.

There are generic standards in the process capability representing. Molina's model mentioned above applies database, while Nielsen introduced "information path" according to the relative ISO standard and its guideline procedures.

3.3 Assessing the process capability

In order to capture the process capabilities which are linking to customers' specifications, Juran and Gryna (1980) firstly gave the definition of capability ratio.

$$Capability \quad ratio = \frac{6\sigma \quad \text{variation}}{tolerance \quad width}$$

Actually, Statistical Process Control (SPC) method is one of the major process capability assessing methods, which assess certain process capability on customers' specification limitation range with statistical indices.

There are much more process capability indices in the field of statistical process control (**SPC**), such as C_p, C_{pk} and C_{pm}. Palmer and Tsui (1999) reviewed and interpreted these capability indices. C_p means a range within which the process performance is respected to deliver. C_{pk} shows the capability loss due to k. The k is the process mean deviation from the midpoint of C_p. The higher C_{pk} value shows the smaller process capability range. C_{pm} uses the loss function formulation to express how process mean fits the target value. When the process mean moves close to target value, C_{pm} increases up to C_p. The target value could be selected from any point within C_p range. That enables the process capability to be measured from asymmetric specification ranges. The variation of different process capability indices are also used to direct process improvements. Table 3-4 is adopted from Palmer and Tsui (1999), C_{pl} or C_{pu} is used to measure the distance between process mean and one-sided customer specification limitation (lower or upper). The C_{pm} (a), a modification of $C_{pm,}$ adds the factor "a" to adjust the weight of the square of process bias.

Table 3-4 Recommended capability indices for process improvements

Customer specification	Current proportion conforming	Recommendations use
One-sided	-	C_{pl} or C_{pu}
Two-sided	<95%	C_p, C_{pk} and k
Two-sided	≥95% and ≤99%	$C_{pm}(a)$ and C_p
Two-sided	≥99%	C_{pm} and C_p

The National Institute of Standards and Technology (NIST, 2010, section 6.1.6) published an engineering statistics handbook including various process capability indices. It is also aware that most of these capability index estimates need a large group of samples from independent data values. As the capability indices in SPC rely on normal distribution, NIST (2010) introduced the method of transforming the data to approximate normality for non-normal data. A popular approach recommended is Box-Cox transformation.

Morris and Watson (1997) summarized the SPC statistical tools such as Chi-Square Test, Hypothesis Testing and F-tests to measure chemical batch process performance and predict the process potential. The application of Hypothesis Testing, F-tests and One-Way Analysis of Variance Test on Excel spreadsheet is demonstrated as well.

Since the usage of these tools may not be efficient enough for decision makers due to the large groups of data demands, the alternative solution, X bar chart and R chart, could be used as the measures of process variance control. The X bar chart expresses if the concerning process is within the control limits; R chart expresses if the process variance is within control limits. These applications could be achieved on small sample size (less than ten). Figure 3-7(NIST, 2010, section 6.3.2) introduces the typical control charts and the assess rules (from

Western Electric Company Rules). The relative equations for X bar and R charts are list as follow (NIST, 2010):

Equation 3-2 X-bar chart UCL

$$UCL = Xdoublebar + A_2 Rbar$$

Equation 3-3 X-bar chart CL

$$CL = Xdoublebar$$

Equation 3-4 X-bar chart LCL

$$LCL = Xdoublebar - A_2 Rbar$$

Equation 3-5 R chart UCL

$$UCL = RbarD_4$$

Equation 3-6 R chart CL

$$CL = Rbar$$

Equation 3-7 R chart LCL

$$LCL = RbarD_3$$

Where UCL means upper control limit;

CL means the Centre line;

LCL means lower control limit;

X double-bar stands for the average of sample means;

R bar stands mean of the sample ranges;

A_2, D_3, D_4, refer Table 3-5 .

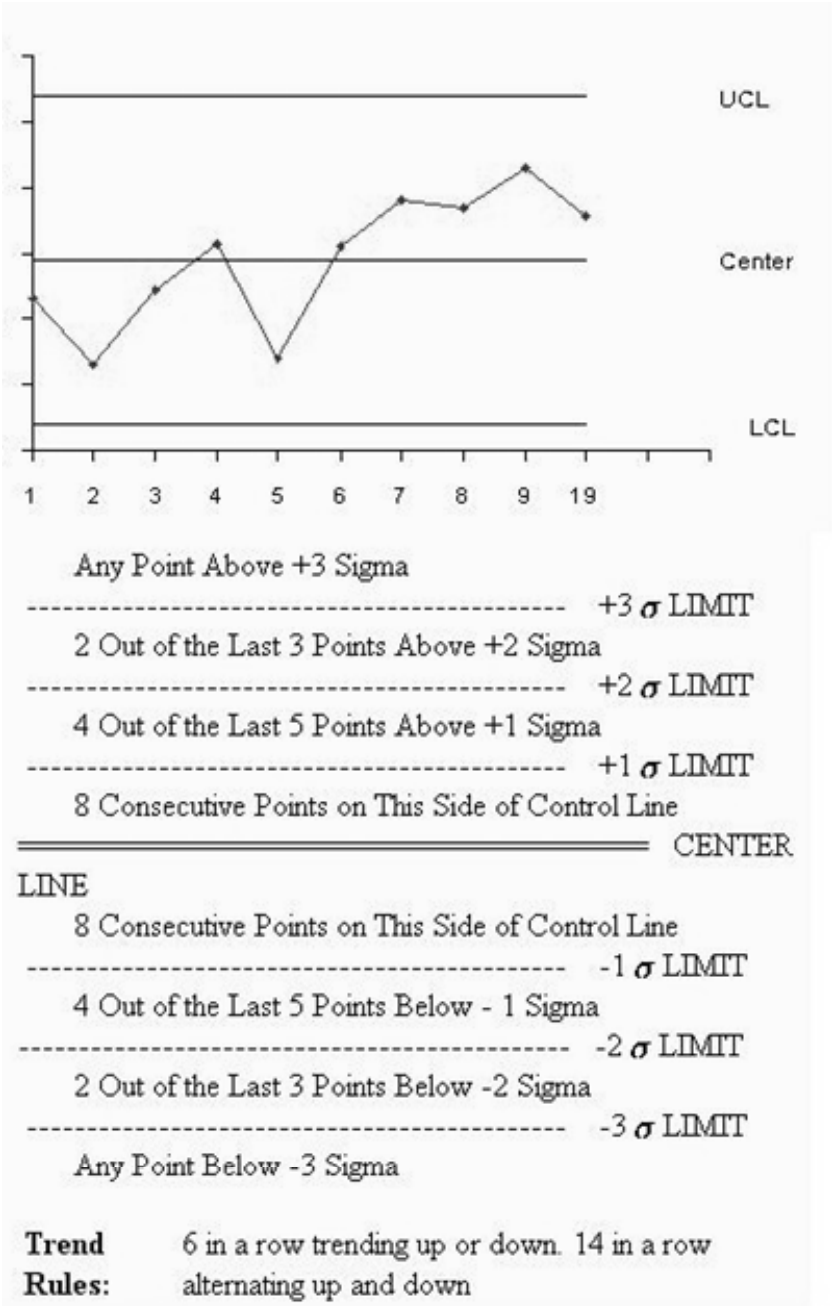


Figure 3-7 Typical control chart and assess rules

There is one important rule for the X-bar and R charts application. Failures on process stability control do not mean the failure on process capability. That is because of the different limits applied. The process may till be capable while it is not stable. However, the process capability indices preset an effective process only when the process is stable.

In order to rapid assess the process capability indices of Cp and Cpk, DAU (2008) established a calculation model with Excel spread sheet. This model bases on the inputs of X double-bar, R bar, n (sample size), specification value and its limits. The rules for assessing process capability are shown in Table 3-6. A plot is used for simulating the normal distribution of samples, see Figure 3-8. And the d2 values used in the model are listed in Table 3-5 (NIST, 2010). The major equations involved in this model are listed as below. The sample quantity is highly recommended higher than 30 in order to get a reasonable a reasonable margin of error or confidence interval

Equation 3-8 Cp

$$C_p = \frac{USL - LSL}{6s}$$

Equation 3-9 Cpk

$$C_{pk} = Minimum\left\{\frac{USL - Xdoublebar}{3s}, \frac{Xdoublebar - LSL}{3s}\right\}$$

Equation 3-10 Sigma

$$s = \frac{Rbar}{d_2}$$

Where USL means upper specification limit;

LSL means lower specification limit;

s means the standard deviation;

X double-bar stands for the average of sample means;

R bar stands mean of the sample ranges.

Table 3-5 Sample size and static factors table

n	d2	A2	D3	D4
2	1.128	1.88	0	3.267
3	1.693	1.023	0	2.575
4	2.059	0.729	0	2.282
5	2.326	0.577	0	2.115
6	2.534	0.483	0	2.004
7	2.704	0.419	0.076	1.924
8	2.847	0.373	0.136	1.864
9	2.97	0.337	0.184	1.816
10	3.078	0.308	0.223	1.777

Table 3-6 Process capability assessing rules

Judgement for Cp	Judgement for Cpk
Cp < 1, Process not capable	Cpk < 1, Process not meeting specification
Cp < 1.33, Process marginally capable	Cpk < 1.33, Process marginally meeting specification
Cp < 2, Process capable	Cpk < 1.5, Process meeting specification
Else, 6 sigma.	Else, 6 sigma.

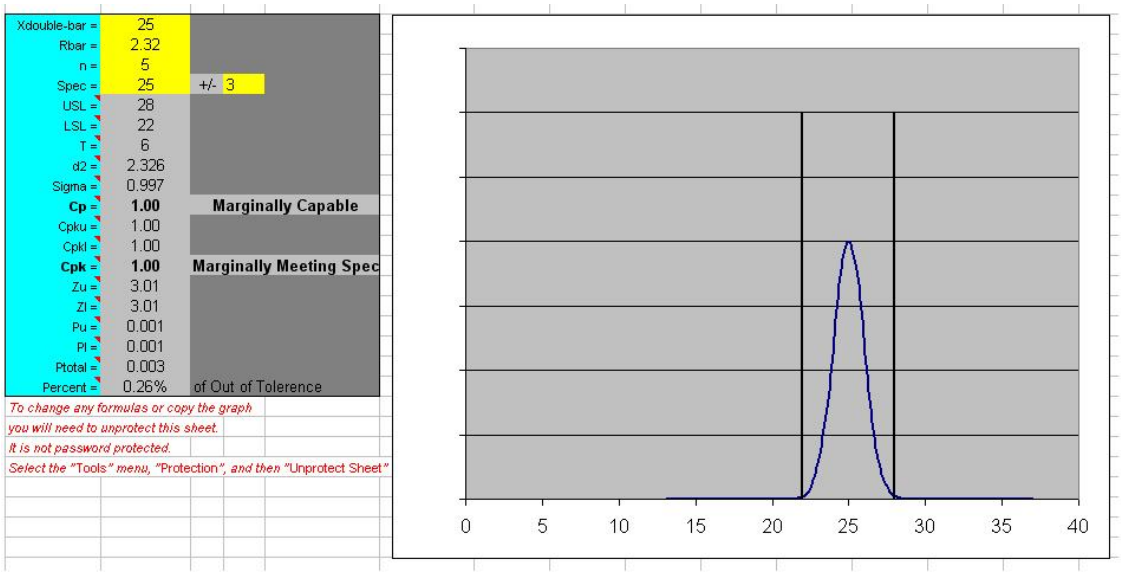


Figure 3-8 DAU Cp and Cpk Model

The advantages of statistics method are simply application and visualization control. The objective of statistics is specific measurable process data which could be represented by diagram. On the other hand these numeric indices are restricted to process performance measures due to the lack of operational strategies' expression. Both of the inputs and outputs of SPC are static expression of data. This kind of disadvantages leaved a gap for information modelling and knowledge based representing.

Summary of this sub section:

- The numeric indices are widely used in nowadays process capabilities measuring.
- This kind of static representing is lack of responding to capturing the capabilities under variable process conditions. Take the Cp for example the historical Cp will be meaningless to the introducing products due to the different process parameters and tolerance range.

3.4 Knowledge application for capturing process capabilities.

Knowledge reuse is in need to meat the requirements of efficient process capability capturing. The process capability indices are easily used to assess the conformity of customers' specification by statistics data. The model application realizes the process capability representing by information delivery. The application of these data and information results of knowledge in specific area. This kind of knowledge usually exists with in certain groups of experts. Groff (2003) give the definition of knowledge as "Knowledge is information combined with understanding and capability; it lives in the minds of people." In order to make more of employees' tacit knowledge explicit, knowledge management is now implemented by different domains companies. Particularly for this project, the factors of knowledge application need to be identified, which are the sources and the delivery media.

The published handbook, reports and industry standards apply the basic knowledge application framework for chemical milling process capability capturing. Enterprise process specification is another source of knowledge application.

Although the specific capability indices in chemical milling process, such as dimension tolerance and surface roughness, actually depend on manufacturers' process performance and resource capability, the general processing accuracy level could be obtained from industrial process specifications, international standards and published handbooks.

For the delivery media of knowledge, the web based techniques were highlighted. Caradec (2009) proposed five recommendations for effective communication within an aerospace company, which are wiki service, profile pages tool, micro blogging tool, online dedicated tool and web meetings.

Rodriguez and Al-Ashaab (2005) introduced a Web-based system of a collaborative product development, see Figure 3-9. This Web-based system covers product design, injection process design and knowledge feedback

advice. There are three layers consist of this system. First, information layer works on the knowledge base. Second, applications layer works on the rules and the interactions organized in a model. Third, end-user layer delivers the output of the system via web browser. This web-based system's application starts from product function definition till final production. The product model feed back advices by capturing the necessary capability information from manufacturing knowledge model. The knowledge model is illustrated with an example of prismatic part developing. The key activities and key knowledge of this system, which are needed during the engineering decision making, are identified by literature survey and industry surveys.

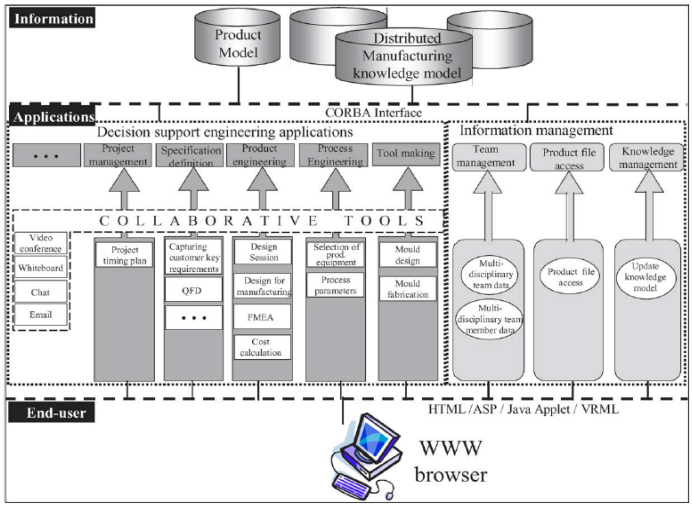


Figure 3-9 Knowledge collaborative product development system architecture

(Rodriguez and Al-Ashaab 2005)

Rodriguez and Al-Ashaab (2007) illustrate more clearly how they developed the knowledge web-based system for injection moulded product development. The domain of their research is defined as product life cycle knowledge representation. The required knowledge of key activities in the product development is identified by top level IDEF0 which defines activities between manufacturer, Product engineer and Toolmaker. Following the knowledge identification and modelling, the UML is used as representing method and the knowledge driven CPD system is proposed as the modelling architecture. The

modelled knowledge is stored in a formation of judging rules, such as “Rule 1 Plastic minimum wall thickness ≤ wall thickness ≤ Plastic maximum wall thickness”. Finally a case study demonstrates how the developed system supports engineering decision-making within the design for manufacturing applications and mould design applications. These rules would determine that the inputting product design/mould design is capable for production or not.

The Web-based system mentioned above well shows that the representing of knowledge is needed in capturing the rules and feeding back customized information. That open a window for this thesis proceeding which is capturing the manufacturing process knowledge to represent the process capability.

Summary of this sub section:

- Knowledge reuse is needed in capturing the process capabilities.
- The sources of knowledge could be the experts experience and publications such as handbooks, reports and industry standards.
- The web based techniques are recommended as efficiency media of knowledge application.
- Unified presenting is important for the knowledge modelling.
- A developed system needs the validation of case study.

3.5 Research gap

From the literature review above, the research gap is profiled as:

1, the capability presentations with models are well developed in machining process; chemical milling process, which is non-conventional machining, is lack of well modelling

2, the majority capability index researches base on the statistics data of the online products. The method of the assessing the on coming product and the variant process factors need to be responded during capturing the process capability on new products.

4 CAPTURE THE MEASURES FOR CHM PROCESS CAPABILITY

4.1 Chemical milling process flow

The typical chemical milling process includes below steps:

4.1.1 Cleaning

The main purpose of cleaning is preparing a clean surface for applying temporary protection coating for chemical milling parts. Parts need to be cleaned by solvents and/or in alkaline liquid tanks. The typical solvent cleaning is proceeded by manually wiping part surface with organic solvents. That obeys local environmental regulations. The popular alkaline liquid application consists of alkaline cleaning, raising, deoxidization, rising and dryness. Performing the aqueous degreasing prior to alkaline cleaning could enhance the surface cleaning condition. Occasionally the conversion processing is used to strength the anti corrosion performance and the adhesion with maskants coating. The cleaning work flow is shown in Figure 4-1(Griffin, 2003). The typical cleaning flow is used to demonstrate the process factors (Table 4-1).

<u>Knowledge</u>

Typical cleaning flow includes aqueous degreasing, alkaline cleaning and deoxidizing. Process tanks are the main facilities.

Cleaning factors include cleaning solutions and the processing time

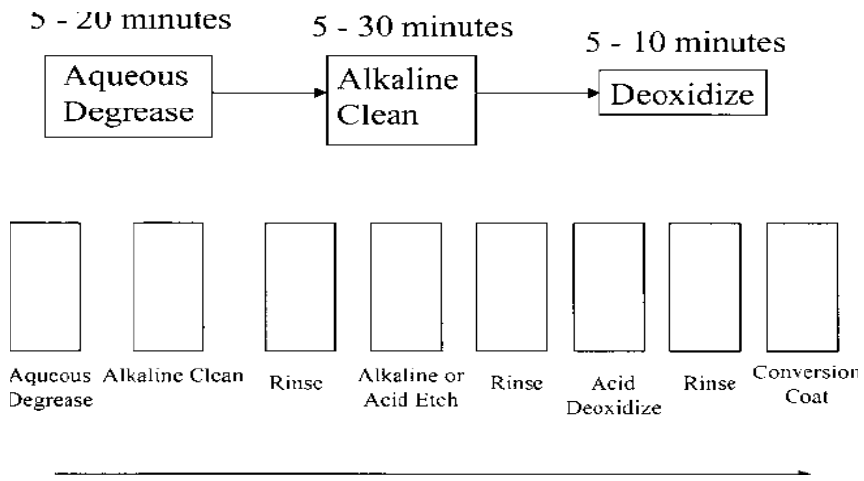


Figure 4-1 Cleaning flow and operation procedures

Table 4-1 Process factors for Cleaning

Cleaning description	Cleaning Product surface in the *Facility* by *Cleaning method* with *Cleaning solution* for *Processing time (CLt, minutes).*			
Cleaning method	Cleaning solution	Processing time (min)		
		LSL	USL	Processing
AD-AC-De	Aqueous Degreasing	5	20	CLt_1 =10
	Alkaline Cleaning	5	30	CLt_2=10
	Deoxidizing	5	10	CLt_3=5
Facility	Cleaning process tanks	Processing time of Cleaning, CLt = 25 min		

The cleaning method in Table 4-1 is only presented with key steps. There would be more detail processing operation during the actual production. The detailed cleaning flow consists of five cleaning operations, which are alkaline cleaning, raising, deoxidization, rising and dryness. The cleaning operations are far more than these. Cleaning could be detailed with more process activities. The operators lord the parts onto the racks and then shift the racked parts through each of the five process tanks. The regulation of parts racking should be applied to avoid the abrasion between parts surfaces. This kind of safety gap would affect parts' loading of each process batch. Thus there are two more issues to

be solved: 1, the definitions of key process activities and the other activities which support key activities; 2, the loading regulations.

First, the definitions for both key process activity and other support activities within the process are particularly established as:

Key process activity

Key process activity delivers the process performance directly to the product and is specified with parameters by process specification.

Support activity

Support activity is called out by process specification and/or creates the processing conditions for the following key process activities.

Second, the loading regulations are expressed with the considerations of, product features and facility limitations.

Table 4-2 Loading limitations

Consideration	Basis	Loading limitations
process operations	By *Cleaning method* with *Cleaning solution* for *Processing time.*	The parts, which are specified with same cleaning method, cleaning solution and processing time, could be loaded within same process batch.
product features	Surface should be free of defects (e.g. abrasion).	Safety gap should be kept during loading.
Facility limitations	Dimensions,	Parts dimensions should fits the facility working dimensions;

	Maximum Volume	The total loading volume should be no more than maximum working volume of the facility.

It could be clarified that process factors define specific chemical milling process from others.

Taking the cleaning step of CHM process for example, the minimum requirement of this procedure is solvent cleaning, and the ideal cleaning procedure requests degreasing and deoxidization. Even so, cleaning could have a wide range of methods and solutions because of various specifications from different manufacturers and products. For the specific cleaning processing in industry application, the working temperature varies from different cleaning agents. It is one of the process control factors which are out of the research scope here. The aim of the temperature control is to keep the cleaning agents working on the stable condition.

Based on the understanding of that, cleaning process factors are defined as Cleaning Product surface in the *Facility* by *Cleaning method* with *Cleaning solution* for *Processing time (CLt, minutes).* The process factors for chemical milling flow are defined in the format of processing description plus parameters for each step within the following sub-sections.

4.1.2 Masking

Although the chemical milling could be achieved on all surface of the part, the selective etching is more popular as the results of strength remain and weight reduction. That means the unselected surface areas need to be protected from the etching. The application methods include brushing, spraying and immersing maskants. As the high risk of pinhole and bubbles in brushing applications, spraying and immersing coating are more popular for industrial. The typical equipment for spraying application is airless painting system (AC-850M, 2010).

The typical immersing facilities are immersion maskant tank, see Figure 4-2. The required coating thickness varies from the selections of maskants and masking methods. Heat-curing facilities are usually applied for immersing and spraying maskant coating in the series production. The curing temperature and time depend on the maskant characteristics.

Knowledge:

Masking flow includes coating and curing.

Masking factors includes maskant material, coating thickness, temperature and curing time.

Coating methods include spraying, immersing and brushing.

Series coating production needs heat-curing facilities

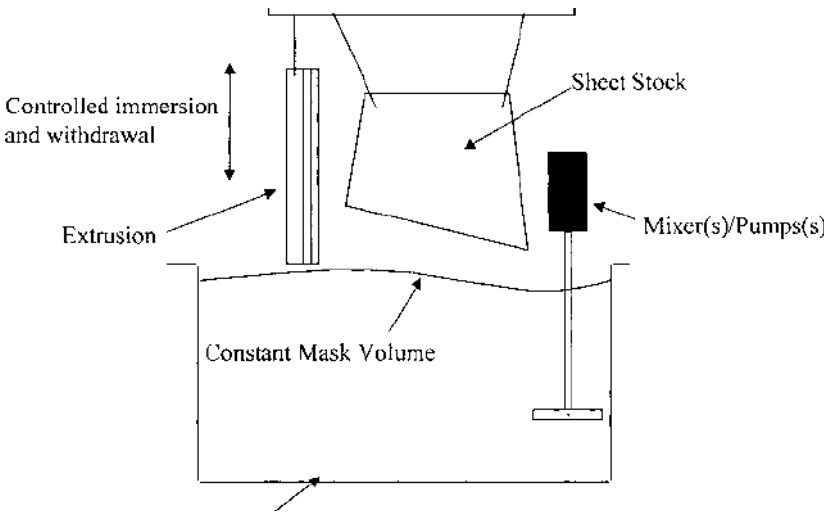


Figure 4-2 Typical Maskant Tank for Immersing Application

The coating operation could be defined as: Apply *Maskant* to Product surface by *Coating method* with *Coating thickness* at *Temperature ºC*.

The curing operation could be defined as:

Cure *Maskant Coating* in Facility for *Processing time* at *Temperature ºC*

4.1.3 Scribing

Both automation laser scribing (Gnanamuthu et al, 1987) (Haas, 2003) and manually could be used for scribing outlines of the milling surface areas. The automation application of laser scribing saves cost on the scribing templates and scribing time under high feed rate about 400 inches per minutes. The laser type, power and beam path length are the key parameters as well. However, the drawbacks are limitation of flat parts, laser focus variation due to the uneven substrates and larger scribing line kerfs' width. Manually scribing is more common for industrial applications. After maskants' curing, the milling areas are located by chemical milling template which is also called tooling. The outline dimensions on the templates are different from the ones on final parts which are affected by etching on both depth and width directions. Chemical milling templates need to be verified on the processing line by qualified parts' pocket dimensions. If all the pocket outlines of multi-steps are scribed at once, the line sealer should be used for protecting subsequence milling pocket outlines from earlier etching. Outlines of multi-steps parts could be scribed separately by numbers of corresponding templates after each step chemical milling. In that case, the costs on templates and setup time for etching increase much higher than the one piece template solution. It seems less attractive for industrial application.

<u>Knowledge:</u>

> Scribing flow includes template locating, pocket scribing and line sealing.
>
> Scribing methods include automation laser scribing and manually scribing.
>
> Laser scribing parameters include laser type, power, beam path length and feed rate. Comparing to manual application, the laser scribing could achieve much higher feed rate and accuracy level.

Although the scribing step includes three operations, the only facility involved in manual application is the chemical milling template. The key operation is

scribing line as template indicates. The outlines of each pocket are profiled on the parts surface as the etching step needs. The accuracy of template is mainly determined by the template design capabilities and the fabrication precision which are out of the research scope of this thesis. Thus both of the Manual application and Laser automation methods could be defined as:

Scribing processes *Pocket outlines* according to the *Steps quantity* of the part by *Scribing method*

4.1.4 Etching

In the etching step of chemical milling, etchants work on the unmasking surface on both of depth and width direction. The processing performance varies even on the same material due to different etchants and temperatures. For aluminium chemical milling, alkaline etchant is more general than the acid based. The etching operation is presented with an equation; see Equation 4-1, (Harris, 1976). Etch rate on specific material is determined by two major factors which are etchant concentration and temperature, substrate material specification and heat-treatment conditions.

Equation 4-1 Etching time

$$E = \frac{s}{t}$$

Where E stands for etch rate, mm/min/surface;

s stands for the etching depth, mm;

t stands for time, min.

Etching realizes the depth and pocket dimensions separately per chemical milling step on the part substrate. The quantity of pockets and the chemical milling steps are the same as the Scribing presented. Thus loading parts to etching tanks are limited to not only the tank dimensions and safety gap regulations but also the different milling configurations, which consist of the

materials, milling steps and their depths. The De-masking operations only strips the maskant coatings as each chemical milling step needs. Thus the Etching is defined as:

Etching achieves the *Depth* and *Width* Dimensions for the *Pockets* on certain *Chemical milling Step* by *Etching rate*

4.1.5 De-masking

For selective etching parts, scribed maskant coating is simply peeled off by hand, so called de-masking, according to the target areas of the etching step before immersing into the etchant. De-masking could be realized by special tools, chemical demaskants or manually striping. The typical De-masking operation is performed manually. The quality measures of chemical milling have been achieved prior to this step. The de-masking is defined as:

Demasking removes the *Maskant coating remain* by certain *Process method*.

The total chemical milling process flow is described with

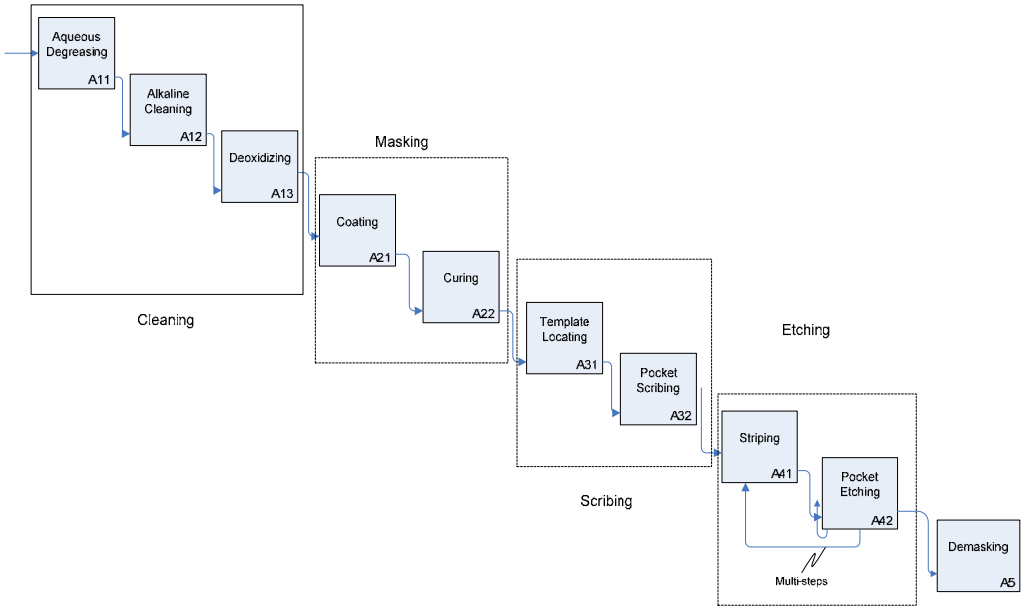


Figure 4-3.

Figure 4-3 The complete CHM process flow

4.2 Capture the CHM process capability measures

In order to capture and assess the CM process capability, it needs to define the measures for representing the process capability. A questionnaire was designed and used to capture the knowledge from appropriate engineers to define the measures.

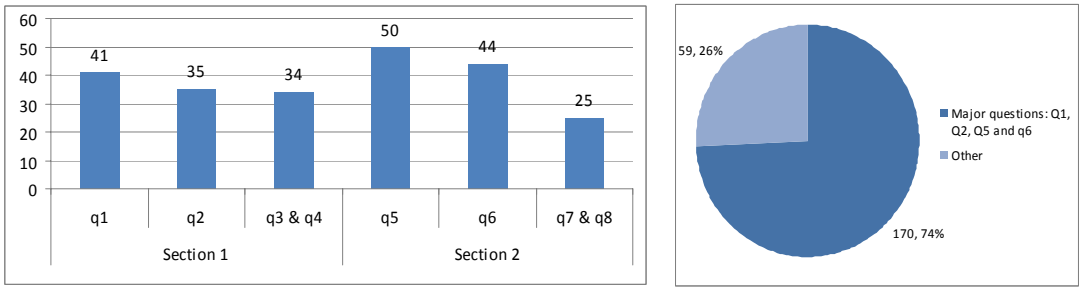


Figure4-4The answers distribution

4.2.1 Questionnaire survey

A questionnaire was given out to understand the aeronautical engineers' constraints on assessing manufacturing process, selecting component suppliers, launching new product and assessing process capability on the new product, see Table 4-3 for Q1, Q2, Q5 and Q6. These are the priority concerns of this thesis at now stage. The 14 respondents are from manufacturing engineering department of an Asian aircraft manufacturing enterprise. Their profiles could be summarized as below:

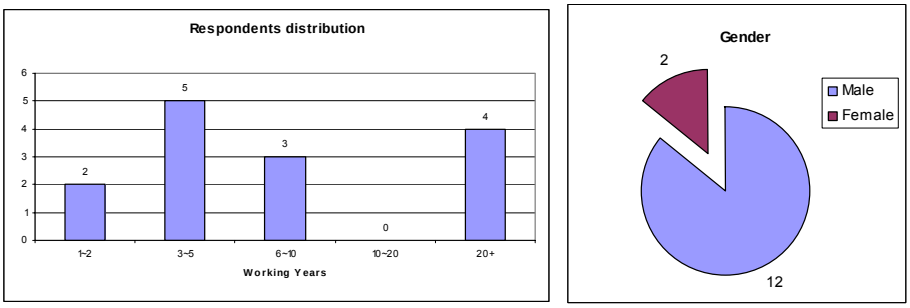


Figure 4-5 Questionnaire respondents profilles

However, there are four more questions to learn about the functions information requests of departments' that involved in the decision making on launching products. They are originally designed to help further research related to the decision making and not the focus of this research. See Appendix A for questionnaire content and answers collected.

Table 4-3 The questionnaire structure

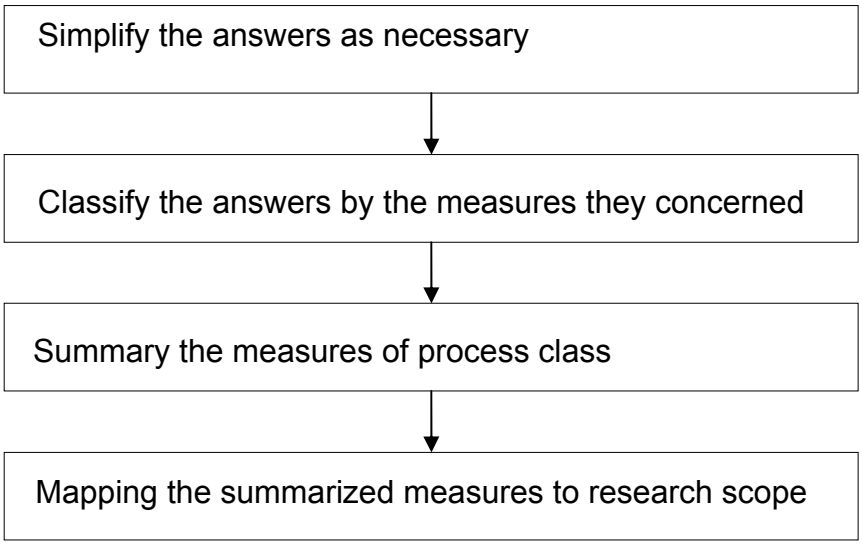
Section 1	Selecting component supplier
Description	An enterprise (E) has a designed component (CP) which needs to select a supplier. Component (CP) mainly needs three naming manufacturing processes, which are P1, P2 and P3. The enterprise E plans to assess three component suppliers (naming A, B and C) and then decide the selection. If this scenario is in your organization/company, please answer the following 4 questions for assessing and selecting component supplier.
Q1	1, From your working domain and understanding, what should be included in the criteria of assessing manufacturing process?
Q2	2, From your working domain and understanding, what should be included in the criteria of selecting component supplier?
Section 2	Launching new product
Description	An enterprise (E) considers accepting the order of a new product (DP). It mainly needs three naming manufacturing processes, which are P1, P2 and P3. If this scenario is in your organization/company, please answer the following 4 questions for assessing the enterprise

	internal process capabilities.
Q5	1, From your working domain and understanding, what should be included in the assessing criteria of accepting the order of a new product (DP)?
Q6	2, From your working domain and understanding, what should be included in the criteria of assessing enterprise process capability on product (DP)?

4.2.2 Answers' collection and processing

About 230 answers were collected from 14 responses by email. These answers vary from each other due to the open question design of the questionnaire. All the information gathered from these answers has to be refined.

The detail refining procedures includes four steps which are:



Two pieces of sample information from the answers of Q1 are used to demonstrate processing procedures. They are:

Sample1 Process parameters comply with specification requirements.

Sample 9 Supplier's capacity, quality management system, the capacities of special processes, project management competence.

First, the key words of the answers were marked with underlines, and the long sentences were divided into independent sense groups by the considering measures. The remarks were applied for the simplified information which is too short to understand separately. The remarking content, such as *assessing process* (for Q1), are the key words of the corresponding questions. Following these rules sample1 and 9 are simplified as:

Sample1 Process parameters comply with specification requirements.

Sample 9_1 Supplier's capacity (assessing process);

Sample 9_2 Supplier's quality management system;

Sample 9_3 Capacities of special processes of the supplier.

Sample 9_4 Supplier's Project management competence.

Second, classify the answers by the measures. All the refined information is classified with the mind map (Figure 4-5) from the top level of manufacturer to detail level of measures. Sample1 concerns about the process parameter and the process specification. The process parameter and the process specification are within the process class.

Then these samples could be classified as:

Sample1 Process parameters comply with specification requirements.

Measures: Process parameters

Measures Class: Process_Manufacturing System_Manufacturer/Supplier

Sample 9_1 Supplier's capacity (assessing process);

Measures: (Processing) capacity

Measures Class: Process_Manufacturing System_Manufacturer/Supplier

Sample 9_2 Supplier's quality management system;

Measures: Quality management system

Measures Class: Quality management system_Manufacturer/Supplier

Sample 9_3 Capacities of special processes of the supplier.

Measures: Capacities of special processes

Measures Class: Process_Manufacturing System_Manufacturer/Supplier

Sample 9_4 Supplier's Project management competence.

Measures Class: Project management System_Manufacturer/Supplier

This project focuses on the chemical milling process capability. From the mind map displayed in Figure 4-5, it is clear that sample 1 and sample 9_1 are mapped into the process class and the research scope; Sample 9_2 to 9_4 are out of the research scope. Although sample 9_3 subjects process class, the specific factors of special processes capabilities make its range beyond the scope of chemical milling.

Third, summarize the measures within measures class of process from each question and incorporate the repeated ones. Then index all the summarized measures according to the measure classes within one excel table and incorporate the repeated once more.Finally there are 31 pieces of factors mapping into the object class of process. Eighteen of them are within the scope of this project (see Table 4-4), and the rest thirteen are out of the scope (see Table 4-5).

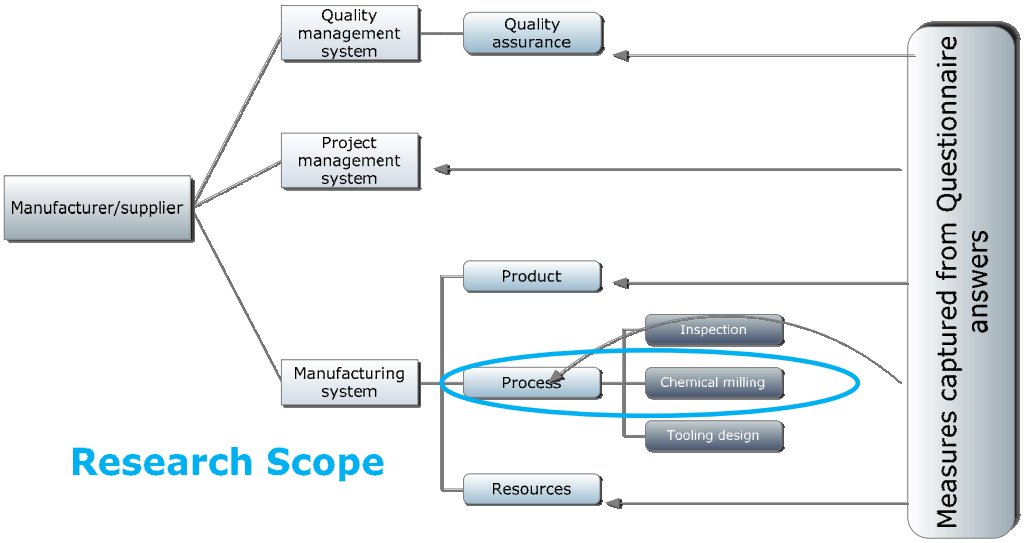


Figure 4-6 Mapping the captured measures to Manufacturing system

Table 4-4 Measures Mapping in the Scope

No	Measures	Explanation
1.	The compliance of process parameters	Process parameters comply with specification requirements
2.	Process feasibility	The feasibility of present process on the new product.
3.	Processing difficulty	Processing difficulty on the product
4.	Product recognition	The new product should be learnt about.
5.	The compliance of engineering design requirements	If the manufacturing process comply with engineering design requirements
6.	Processing accuracy	The processing accuracy of the facilities.
7.	Process stability	The manufacturing process is stable
8.	Systemic specifications	There are systemic specifications for the processes which are called out by the new product.
9.	The integrity of process system	The complete coverage of the capable processes which are required by the new product.
10.	Delivery schedule	The delivery schedule request of new product.
11.	Product demand	The overall product demand of the new product.
12.	The qualified product	The qualified product could be delivered.
13.	Requests on facilities	The production (processing) requests on facilities.
14.	Manufacturing/ Processing capacity	Manufacturing/processing capacity meets the new product request.
15.	The efficiency	The present process should achieve requesting efficiency.
16.	Process flows	Process flows steps and length
17.	Process method	The selected process method is reasonable, efficient and stable
18.	Process economic	The fabrication process economic.

Table 4-5 Measures Mapping out of the scope

No.	Measures	Causes of mapping out
1	Process aids	Detail level, out of the research scope
2	Technical preparation	Detail level, out of the research scope
3	Process advancement,	This consideration needs to compare the process capabilities between different manufacturing systems, could be the focus for future research.
4	Operation design Capability	Out of chemical milling process
5	Remedial measures,	Detail level, out of the research scope
6	Impacts on environment	This consideration is out of the manufacturing system scope, could be the focus for future research
7	Heat-treatment standards	Out of chemical milling process
8	Machining accuracy	Out of chemical milling process
9	Tooling design Capacities	Out of the research scope.
10	Production life cycle	Need considering the relative processes, out of chemical milling process
11	Inspection capacity	Out of chemical milling process (quality assurance)
12	Special processes capabilities	Out of chemical milling process
13	Surface-treatment standards,	Out of chemical milling process.

5 CHEMICAL MILLING PROCESS CAPABILITY ASSESSMENT

In order to assess each measure of the CM process capability, some process factors, e.g. process parameters etc, need to be captured, and the methods for assessing each CM process measure need to be developed. This chapter describes the process factor capture, and the assessing methods for each CM process capability measures (5.1 to 5.18).

5.1 The compliance of process parameters

Process parameters should comply with process specifications of the new product. There are three sources of process parameters within the manufacturing system. They are internal process specifications (process), the product's process specifications (product) and the applied parameters on the present processing line that are performed by facilities (resource). In order to assess the process parameters, Table 5-1 lists the concern factors according to the process flow which is summarized from section 3 and section 4.

Taking cleaning parameters for example, there logically are three cases for comparing the parameters between processing line and process specifications of new product.

First one is the case of totally complying with. It means that all of the cleaning method, cleaning solution and processing time comply with product's process specifications or there is no specific requirement for cleaning method in product's process specifications. Then the processing line applied parameters will be capable within the range of internal specification. The process parameters should be considered as complying with product's process specifications.

Second one is the case of partially complying with. It means that the cleaning method, or both of cleaning method and cleaning material, or the cleaning method, cleaning solution and some of the processing times comply with

product's process specifications. The practical solution for this case is seeking for qualified process deviation. Then the process parameters need to be approved.

Table 5-1 The factors for the compliance of process parameters

		Process		Product		Resources
		Internal specification		process specifications		processing line
Process flow	process method	LSL	USL	LSL	USL	Applied
Cleaning						
	Aqueous Degreasing	time		time		time
	Material brief					
	Alkaline Cleaning	time		time		time
	Material brief					
	Deoxidizing	time		time		time
	Material brief					
	Conversion Coating	time		time		time
	Material brief					
Masking						
Coating	Material	Maskant		Maskant		Maskant
	(Material brief with	thickness		thickness		thickness
	curing	Layers number		Layers number		Layers number
	Temperature)	Interval time		Interval time		Interval time
	Method	Method		Method		Method
Curing	Heating up	time		time		time
Scribing						
	Laser	Power		Power		Power
	Manually	-	-	-	-	-
Etching						
	Alkaline Cleaning	time		time		time
	Material brief					
	Pocket Etching	Depth		Depth		Depth
	Material brief					
		Surface finish		Surface finish		Surface finish
	Desmuting	time		time		time
	Material brief					
De-masking						
	Chemically	time		time		time
	Material brief					
	Manually	-	-	-	-	-

Last one is the case of not complying with. It means that the cleaning method is completely different from product's process specifications. In this case the cleaning of new product would not be realized on present processing line as required. The process parameters should be considered as not complying with.

The assessing rules are summarized as:

Rules 5-1 Processing parameters

A, complying with,

if the applied parameters are capable for all the range of internal specification.

B, to be approved,

if the parameters are different from product specification, and can not be applied to new product without further approval.

C, not complying with

if the process method is not applicable to the new product within the allowance of product specifications.

5.2 Process feasibility

The process feasibility expresses if the chemical milling quality measures are achievable by present process. As it is reviewed in section3.1, chemical milling quality measures include four features: depth, pocket dimensions, surface finish and surface quality.

The quality measures of depth and surface finish are directly determined by process performance. The pocket dimensions are formed after template positioning and the tooling design. The measured pocket dimensions may be results of several factors. Surface quality mainly depends on the surface condition prior to chemical milling process; any surface defect must be

corrected before etching. Thus, the depth and surface finish are considered as the indices of process feasibility measure.

For most kinds of the situations, the variation of depth and surface finish increase while the etching goes deeper. To the same material, say 2024T3, if the accuracies of deeper etching comply with the specification limits, should the lower ones do. From the Equation 3-8 and Equation 3-9, the standard deviation and X double bar represent the process performance on the conditions of certain material and etching depth; and the Cp and Cpk are used to measure the achievements on specification limits. That means Cp and Cpk could be measured with new product specification limits from the samples or similar product from process line with same material and etching depth (or deeper).

Assuming the process is stable, process feasibility could be measured by Cp/Cpk as Table 5-2:

Table 5-2 Process feasibility factors

Factors	Input	Out put
Depth, Cp	Depth samples data of same material and depth; Product specification limits	Cp and judgement
Judgement assessing rules	Cp < 1, Process not capable Cp < 1.33, Process marginally capable Cp < 2, Process capable Else, 6 sigma.	
Surface finish	Surface finish samples data of same material and depth; Product specification limits	Cpk and judgement
Judgement assessing rules	Cpk < 1, Process not meeting specification Cpk < 1.33, Process marginally meeting specification Cpk < 1.5, Process meeting specification Else, 6 sigma.	

5.3 Processing difficulty

The process difficulty is used for measuring how the defined process responds the new product process requests. From the Rules 5-1, there are three judgements:complying with, to be approved, and not complying with. If the complete CHM process flow get all judgements of complying with from every single step, there would be no issue for the CHM process. As the numbers of steps with 'to be approved' or 'not complying with' increase, the existing CHM process might responds the certain product request with more issues. Thus the total quantities of complying with, to be approved, and not complying judgements within certain complete process flow could be considered as the factors for the assessment of processing difficulty. Any finds of not complying with or to be approved should be identified. The finding items could be listed as Table 5-3.

Table 5-3 Process difficulty factors and assessment

<table>
<tr><td>Inputs factors

Process flow, Process specifications, Engineering requirements,</td><td>Outputs

Factors of complying with,

Factors of to be approved,
Factors of not complying.</td></tr>
<tr><td>Assessing rules

If the measuring item is judged as “not complying” or “to be approved”, then mark it as a finding for processing difficulty.</td><td></td></tr>
</table>

5.4 Product recognition

For the new product, both of the engineering requirements and process requirements need to be achieved. The measure is specially used for assessing if the new product has been understood with common consensus by both manufacturer and customer. According to the defined chemical milling process flow, the process requirements required by product recognition are list in **Table 5-9.**

The process requirements from new product could be identified from the process specifications. In order to keep the process performance on a stable level, the process specifications normally regulates the process limitations, process quality measures and process control requirements the like ADET specifications of AIRBUS. Other process specifications may include more detail requirements on methods, materials, parameters, facilities and process aids like BAC specifications of Boeing.

The requirements from engineering design could be identified from the engineering drawings. They may include the parts dimensions, materials, surface finish allowance, dimension tolerance, etching areas and steps, see section 5.5.

To clearly impress the product recognition both identified factors and unidentified factors of the new product should be specified as

Table 5-4 Product recognition factors and assessment

Factors	Identified	unidentified	ratio
Process, Table 5-9.			
Product, Table 5-5			
Total	Total identified	Total unidentified	Unidentified/total

5.5 The compliance of engineering design requirements

The product requirements from engineering design cover a wide range of information. They could be classified to three major classes, which are part information, processing information and tolerance. The part information includes part name, basic dimensions and material; the processing information indicates the etching areas, pocket dimensions, steps and depths; the tolerance from engineering design has higher priority than the one regulated in process specifications.

The typical requirements from engineering design for chemical milling process could be summarized as Table 5-5.

Table 5-5 The factors of engineering design requirements

Class	Factor	Assessment
Part information	Part name, Part dimensions, Part material	
Processing information	Etching surface areas, Pocket dimensions, Etching steps, Etching depths	
Tolerance	Depth limits, Surface finish limits	

5.6 Processing accuracy of the facilities

From the factors listing in Table 5-1, there seems no parameter is directly involved with facility except the laser scribing facility that has been assessed in the measure of compliance of process parameters. But for the process facilities which are required for heating up, temperature accuracy would be the process factor determined by facilities. Thus, the temperature control accuracy of process tanks should be achieved according to the product specification, The factors and assessments are listed in Table 5-6

Table 5-6 The factors and assessment for temperature accuracy

Inputs factors:	Outputs
Process flow, Process specifications, Facilities temperature accuracy.	Temperature accuracy compliance
Assessing rules If the range of facility temperature accuracy is less than the specification required, then it is complying with; Else, it is not complying with	

5.7 Process stability

Process stability means the state of manufacturing process is stable. One of the practical methods is applying X-bar chart and R chart to assess the quality measures of the chemical milling process. If the quality measures and their variance stay within the control limits, the process is considered as stable one. The assessing measures and rules are defined as Table 5-7:

Table 5-7 Process stability factors and assessment

Factors	Method	Assessing rules
Depth	X-bar and R charts	If no point is out of control limits, process is stable. Else, process is unstable.
Surface finish		

Input for process stability measures is listed as Table 5-8:

Table 5-8 Process stability assessment input and output

Factors	input	Output
Depth	Samples, Sample size n, $3 \leq n \leq 10$; Subgroups k, $k \geq 20$;	Process stability statement X-double bar R-bar UCL, LCL
Surface finish		

5.8 Systemic specifications

This measure expresses if all steps of the corresponding internal processes are under the control of applicable internal specifications. The new product may require more than one process to fabricate. When each step of required processes within the chemical milling process flow is covered by at least one internal specification, the systemic specifications measure should be considered as confirmed. A list of applicable process specifications should be presented including both internal specifications and product's process specifications. The factors for assessing this measure is shown in Table 5-9. The assessing rules are expressed as:

Rules 5-2 Systemic specifications

If the each step of the required processes flow is covered by internal specification(s), then Systemic specifications are confirmed; If not all steps of the required process flow are covered by internal specifications, then systemic specifications are not confirmed.

5.9 The integrity of process system

This measure expresses if the required process flow can be fully realized. The new product may require more than one process to fabricate; and more than one processing method might be available within certain process. When the internal processes achieve at least one process method of each required step, the integrity of process system measure should be considered as confirmed. A list of applicable process flow should be presented, which complies with both internal specifications and product's process specifications. The factors for assessing this measure is shown in Table 5-9. The assessing rules are expressed as:

Rules 5-3 The integrity of process system

If each required step can be achieved with at least one method of product specifications by internal processes, the integrity of process system is confirmed; If not all required steps can be achieved with at least one method of product specifications by internal processes, the integrity of process system is not confirmed.

Table 5-9 Assessing factors of process specification and system

Process flow	Process method	Internal specifications	Product's process specifications
Cleaning	Cleaning method and solutions applied	Cleaning process specification	Cleaning process specification
Masking	Masking method and maskant applied	Masking process specification	Masking process specification
Scribing	Scribing method and facility applied	Cleaning process specification	Cleaning process specification
Etching	Etching method and solutions applied	Etching process specification	Etching process specification
De-masking	Cleaning method (and solutions) applied	De-masking process specification	De-masking process specification

5.10 Delivery schedule

The delivery schedule of the new product defines the required delivery date and the quantity. The delivery rate is usually counted with ships per month. It usually looks like a climbing up plan during the industrial cooperation. By measuring the delivery schedule at average level, the average delivery rate (R_{DL}) could be used to assessing the production rate (R_{Pd}) of the remaining capacity in present manufacturing system. The details of R_{Pd} are clarified in section5.14. The assessment method of delivery schedule measure is summarized in Table 5-10.

Equation 5-1 Average delivery rate

$$R_{DL} = Q/P$$

Where R_{DL} means the average delivery rate;

Q means the total product quantity;

P means the total delivery period.

This measure should be considered as satisfied if the production rate meets the average delivery rate.

Table 5-10 Delivery schedule factors and assessment

Input factors	output
Product demand (Q, P), Production rate (R_{Pd})	R_{DL}; The achievement of R_{DL}.
Assessment method Equation 5-1 If $R_{DL} \leq R_{Pd}$, then the delivery schedule could be achieved. Else, it is not achievable.	

5.11 Product demand

The product demand should be clearly identified with the total product quantity and the product configuration. The product configuration specifies the exact parts list and their quantities for each delivery ship. The identified product demand could be detailed as Table 5-11.

Table 5-11 Product demand factors and assessment

Product Name:	Product AB	Total delivery ships:	Q	Assessment
Configuration	Part name	Part number	Part quantity	Table 5-4
Pro_Cfg	P_a	001	n_a	
	P_b	002	n_b	

5.12 The qualified product

The product could be qualified and delivered in accordance with the product specifications and delivery schedule. From this measure there are two factors to be assessed, which are quality and delivery. The quality factors of process feasibility and process stability need to be confirmed first, and then come to the factor of delivery schedule. The qualified product could be delivered only if all factors of the process feasibility, process stability and the delivery schedule are confirmed. Otherwise it would not be achievable. The assessing rule for this measure could be expressed as Table 5-13:

Table 5-12 The factors and assessment of qualified product

Input factors Process feasibility, process stability, delivery rate and manufacturing capacity	output If the product could be qualified. and If the product could be delivered.
Assessment method If Cp≥1 (depth), Cpk≥1 (surface finish) and process is stable, product could be qualified. If $R_{DL} \leq R_{Pd}$ (Table 5-10), then the product could be delivered.	

5.13 Requests on facilities

The product would be physically realized on the processing line with the corresponding facilities. Thus processing requests on the facilities should be measured by the factors of time and space.

The time factor assesses the time capacity of certain facilities for the new product. This is critical to the processing. The time capacity (t^{max}) of certain facility for the product could be defined as:

Equation 5-2 Time capacity of facility

$$t^{\max} = C \times t$$

Where C stands for the maximum time capacity percentage of certain facility for single product within certain period;

t stands for the total available time for all products within certain period of the processing line.

According to product demand and delivery schedule, the time request of single product on certain facility (t^{Req}) could be defined as:

Equation 5-3 Time request of product

$$t^{Req} = T_{op} \times R_{DL}$$

Where R_{DL} means the average delivery rate;

T_{op} means the facility operation time per delivery ship;

Table 5-13 The factors and assessment for time request on facility

Input factors:	Output:
C, t, T_{op} and R_{DL}. Equation 5-2, Equation 5-3	Time request achievement
Assessment rules: If $t^{Req} \leq t^{max}$, the time request is achievable for the concerning facility; If $t^{Req} > t^{max}$, the time request could not be achieved by the concerning facility.	

The space factor assesses the working dimensions capacity for the new product. Safety margin between loading parts are needed as well. That means the largest dimension of product plus safety margin should be fitted with facilities working dimensions at least. The detailed assessment could be expressed as Table 5-14:

Table 5-14 The factors and assessment for space request on facility

Input factors:	Output:
Product dimensions (length, height, contour depth); Facility working dimensions (length, height, contour depth); safety gap margin.	Space request achievement
Assessing rules:	

If {Max (Product dimensions) + gap} ≤ Max (facility working dimensions- gap) and {Min (Product dimensions) + gap} ≤ Min (facility working dimensions- gap), then the space request is achievable for the concerning facility; else, it could not be achieved.	

5.14 Manufacturing/processing capacity

The manufacturing capacity defines highest production rate (R_{Pd}) of present processing line. In the case of products sharing same processing line, the manufacturing capacity of specific product depends on its facility operation time per delivery ship (T_{op}) and the maximum available time capacity of the facility (t^{max}).

Equation 5-4 Manufacturing capacity

$$R_{Pd} = \frac{t^{\max}}{T_{op}}$$

If the product is realized through series facilities, the actual manufacturing capacity would be limited by the lowest production rate of these facilities'.

Equation 5-5 Manufacturing capacity by series facilities

$$R_{Pd} = \min\left(R_{Pd}^{1}, R_{Pd}^{2}, R_{Pd}^{3}, ..., R_{Pd}^{j}\right)$$

Where R^{j}_{Pd} stands for the facility j;

j = 1, 2, 3 …

According to the product demand, there may be more than one part consisting of the product configuration. In these cases, the single ship operation time could be defined as:

Equation 5-6 Single ship operation time

$$T_{op} = \sum (T_{op\,i} \times n_i)$$

Where T_{opi} means the operation time of part i;

n_i means the quantity per ship of part i;

i = 1, 2, 3...

For specific part, processing time (t_{pc}) could be calculated directly by parameters and part features; and the actual operation time on corresponding facility could be measured. Then a coefficient (e_{co}) obtained as Equation 5-7 could be used to estimate the new product's operation time (see Equation 5-8).

Equation 5-7 Operation time coefficient

$$e_{co} = \frac{T^*_{op}}{t^*_{pc}}$$

Where T^*_{op} means the referring part's operation time per batch;

t^*_{pc} means the referring part's processing time per batch.

Equation 5-8 Operation time estimation

$$T_{OP} = t_{pc} \times e_{co}$$

Basing on

Equation **5-4** to Equation 5-8, the manufacturing capacity of the new product and the single ship processing time t^t_{pc} could be expressed as:

Equation 5-9 Manufacturing capacity assessment

$$R_{pd} = \min\left(\frac{t^{\max 1}}{T^{t1}_{op}}, \frac{t^{\max 2}}{T^{t2}_{op}}, \ldots, \frac{t^{\max j}}{T^{tj}_{op}}\right)$$

Equation 5-10 Total single ship processing time

$$t_{pc}^{t} = \sum_{i} t_{pci} \times n_i$$

Where t^{maxj} stands for the maximum available time capacity of the facility in step j;

j = 1, 2, 3...

t_{pci} means the processing time of part i;

T^{tj}_{op} means the total operation time of single ship producing in step j;

n_i means the quantity per ship of part i;

i = 1, 2, 3...

As it is mentioned before, the product is usually delivered as product configuration and is produced by batch fabrication of parts. The loading capacity (L_d) of each facility in series production determines how many parts could be processed per batch. The single part processing time could be calculated from:

Equation 5-11 Single part processing time

$$t_{pc} = \frac{T_{bth}}{L_d}$$

Where T_{bth} means the processing time of the batch;

L_d means the loading number of the part.

The processing time assessments of major processing steps are expressed as

Table 5-15 according to the process flow and process factors indentified. The manually processing methods are considered as being applied to each part one by one that means L_d equals 1.

Table 5-15 Processing time factors and assessment

Flow	Facility	Factors		Single part processing time
		Process	Product	
Cleaning	Tanks	Cleaning time, T_{bth}	loading number, L_d	T_{bth}/L_d
Coating	Coating system	Coating rate (R_{ct}), layer number (n_{ln}), interval time, (t_{bt})*	Surface per part (S); Loading number $L_{d'}$	n_{ln} X(R_{ct} X SX $L_{d'}$+ t_{bt})/L_d
Curing	Heating room	Drying cycle time, T_{bth}	loading number, L_d	T_{bth}/L_d
Scribing	Manually /Laser	Scribing rate (R_{scr}),	Part scribing line length (L_{scr});	R_{scr} / L_{scr}
Etching	Tanks	Striping rate (R_{stp})	Etching surface(S_{eth})	S_{eth} x R_{stp} + (D/ R_{etc}+ n_{stp} x t_{step})/ L_d
		Etching rate (R_{etc}), Step checking time, t_{step}	Depth (D); Steps' quantity, (n_{stp}); Loading number, L_d	
De-masking	Tanks	Dipping time T_{bth}	loading number, L_d	T_{bth}/L_d
	Manually	Striping rate (R_{stp})	None etching part surface S_{noe}	S_{noe} x R_{stp}

* refers AC-850M (2010).

Table 5-16 Parts loading considerations

Flow	Facility	Loading considerations
Cleaning	Tanks	1, space request on facility; 2, maximum loading number.
	Manually	Processing parts individually.
Coating	Coating system	1, space request on facility; 2, maximum loading number.
Curing	Heating room	1, space request on facility; 2, maximum loading number.
Scribing	Manually /Laser	Processing parts individually.
Etching	Tanks	1, space request on facility; 2, maximum loading number; 3, both the etching steps and depth per step are need to be same.
De-masking	Tanks	1, space request on facility 2, maximum loading number
	Manually	Processing parts individually.

From table above, it is shown that the etching step has more limitations on part loading than others. The special consideration of same batch loading is analysed with three scenarios, which are listed in estimation stay within the safety margin of actual ones. The loading number assessment is expressed as

Equation 5-12 to Equation 5-14. The racking positions for typical parts are illustrated in Figure 5 1:

Table 5-17.

In the case of different parts sharing the same processing batch, there should be a specific quantities ratio between the loaded parts to achieve the efficiency of processing. Then the overall loading number would be different from single type parts loading numbers of them. To keep the particular loading parts quantities ratio, the receiving rates of them have to be stable. That would be not necessary for industrial application. To stay in the safety side for loading number estimation, the parts fabrication needs to be considered as continuous for same type and non-synchronous for different parts. For the similar parts, the overall loading number of sharing batch would be similar to single type parts loading number due to the close dimensions. In the understanding above, calculating the loading number separately for series production would make the estimation stay within the safety margin of actual ones. The loading number assessment is expressed as

Equation 5-12 to Equation 5-14. The racking positions for typical parts are illustrated in Figure 5 1:

Table 5-17 Same batch loading scenario for etching

Same batch parts scenarios	Loading number	Stable Receiving Rates
Same parts	Same	The receiving rate achieves delivery rate at least.
Similar dimensions parts	Similar Loading number	Low request in Series production
Distinct dimensions parts	Distinct Loading numbers	In highly requesting to keep stable loading number in all situations.

Equation 5-12 Loading number

$$L_d = r_{ow} \times l_{in}$$

Equation 5-13 Loading rows

$$r_{ow} = Round\left(\frac{w - g_{ap}}{d_{pt} + g_{ap}}\right)$$

Equation 5-14 Loading Lines

$$l_{in} = Round\left(\frac{l - g_{ap}}{l_{th} + g_{ap}}\right)$$

Where r_{ow} means the parts loading rows number at the width direction of certain facility;

l_{in} means the parts loading lines number at the length direction of certain facility;

w means the working dimension at width direction of the facility;

d_{pt} means contour depth dimension of the racking part;

l means the working dimension at length direction of the facility;

l_{th} means the contour length dimension of the racking part;

g_{ap} means the safety margin of the racking requirements.

It has been expresses from Equation 5-5 that the manufacturing capacity is limited to the minimum production rate in series facilities. And Equation 5-11 has pointed out that the loading number can be assessed from parts and facilities dimensions the for single part processing time calculation. The operation time T_{op} (Equation 5-8) can be estimated by the coefficient of reference product from present processing line. Then the assessment of manufacturing capacity could be generated as **Table 5-18**.

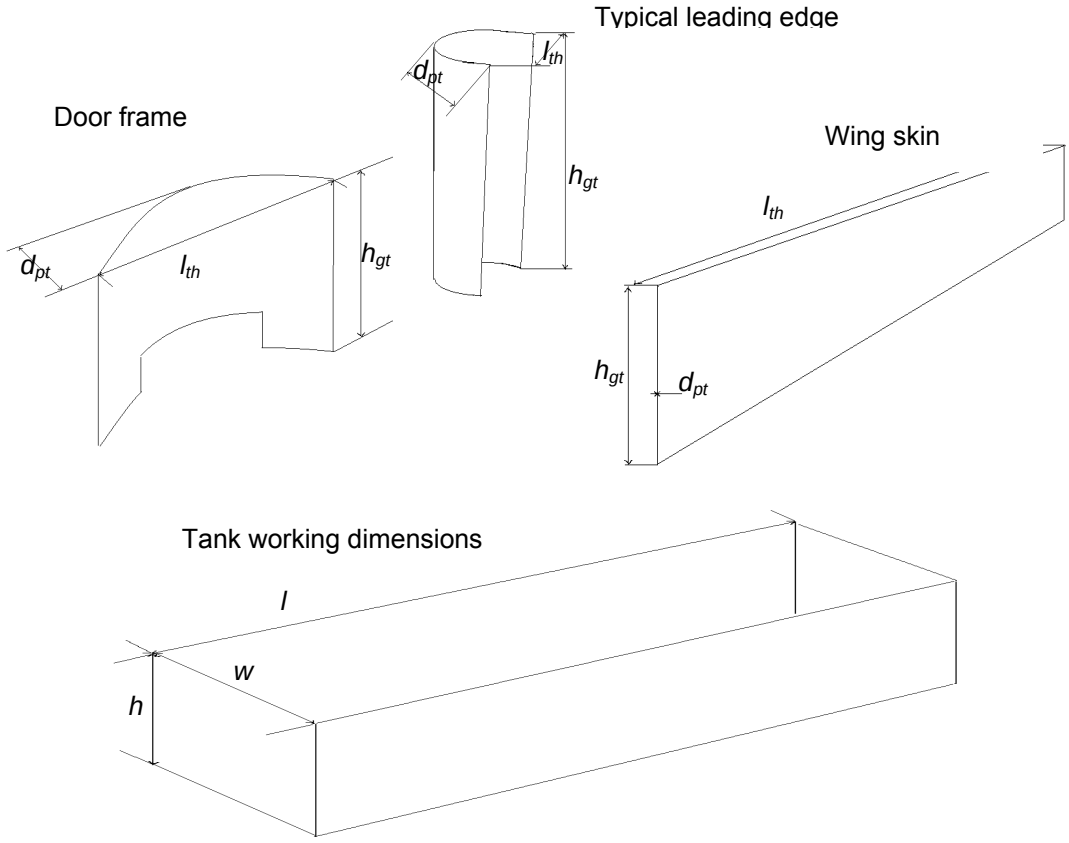


Figure 5-1 Racking illustration

Table 5-18 Manufacturing capacity factors and assessment

Inputs	outputs
Factors in **Table 5-15**, e_{co} , t^{max}, facilities working dimensions, product dimensions, loading gap.	Manufacturing capacity R_{Pd}; Total operation time of single ship producing $T^{t}_{op.}$
Assessing methods	
Equation 5-6, Equation 5-9, Equation 5-10, Equation 5-11,	

Table 5-15,	

5.15 The efficiency

The present process should achieve requesting efficiency.

The process efficiency (e_p) is measured from the value-add time and the non-value-add time. The value-add time in this research is defined as: the time of achieving the parameters required by process and product. It equals the processing time t_{pc}. Non-value-add time in this research is defined as: the rest of producing time taken by production activities than processing time.

For the new product, the total producing time equals to the available working hours from shop floors (T^{max}); and the processing time requested are determined by the delivery rate (R_{DL}) and the total single ship processing time (t^{t}_{pc}).

Equation 5-15 Requested process efficiency

$$e_{req} = \frac{\sum_j t^{tj}_{pc} \times R_{DL}}{\sum_j T^{\max j}}$$

Equation 5-16 Maximum process efficiency

$$e_{\max} = \frac{\sum_j t^{tj}_{pc} \times R_{Pd}}{\sum_j T^{\max j}}$$

Where t^{tj}_{pc} stands for the single ship processing time of new product in step j

T^{maxj} stands for total available working hour for the new product in step j;

j = 1, 2, 3……

R_{DL} stands for the requested delivery rate;

R_{Pd} stands for the manufacturing capacity for the new product.

Since e_{req} and e_{max} are different on the production rate of R_{DL} or R_{Pd}, the process efficiency measure could be assessed and determined by the delivery rate R_{DL} requested as shown in Table 5-19:

Table 5-19 Process efficiency factors and assessment

Inputs factors	Outputs
T^{max} , R_{DL} , R_{Pd} , $t^{t}_{pc,}$	e_p achievement
Assessing method If $R_{pd} < R_{DL}$, then e_p does not achieve the request; If $R_{pd} \geq R_{DL}$, then e_p could achieve the request, $e_p = e_{req}$ (Equation 5-15).	

5.16 Process flow

The process flow of the new product defines the overall processing steps, methods and their procedures. It is realized on the processing facilities and controlled by specifications including the process and product specifications. The typical procedures have been summarized in

Figure 4-3. It could be used to initialize the framework of present facilities, processing steps and the available methods. And then the process requirements from the new product are introduced to assess and define the capable process flow. The process flow should clearly specify the process method and the applicable process parameters. The assessing factors refer Table 5-1.

5.17 Process method

The considerations of process method measure are reasonable, efficient and stable. The judgement used for reasonable process method is satisfying the process and product specifications. For particular processing line, the efficient and the stable judgements could be made from the common sense by ranking the available methods. The basic rules for the ranking are recommended by this research are explained in Table 5-20.

Table 5-20 Process methods assessing factors and rules

Measures and factors	Assessing rules
Process	
Compliance	If methods are confirmed by both product specification and internal process specification;
Parameters	If the selected method could minimum the process parameters adjustment ;
Product	
Tolerance	If the method meat the lowest tolerance;
Heating	If the method is free of heating;
Inspection activity	If the method is free of additional inspection activity
Resource	
Loading per batch	If the method could maximum the batch loading;
Testing	If the method is free of additional testing equipments.

equipment	

5.18 Process economic

This measure here assesses the present cost level on the new product. Harris (1976) introduced the operating costs estimating by the usages of man hours data and material costs data. The operating costs data need to be refined while the estimation.

The man-hours data listed in Figure 3-3 estimates the time of manually operating within process activities. It may result in different levels of man hours per part because of the variant of processing batches loading and the etching steps. The batch loading affects the man hours levels of degrease and pickle, apply maskant and its handling, etching handling and the de-masking handling which are performed per batch rather than single part. To enable the initial estimation for parts sizing between 1 m^2 and $5m^2$, the mean values of man hours from 1 m^2 and $5m^2$ are deployed. The man hour data adapted from Harris (1976) are listed in Table 5-21.

The material costs data based on the prices level of 1974, see Figure 3-3 and Figure 3-4. Taking two of the materials, etchant (NaOH) and the Toluene as indices, the present prices have risen to 2.82 times higher, see Table 5-22. The material cost data, experience coefficients and the adapted price (refers Figure 3-5) are edited as Table 5-23.

The operating cost assessment is expressed in Table 5-25.

Table 5-21 Initial data for Man-hours estimation

Process flow*	Unite	Flat			Formed		
		About $1m^2$	$3\pm1m^2$	About $5m^2$	$<1\ m^2$	$3\pm2\ m^2$	$>5\ m^2$
a, degrease and pickle	Min/ m^2	7	4.5	2	7.5	4.875	2.25
b, apply maskant	Min/ m^2	18	10.5	3	18	10.5	3
handling	Min/ m^2	8	5.5	3	8	5.5	3
c, check maskant	Min/ m^2	5	5	5	5	5	5
d, template handling	Min/template	4	6	8	5	7.5	10
e, scribing	min /m	0.50	0.33	0.25	0.67	0.44	0.33
f, maskant peeling	Min/ m^2	20	20	20	20	20	20
g, etching handling	Min/ m^2	3	4.5	6	3	4.5	6
etching rotating	Min/ m^2	0	0.25	0.5	0	0.25	0.5
h, thickness check	Min/step	1	2	3	1	2	3
f, de-masking handling	Min/part	4	12	20	5	14.5	24
de-masking peeling	Min/ m^2	4	4	4	5	5	5

***Adapted from Harris (1976, Table 10.3).**

Table 5-22 Material price rising estimation

Items	1974	2009-2010
Toluene (ρ=0.8669 g/ml)	£0.175 /L	$765/tonne (Aliexpress, 2010)
NaOH	£0.08 / kg	$ 304.12/tone (Chakravarty, 2010)
Exchange GBP TO USD (PACIFIC, 2010)	-	1.5645
THE AVERAGE COST RISING ESTIMATION		(2.43+3.21)/2 = 2.82

Table 5-23 Material cost data

Process flow	Material	Unite	Usage rate	Material Price £, (2009-2010)
Cleaning	Alkaline degrease	Kg/m^2	0.045	0.790
	Pickle	kg/m^2	0.045	0.079
Masking	Maskant	L/m^2	0.9	1.833
	Toluene	L/m^2	0.3	0.494
Etching	NaOH	kg/kg Al dissolved	3	0.226
	De-smut	kg/m^2	0.045	0.265
De-masking	De-mask solution	L/m^2	0.42	0.688

Table 5-24 operating cost factors and assessments

<table>
<tr><td>Input factors
• Product configuration
• Process flow
• part surface area;
• total etching surface area;
• un-etching surface area;
• scribing line length;
• etching steps;
• weight reduction after etching
• loading number.</td><td>Output
Single ship man hour and material cost estimation.</td></tr>
<tr><td>Assessing method
Use data in Table 5-21, Table 5-23, as initial ones, and customize them if necessary.</td><td></td></tr>
</table>

6 CHEMICAL MILLING PROCESS CAPABILITY MODEL DEVELOPMENT

A Computer model for capturing and assessing the CHEMICAL MILLING PROCESS CAPABILITY has been developed based on MS Excel. And VBA language was used to implement the functions, e.g. interface, calculations etc.

This chapter introduces the development of CHEMICAL MILLING PROCESS CAPABILITY MODEL.

6.1 Model Inputs and Outputs

6.1.1 Inputs

Input data, which are captured from the concerned chemical milling process and the target product, will be called out by using corresponding factors. All the input information used for capturing chemical milling process capability is listed in the following tables. All the interfaces of this model have been illustrated in Appendix B and Appendix C, however, the main page and etching process step page are is shown in the following page..

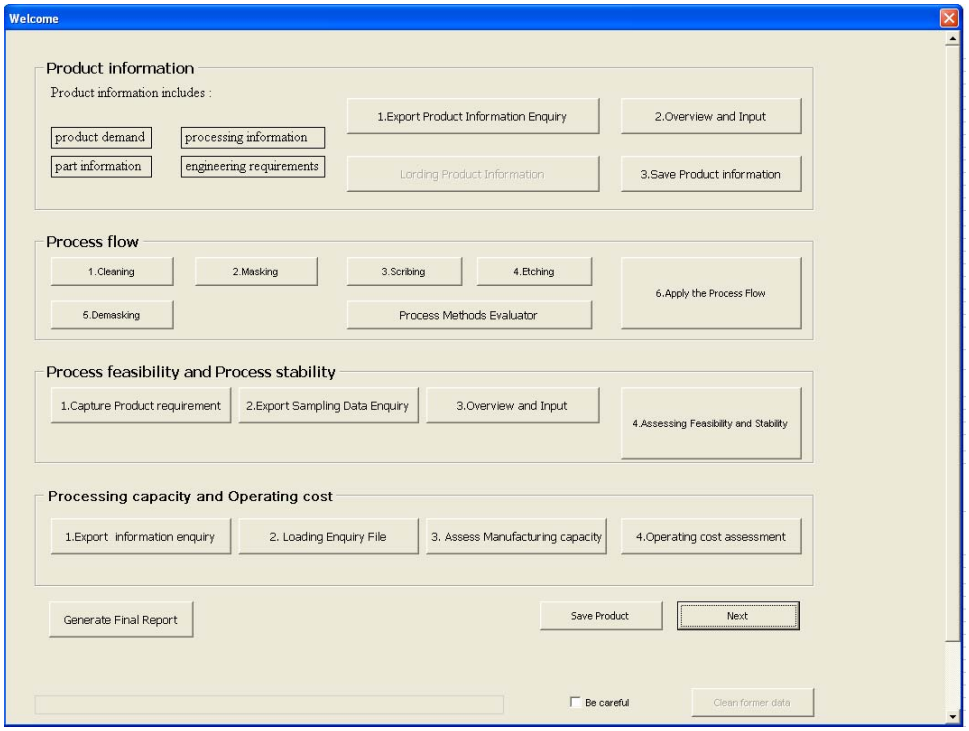


Figure 6-1 Input interface – Main page

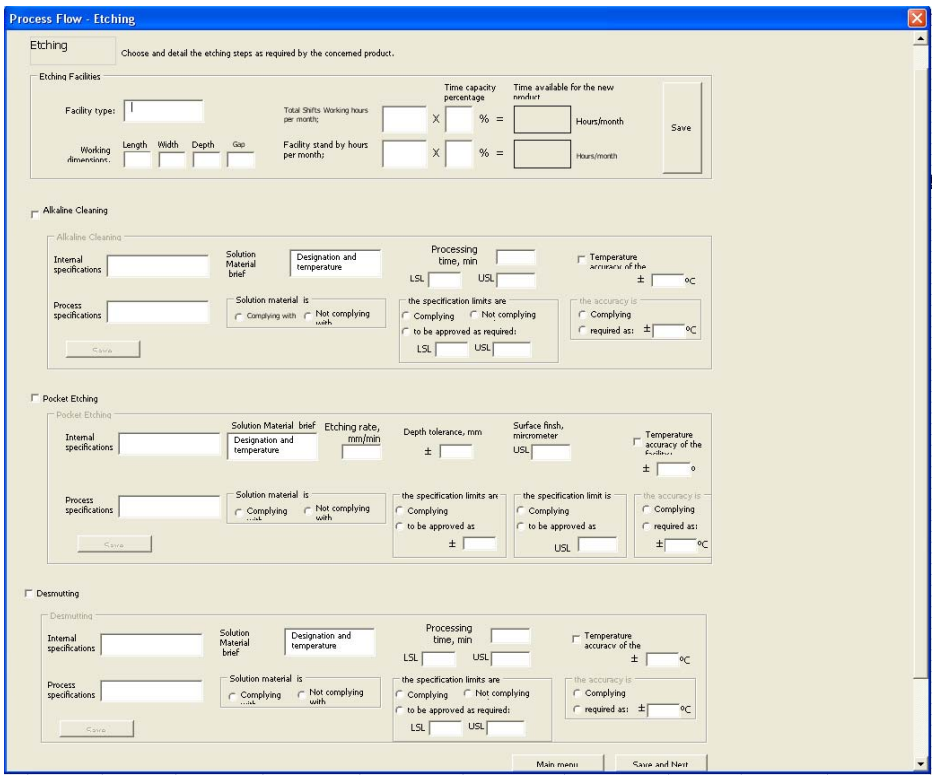


Figure 6-2 Input interface - etching step

Table 6-1 Model inputs and assessment methods summary

Measures	Input Factors	Assessment methods
The compliance of process parameters	• Internal process specifications • Product specifications • Process flow • Process method • parameters	Rules 5-1
Process feasibility	• Depth • Surface finish	Table 5-2
Processing difficulty	• Process flow, • Process specifications, • Engineering requirements,	Table 5-3
Product recognition	• Process factors in • Table 5-9. • Product in Table 5-5	Table 5-4
The compliance of engineering design requirements	• Part name, • Part dimensions, • Part material • Etching surface areas, • Pocket dimensions, • Etching steps, • Etching depths • Depth limits, • Surface finish limits	Table 5-5 Table 5-2 Table 5-7
Processing accuracy of the facilities	• Process flow, • Process specifications, • Facilities temperature accuracy.	Table 5-6
Process stability	• Depth • Surface finish	Table 5-7
Systemic specifications	• Internal process specifications • Product specifications • Process flow	Rules 6-1
The integrity of process system	• Process flow • Process method • Product specifications	Rules 5-3

Delivery schedule	• Product demand (Q, P), • Production rate (R_{Pd})	Table 5-10
Product demand	• Product Name: • Configuration • Total delivery ships	Table 5-11
The qualified product	• Process feasibility, • process stability, • delivery rate and manufacturing capacity	Table 5-13
Requests on facilities	• Time • space	Table 5-14 Table 5-15
Manufacturing/processing capacity	• Factors in Table 5-15, • e_{co} , • t^{max}, • facilities working dimensions, • product dimensions, • loading gap.	Table 5-19
The efficiency	• T^{max} , • R_{DL} , • R_{Pd} , • t^{t}_{pc}	Table 5-20
Process flow	• Internal process specifications • Product specifications • Process flow • Process method parameters	Rules 5-1 Rules 5-2 Rules 5-3
Process method	• Process • Compliance • Parameters • Product • Tolerance • Heating • Inspection activity • Resource • Loading per batch • Testing equipment	Table 5-21
Process economic	• Product configuration • Process flow • part surface area; • total etching surface area;	Table 5-22

	• un-etching surface area; • scribing line length; • etching steps; • weight reduction after etching • loading number.	

6.1.2 Outputs

The output of this model is a chemical milling process capability report which consists of five sections, the detail section layout has been shown in case study andsection 7, Appendix B, and Appendix C. illustrated The overall view of final report is as

1 Introduction

- Processing difficulty
- Product recognition
- The qualified product

2 Process flow

- Process flows
- The compliance of process parameters
- Systemic specifications
- The integrity of process system
- Process method

3 Process feasibility and stability

- Process feasibility
- The compliance of engineering design requirements
- Process stability

4 Manufacturing capacity

- Manufacturing/ Processing capacity
- Processing accuracy
- Delivery schedule
- Product demand
- Requests on facilities
- The efficiency

5 Process economic

- Process economic

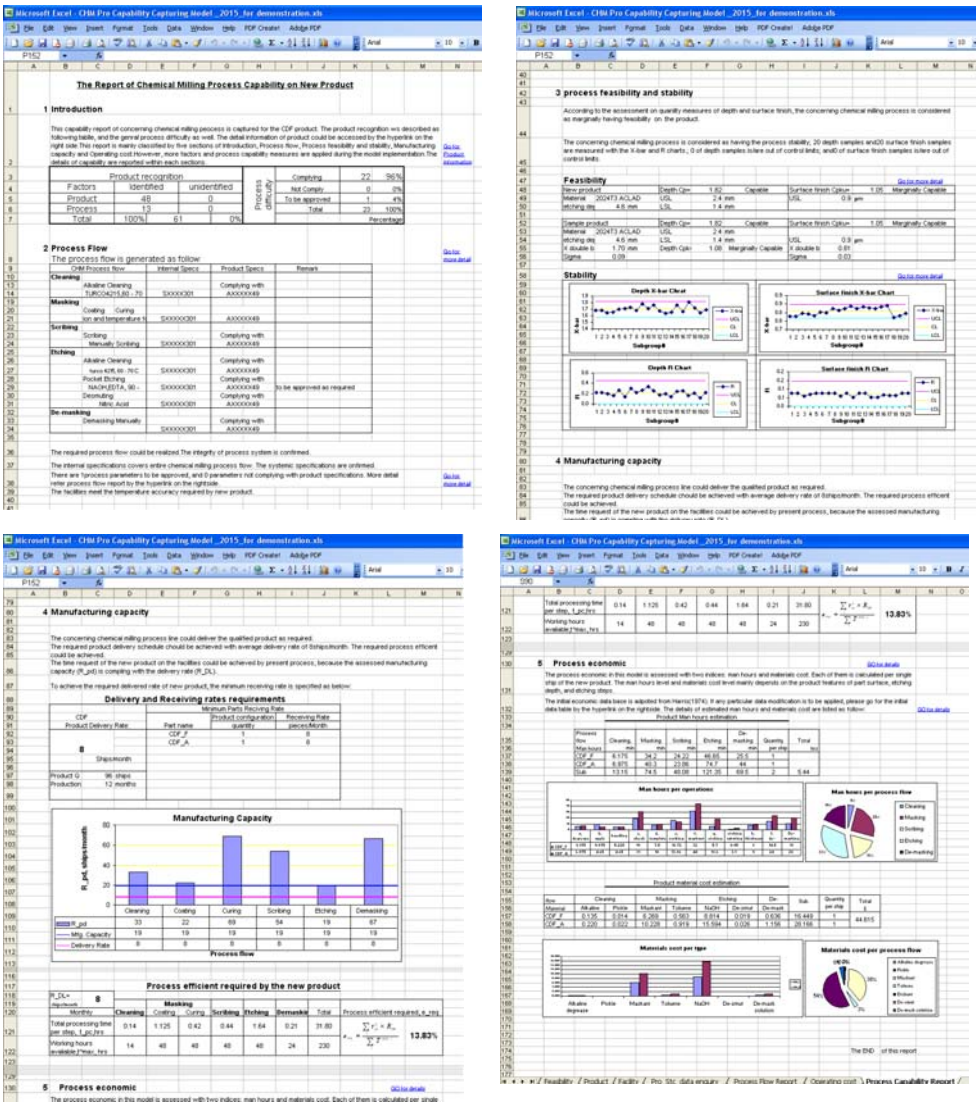


Figure 6-3 Capability report overview

6.2 Ground rules

The assessment of the each CHM process capability measure using the factors also depends on some other facts, i.e. the ground rules. The ground rules used in this model are listed below:

1, chemical milling operators are considered as skilled and qualified personals.

2, the model implementation bases on one processing method available at the same time. If there were multi options for single processing step on the processing line at the same time, please apply this model once for each option and then pick up the capability which you would prefer.

3, template tolerance affects the pocket dimensions accuracy. As the measures of template design and fabrication are out of the research scope, the pocket dimensions factor is not included in the capability assessment.

4, the process inspection is considered as support activity for chemical milling processing.

5, the coating operation is assumed at the room temperature between 20 ºC and 25ºC.

6, the part fabrication occupies the processing batch according to detail part types; the product is delivered as product configuration.

7, the default parameters should be customized. If not, they would be set as the mean value of USL and LSL or the value of one-side limit.

8, all the etching steps are scribed under same template at once; and each type of parts occupies one template.

9, the present process parameters are used to assess the processing time of the not complying steps.

6.3 Implementation of the calculation of the Chemical Milling Process capability measures

VBA is used to implement the functions and validation. The assessment methods and rules have been expressed in section 5, the source code for all the functions of this model is attached in Appendix C. However, one of the capability measures, manufacturing capacity, is taken as a example to illustrate the procedures of the implementation.

The one of the outputs of manufacturing capacity is R_{Pd}. It is calculated from **Equation 5-4**, and needs T_{op} as input. Meanwhile, T_{op} is calculated from Equation 5-8 with the input of t_{pc}. All the related factors would be listed with the assessing rules or the calculation equations till the product dimensions and process parameters are used to calculate the output which is being looked for. Following this rule, the procedures of manufacturing capacity assessment could be summarized as follow:

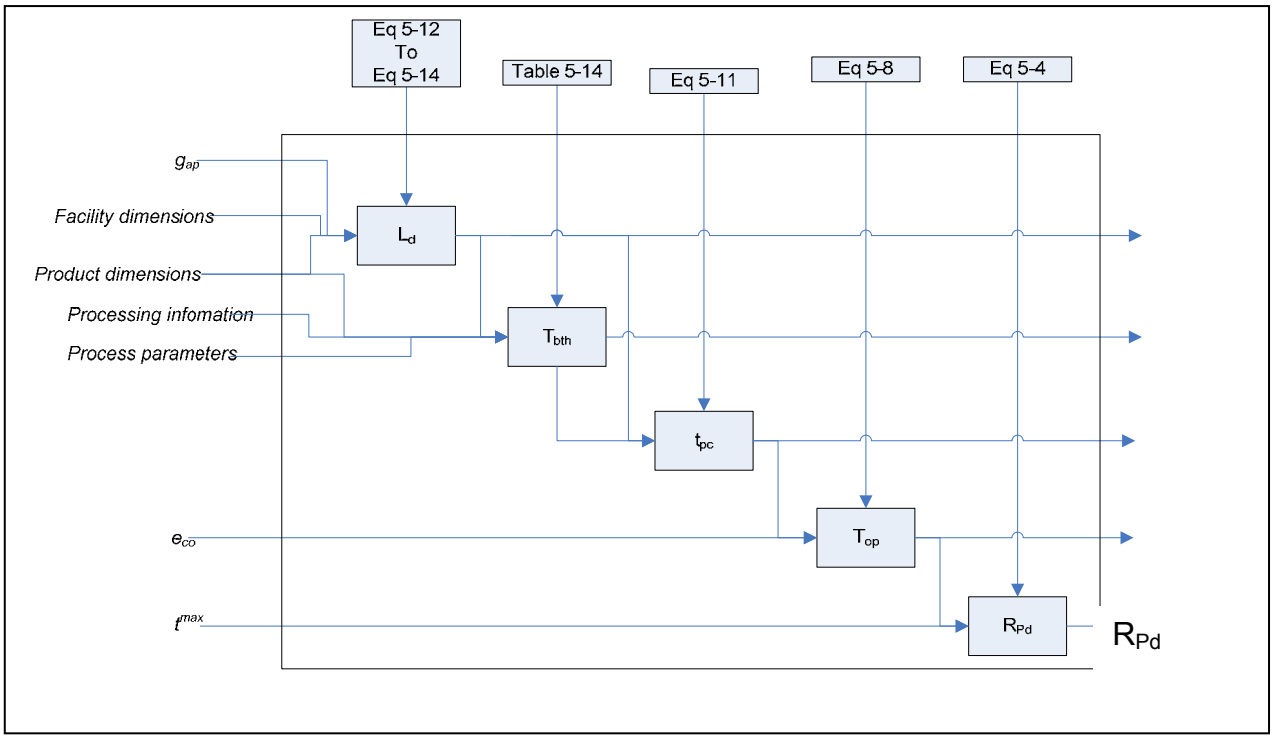


Figure 6-4 Manufacturing capacity assessing procedure

Following this procedure, the formulization of each capability measures would be handleable.

The finalized model has been illustrated in Appendix C with interface and VBA source codes.

7 VALIDATION AND CASE STUDY

7.1 Model validation

Two actual examples of products were used to validate the model outputs with actual production data. Industrial engineers are invited as experts to give the judgement. All of them have more than 3 years working experience in corresponding fields within the same company which the questionnaire responses were collected from. Two of them are working as process planners in chemical processing shop, and occupied chemical milling process planning at least one year. The third expert works as an internal quality audit engineer.

First, the research background, aim and scope were briefed. The model framework, assessing procedures and rules were also introduced at the early stage of communications.

After then two groups of product information were used to demonstrate the model functions, data processing and outputs delivery. The first group of product information was from two pieces of wing skin parts, which are sizing about 8m x 1mx 2mm with maximum 1.2 mm etching depth; the other group was from two pieces of cargo skin parts, which are sizing about 2m x 3m x 6mm with maximum 4.6mm etching depth. Some details of inputs were explained during the model application. The factors of model assessments covered the majority of process flows, product physical features and process specification limits. The captured information of product, process and facilities were sufficiently driving this model throughout the process capability assessing. The quantitative outputs, such as manufacturing capacity, were within a reasonable accuracy level. The operating cost module was conceptually validated due to lack of actual cost data from the referring products.

According to the demonstrations and outputs comparison of two groups of product information, experts agreed with the assessing method and rules of this model under three comments.

1, loading number

For some etching processes, there is a limit of maximum loading of two rows. This is because of the hot water spraying requirement for the etchants remain and should be considered during calculating the Loading numbers.

2, variant delivery rate between shop floors

For some products, the variant delivery rates between shop floors do not maximum the CHM facilities efficiency. That should be considered.

3, feasibility and stability assessments

The quality engineer pointed out that the X-double bar and R chart may not be popular with some companies, neither the indices of Cp and Cpk. In that case corresponding assessing modules, which base on the specific data, would be more practical.

7.2 Model improvement

All of the three comments have been accepted and incorporated to the Chemical milling process capability capturing model. The buttons on input page were arranged with numbers in accordance with the assessing subsequence. Three major improvements are detailed as follow:

1, Loading limit for etching step.

The loading limit has been enabled by asking for model user's preference. When the loading numbers are calculated for each part, there is pop-up MsgBox control which would feedback model user's choice to the loading numbers calculation. The source codes are list as follow:

```
'get loading number for Etching
Dim i as Integer
For i = 21 To 28
If Sheet2.Range("a" & i).Value = "" Then
Exit For
End If
'r_ow =(w-g_ap)/(d_pt+g_ap)
row = ((Sheet13.Range("f20").Value - Sheet13.Range("h20").Value) / (Sheet2.Range("h" & i).Value +
Sheet13.Range("h20").Value))
'r_ow =(l-g_ap)/(l_th+g_ap)
line = ((Sheet13.Range("e20").Value - Sheet13.Range("h20").Value) / (Sheet2.Range("f" & i).Value +
Sheet13.Range("h20").Value))
If row < 1 Or line < 1 Then
MsgBox "Please check the Etching facility dimensions and product dimensions."
End If
R = Int(row)
L = Int(line)

'#######
'accept experts' comments, incorporated Loading limit for Etching tank
Dim LoadingLMT As Variant
If R > 2 Then
LoadingLMT = MsgBox("There usually is a limitation of 2 rows loading for etching tanks. That will help to enhance
spraying cleaning quality and minimum the influence of etcants remain. Press Yes the 2 Rows Loading limit will be
applied to the etching tank; Press No will ignore this limit.", vbYesNo, "Loading Limit for etching tank")
End If
If LoadingLMT = 6 Then
R = 2
MsgBox "The limit has been applied to the new product."
End If
If LoadingLMT = 7 Then
MsgBox "The 2 rows loading limit for etching has been ignored."
End If
'########
Sheet8.Range("u" & (i + 73)).Value = R * L
Next i
```

2, Clarify the minimum delivery rate between shop floors

Assuming that the new product would be fabricated in series production, the delivery rate R_{DL} is clarified as the minimum receiving and delivery rate between shop floors to continuously achieve the product demands.

The improvement on model is realized on the product information capturing stage. As the product is produced by parts and delivered by product configurations, the specific quantity for each type of parts needs to be listed with minimum receiving rate r_{rc}. The source codes are listed as below.

Equation 7-1

$$r_{rc(i)} = n_i \times R_{DL}$$

Where $r_{rc(i)}$ stands for the minimum receiving rate for part i;

n_i means the part i delivery quantity of single ship product;

R_{DL} means the delivery rate required by the new product.

```
Private Sub CommandButton3_Click()
' 3.Save product information
'get the receiving and delivery rate for final report
Sheet3.Range("b90").Value = Sheet2.Range("b3").Value ' product name
Sheet3.Range("c97:c98").Value = Sheet2.Range("b4:b5").Value
Sheet3.Range("b92").Value = (Sheet2.Range("b4").Value / Sheet2.Range("b5").Value) 'R_DL
Sheet3.Range("e92:e99").Value = Sheet2.Range("a41:a48").Value ' parts names
Sheet3.Range("g92:g99").Value = Sheet2.Range("b21:b28").Value ' product configuration

Dim n As Integer
For n = 92 To 99
If Sheet2.Range("a" & (n - 71)).Value = "" Then
Exit For
End If
Sheet3.Range("i" & n).Value = (Sheet3.Range("g" & n).Value * Sheet3.Range("b92").Value)
Next n
MsgBox "minimum R_DL and r_rc are saved."
MsgBox "Product information saved."
ThisWorkbook.Save
End Sub
```

3, Feasibility and stability assessing modules

According to experts' comments, the process feasibility and stability assessing modules are developed. The assessing factors of depth and surface finish have been expressed in 5.2 and 5.7. The assessing methods of calculating the Cp, Cpk, X double bar and R have been reviewed from Equation 3-2 to Equation 3-10.

Defining the worksheet10 as sample product data table, worksheet4 as stability assessing data table, and the worksheet6 as the feasibility data table, the stability assessing module could be implemented, for more detail about this model please refer the Appendix C.

7.3 Case description

The chemical milling process capability model was demonstrated with a case study in an Asian aerospace manufacturing enterprise. Two of the products on the processing line were chosen and studied during the model validation. One of them, which name is CDF (Cargo Door Frame) product, is used to demonstrate the case study procedures and model implementation. The CDF is kind of thick cargo skin product including two pieces of part. The product information is shown in Figure 7-1. The concerning chemical milling process line is within an Asian airframe manufacturer who has multi products occupied on this processing line. The defined process flow is shown in Figure 7-2.

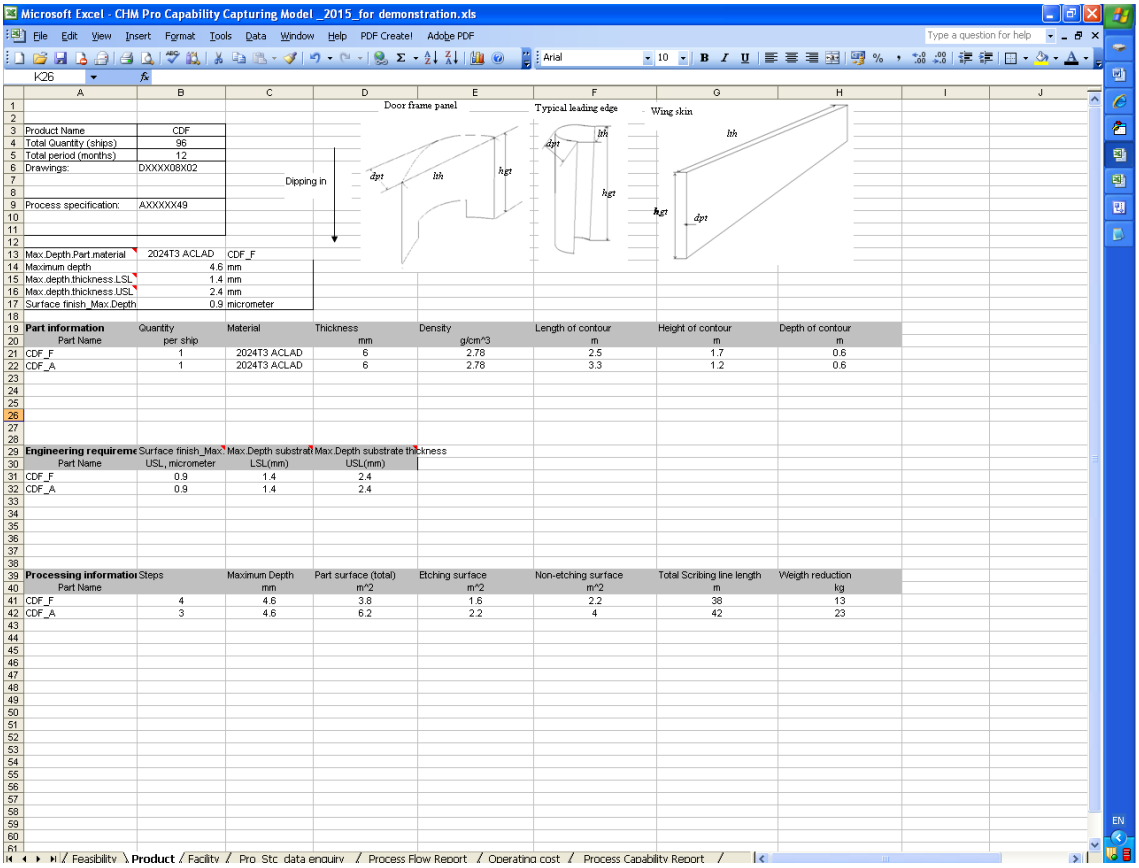


Figure 7-1 Case study CDF product information

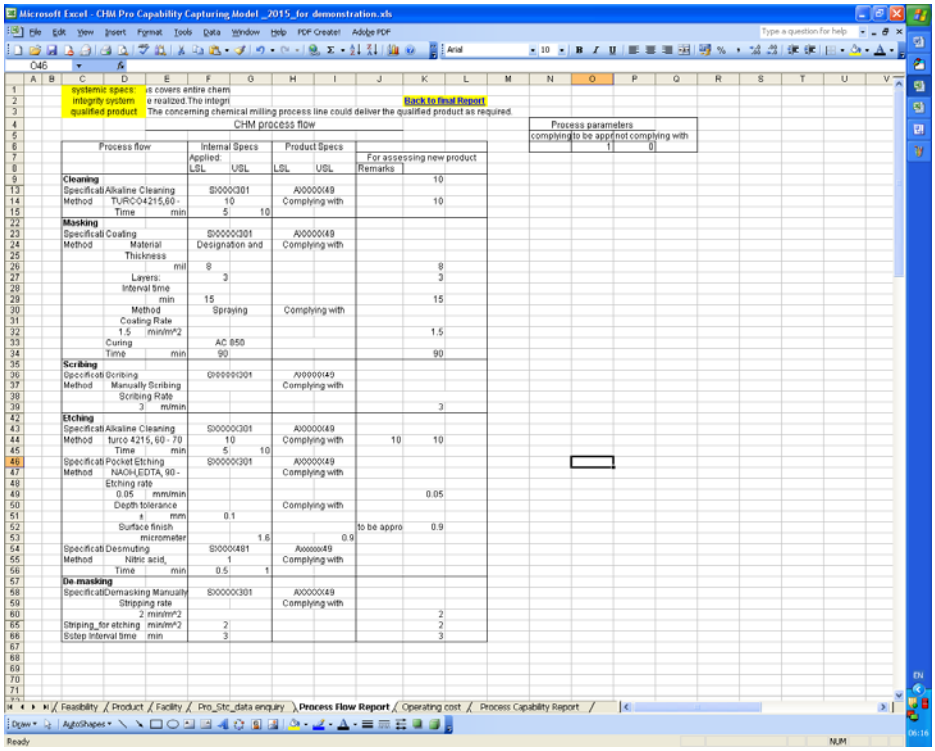


Figure 7-2 The defined CHM process flow

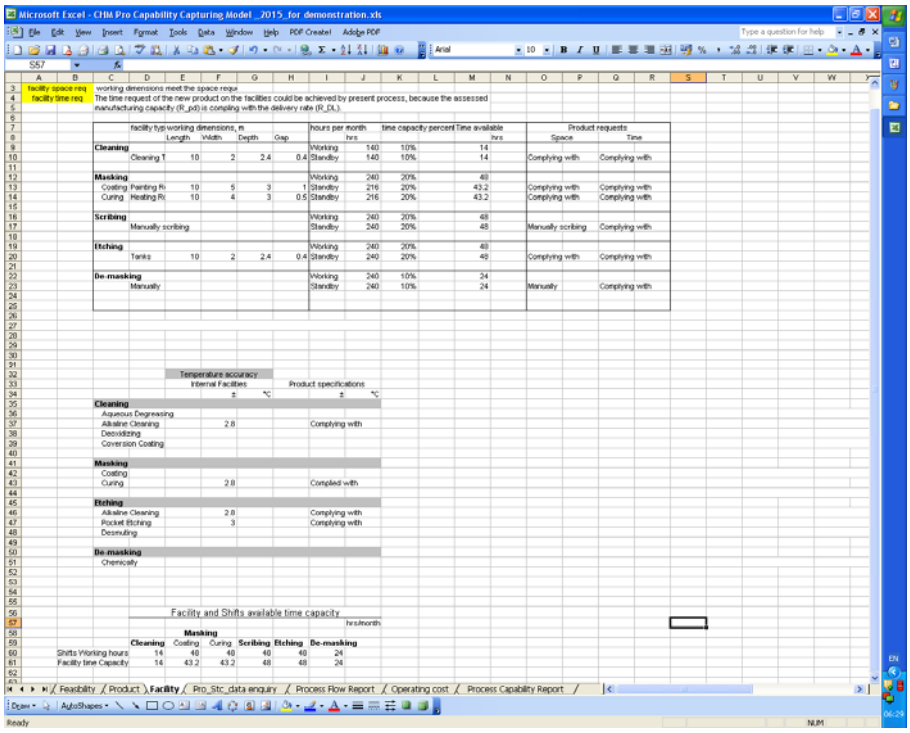


Figure 7-3 The defined CHM process facilities

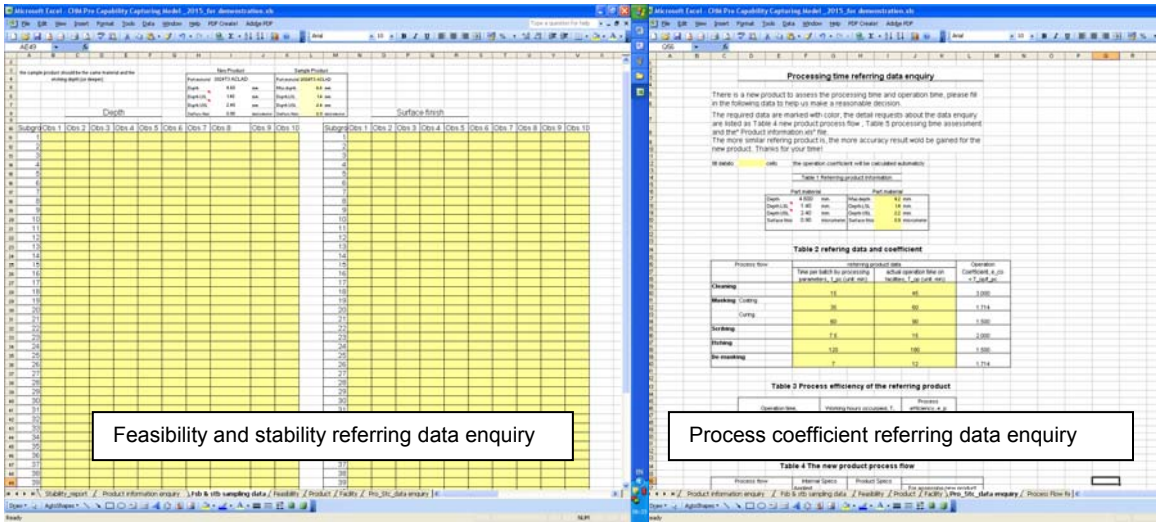


Figure 7-4 Referring product data enquiry

In order to avoid commercial disputes some of the data displayed here were rounded and/or modified.

The data used to demonstrate this model are modified and rounded in order to avoid leaking any confidential information of industrial application. However, the characteristics and trends of them are kept as much as possible. Taking the surface finish data for example, they are modified from six groups of inspection values. During the series production, the increasing aluminium ion reduced surface finish from 29 (as shown in the data table) to 33 micro inches (close to the upper control limit). After etchant maintenance, the surface finish level is regained as shown in the X double bar chart. This model assessed the modified data and output the X double bar chart, R chart, Cp values and Cpk values. The overall modifications of the input data are illustrated as:

Table 7-1 Data declaration

Data domain	Data deviation
Process	Rounded.
Product	Rounded before collects; Modified before model demonstration.
Facilities	Approximation values

With the inputs from Figure 7-1 to Figure 7-4, the model implemented 18 process capability measures assessments as section 5 defined; the final CHM process capability report was generated with formation of MS EXCEL® file.

The final report summarized the CHM process capability information in 5 sections: Introduction, process flow, feasibility and stability, manufacturing capacity and the process economic; meanwhile the hyperlink to detail report is available.

From the introduction section, the product recognition and process difficulty were briefed with only known issue of “to be approved”.

The section of process flow presented the defined method of each step with a comparison table between internal process and product specifications. The capability measures of facility temperature accuracy, integrity of process system and the systemic process specification were confirmed.

The section of process feasibility and stability captured the process capability on referring product and assessed the chemical milling process with new product specifications. The results showed that present state of the concerning process is stable; and the feasibility on new product was confirmed positive.

The section of manufacturing capacity assessed the maximum production rate and required delivery rate of new product based on the defined process flow. The achievements on delivery rate, qualified product, time request on facilities and the required process efficient were confirmed positive.

The process economic in this model is assessed with two indices: man hours and materials cost. Each of them is calculated per single ship of the new product. The man hours level and materials cost level mainly depends on the product features of part surface, etching depth, and etching steps. The results showed that man hours for single ship of new product are about 5.4hours; the direct material cost is about £44.6 per single ship; the etchant and maskant takes about 92% of the direct material cost. Screen shots of final report are shown as follow:

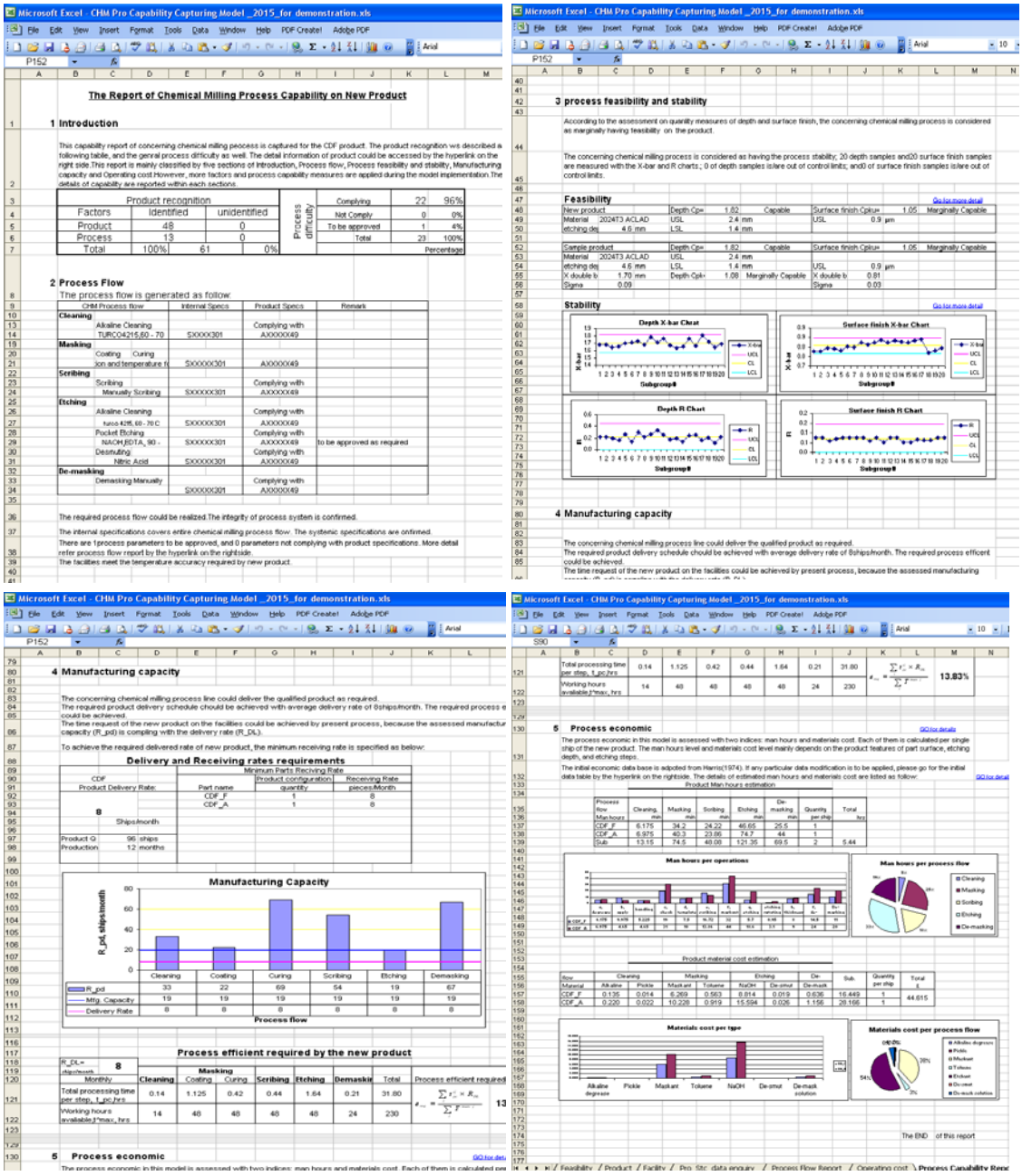


Figure 7-5 Case study final process capability report

8 CONCLUSION

The research has developed a model to capture and assess the chemical milling process capability on the coming product. The chemical milling process knowledge was captured for developing this model. Process capability measures are captured from questionnaire survey. Assessment methods have been developed by analysing the process flow and capability factors, the chemical milling process capability measures covered in this model are:

- The compliance of process parameters
- Process feasibility
- Processing difficulty
- Product recognition
- The compliance of engineering design requirements
- Processing accuracy of the facilities
- Process stability
- Systemic specifications
- The integrity of process system
- Delivery schedule
- Product demand
- The qualified product
- Requests on facilities
- Manufacturing/processing capacity
- The efficiency

- Process flow
- Process method
- Process economic

The process capability model was developed with excel plus VBA module which responses model users' inputs with process capability report.

The framework of the improved model could generally support industrial application on capturing chemical milling process capability. The calculations of these measures involve more than two thousands lines source codes.

They had been well noted with function explanations during the developing. That would sufficiently support further developing on more detail levels of CHM process modelling.

A actual examples case study of wing skin product and cargo panel product were used to verify the function of this model. The case study confirmed that this model output 18 chemical milling processing capability measures with 5 sections report. Industry experts considered the output and model as reasonably accuracy and logically structured. The process economic measure was assessed without industrial data validating due to lack of access to corresponding cost information. Experts' comments are applied for improving the model.

9 DISCUSSION

The chemical milling process capability model deliver the capability with four major class measures: process flow, process feasibility and staility, manufacturing capacity and process economic.

The former three major measures have been well tested and validated on two different types product during the validation and case study stage. The process economic measures are variant from each other processes and products. The initial man hours database and direct material cost database need to be refined before proceeding high accuracy operating cost assessment. That would involve more thorough researches in this specific field. That is considered as one of the future works for now.

In order to simplify the considerations on geometry and materials of product, the developed model focus on the typical aluminium chemical milling parts, such as fuselage skin, wing skin and leading edge.

However, not all the factors indentified during the analysing the questionnaire's answers are covered in the research scope of this thesis, such as remedial measures, process aids, leading time of the technical preparation and impacts on environment.

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APPENDICES

Appendix A Questionnaire Content and the Answers collected

A questionnaire was given out to capture the aeronautical engineers' constraints on assessing manufacturing process, selecting component subcontractors, launching new product and assessing process capability on the new product, see Q1, Q2, Q5 and Q6. These are the priority concerns of this thesis at now stage. However, there are four more questions to learn about the functions information requests of departments' that involved in the decision making on launching products , see Q3, Q4, Q7 and Q8. They are originally designed to help further research related to the decision making and not the focus of this research. The collected answers of four major questions are list in Table A.2-1 to

Table A.2-4.

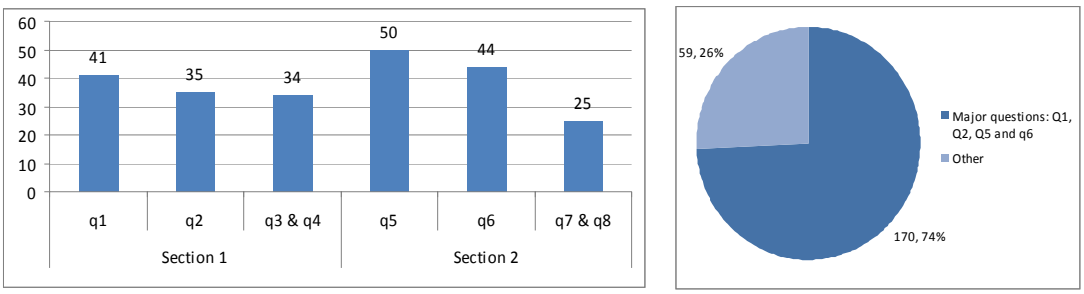
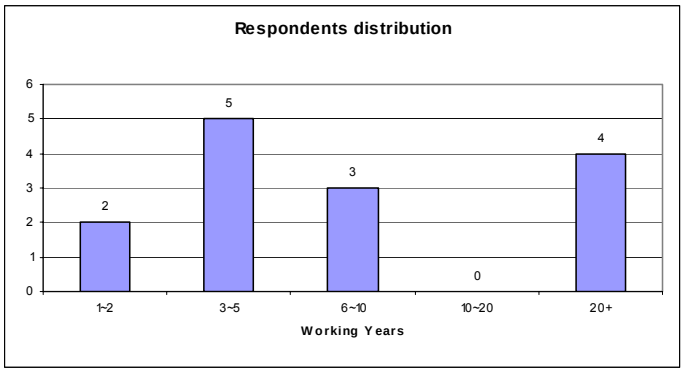


Figure A-1 The answers distribution



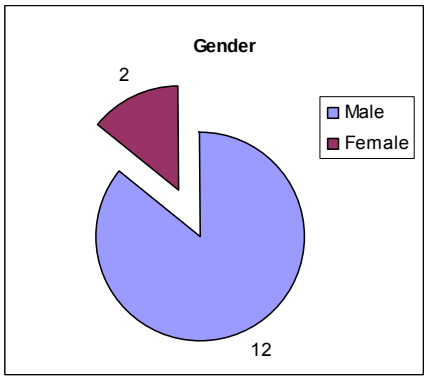


Figure A-2 Respondents profiles

A.1 Questionnaire content

Section 1, selecting manufacturing process sources

An enterprise (E) has a designed component (CP) which need to select a supplier. Component (CP) mainly needs three naming manufacturing processes, which are P1, P2 and P3. The enterprise E plans to assess three component suppliers (naming A, B and C) and then decide the selection.

If this scenario is in your organization/company, please answer the following 4 questions for assessing and selecting component supplier:

Q1, From your working domain and understanding, what should be included in the criteria of assessing manufacturing process?

_____ . _____ .

_____ . _____ .

_____ . _____ .

Q2, From your working domain and understanding, what should be included in the criteria of selecting component supplier?

_____ . _____ .

_____ . _____ .

_____._____.

3, What support could be provided by your department in assessing and selecting the suppliers?

4, what information does your department need in order to provide the support?

Q3： Supports could be provided	**Q4**： Information needed
•	•
•	•
•	•
•	•

Section 2, Launching new product

An enterprise (E) considers accepting the order of a new product (DP). It mainly needs three naming manufacturing processes, which are P1, P2 and P3.

If this scenario is in your organization/company, please answer the following 4 questions for assessing the enterprise internal process capabilities:

Q5, From your working domain and understanding, what should be included in the assessing criteria of accepting the order of a new product (DP)?

_____._____.

_____._____.

_____._____.

Q6, From your working domain and understanding, what should be included in the criteria of assessing enterprise process capability on product (DP)?

_____._____.

_____._____.

_____._____.

3, What support could be provided by your department in the assessing and decision making?

4, what information does your department need in order to provide the support?

Q7： Supports could be provided	**Q8**：Information needed
•	•
•	•
•	•
•	•

A.2 The answers collected

Table A.2-1Answers collected from Q1

Sample 1	Process parameters comply with specification requirements
Sample 1	Process facilities are certificated and within the validity
Sample 1	If the operators have been trained
Sample 1	If the production records available
Sample 1	Process aids are within the validity of certifications
Sample 2	Process feasibility
Sample 2	Process advancement and the quality of the processed product
Sample 2	Comply with the process requirements of this product
Sample 2	The impacts on the environment within the processing flow
Sample 2	Process remedial measures
Sample 3	Manufacturing process capacity meets product requests.
Sample 3	Quality system comply with corresponding requirements
Sample 3	Project management competence, including supplier chain control
Sample 3	Customer service competence
Sample 4	Process specification and standards
Sample 4	Requests on facilities
Sample 4	Processes flow length
Sample 4	Process advancement
Sample 4	Process operability

Sample 5	The processed product comply with the requirements
Sample 5	Fabrication Process economic
Sample 6	Accurately achieve and comply with the design requirements
Sample 6	Process method is reasonable, efficient, economic and stable
Sample 6	The applied process specification and technical standards are effective and capable
Sample 7	The delivered products satisfy customer's manufacturing requirements
Sample 7	The supplier could deliver the qualified products as schedule
Sample 7	The delivered products satisfy customer's schedule
Sample 7	Lower cost as much as possible
Sample 7	Manufacturability is conductive to customer's further producing
Sample 8	Systemic process specifications or procedures
Sample 9	The supplier's capacity, quality management system, project management competence
Sample 10	Systemic process specifications or procedures
Sample 11	Systemic process specifications or procedures
Sample 12	The supplier's capacity, quality management system, the capacities of special processes, project management competence
Sample 13	The performance of quality management system
Sample 13	The capacities of special processes,
Sample 14	Project management competence
Sample 14	The performance of quality management system
Sample 14	The quality of personnel
Sample 14	Manufacturing process capacity
Sample 14	The capacities of special processes,

Table A.2-2 Answers collected from Q2

Sample 1	The integrity of quality management system
Sample 1	If the manufacturing capacity available
Sample 2	Manufacturer could deliver the qualified product
Sample 2	Product could be delivered as schedule
Sample 2	The integrity of quality management system
Sample 2	Long-term cooperation
Sample 2	Having keen sense of responsibility
Sample 3	Process design capacities
Sample 3	Manufacturing capacity
Sample 3	Operation design capacity
Sample 4	Supplier's manufacturing capacity
Sample 4	Supplier's on-site service capacity
Sample 4	Supplier's support service capacity within product life cycle
Sample 4	Supplier's ability to respond to the unexpected problems
Sample 5	Supplier's manufacturing capacity
Sample 5	The performance of quality management system on quality assurance
Sample 5	The convenience and economy for both of the product delivery and communication
Sample 6	If the technical capacity reserve available for the product manufacturing
Sample 6	The production (processing) requests on facilities
Sample 6	The length of technical preparation cycle
Sample 6	The process state is stable

Sample 7	Delivering component as schedule
Sample 7	Comply with customer's manufacturing requirements
Sample 8	The integrity of process system
Sample 9	The capacities of facilities, tooling design and fabrication
Sample 10	The integrity of process system
Sample 11	The integrity of process system
Sample 12	Manufacturing capacity, including capacities of facilities, tooling design and fabrication, process design capacity, performance of quality management, quality assurance capacity(including physical and chemical measuring, inspection and testing)
Sample 13	The performance of quality management system
Sample 13	Quality assurance capacity (including physical and chemical measuring, inspection and testing)
Sample 13	Manufacturing capacity, including capacities of facilities, tooling design and fabrication, process design capacity
Sample 14	The performance of quality management system
Sample 14	The performance and quality range of the quality assurance system
Sample 14	Physical and chemical measuring capacity, inspection and testing facilities
Sample 14	Manufacturing capacity, including capacities of facilities and the quality of personnel

Table A.2-3 Answers collected from Q5

Sample 1	Feasibility of the processes solution
Sample 1	Quality system
Sample 1	Testing capacity
Sample 2	If the present process comply with the process required by the product
Sample 2	The cooperative processing for unachievable processes should be available
Sample 2	If the product order is able to be efficiently completed as the schedule
Sample 3	Manufacturing process capacity comply with the requests
Sample 3	Inspection capacity comply with the requirements
Sample 3	Personal qualification comply with the requirements
Sample 4	The production life cycle of the new product
Sample 4	The total product demand
Sample 4	The manufacturing cost of the product
Sample 4	Processing difficulty on the product
Sample 5	Manufacturing capacity
Sample 5	Various costs called by the product manufacturing
Sample 5	Development planning and positioning of this company
Sample 6	If the technical capacity reserve comply with the product manufacturing
Sample 6	If the present space, facilities and equipments comply with the product manufacturing
Sample 6	If it helps the company improve the present technical performance
Sample 7	If the manufacturing capacity is enough to deliver the qualified product as schedule
Sample 7	If the enough profit available
Sample 7	There is no issue of technical cause for the enterprise.
Sample 8	The product's processing requirements, the deliver rates requests.
Sample 8	Processing capacity
Sample 9	Product purchasing information
Sample 9	Process requirements

Sample 9	Quality requirements
Sample 9	Delivery schedule
Sample 10	The product's processing requirements, the deliver rates requests.
Sample 10	Processing capacity
Sample 11	The product's processing requirements, the deliver rates requests.
Sample 11	Processing capacity
Sample 12	Product purchasing information
Sample 12	Process requirements
Sample 12	Quality requirements
Sample 12	Delivery schedule request
Sample 12	The packing and shipping requirements of the component
Sample 12	Input requirements of acceptance criteria and other aspects
Sample 13	Product purchasing information
Sample 13	Process requirements
Sample 13	Quality requirements
Sample 13	Delivery schedule request
Sample 13	The packing and shipping requirements of the component
Sample 13	Input requirements of acceptance criteria and other aspects
Sample 14	Product purchasing information
Sample 14	Process requirements
Sample 14	Quality requirements
Sample 14	Delivery schedule request
Sample 14	The packing and shipping requirements of the component
Sample 14	Acceptance criteria

Table A.2-4 Answers collected from Q6

Sample 1	If it is feasible for the facilities
Sample 1	If the labour capacity is available
Sample 1	Testing capacity
Sample 2	The present process is in accordance with the requesting one
Sample 2	The present process could perform the requesting process parameters
Sample 2	The present process should achieve requesting efficiency.
Sample 3	Production capacity meets the request
Sample 3	Inspection capacity meats the request
Sample 4	Toolings fabrication capacity, inspection capacity
Sample 4	The facilities' processing accuracy of the enterprise
Sample 4	Requests on the space
Sample 4	Processing methods and flow for the new product's fabrication
Sample 5	The manufacturing capacity could achieve both of the quality and quantity requests on the qualified products
Sample 5	Production plan of this enterprise
Sample 5	The profit for this company
Sample 6	The present technical standard, specification are capable to the new product
Sample 6	Current technical preparing schedule comply with order schedule
Sample 6	The present manufacturing capacity could achieve product feature indices
Sample 7	The accuracy standard of machining
Sample 7	Material specifications

Sample 7	The achievable accuracy of present machines
Sample 7	Inspection standards
Sample 7	Heat-treatment standards and surface-treatment standards,
Sample 7	Delivery standards
Sample 8	If the processing capacity meets the product request
Sample 9	Understand the product
Sample 9	The present facilities could meet process requirements
Sample 10	Processing capacity meets the request
Sample 11	The manufacturing capacity could meet requests of the new product
Sample 12	Understand the product
Sample 12	The present facilities could meet process requirements
Sample 12	If the manufacturing process comply with engineering design requirements
Sample 12	If the personals are qualified for the product manufacturing
Sample 12	Inspection and testing capacities
Sample 12	Assessing implementing competence on contracts
Sample 13	Understand the product
Sample 13	If the manufacturing process comply with the requirements
Sample 13	Assessing implementing competence on contracts
Sample 13	Inspection and testing capacities
Sample 14	Understand the product
Sample 14	If the manufacturing process comply with the requirements
Sample 14	Assessing implementing competence on contracts
Sample 14	Inspection and testing capacities

Appendix B The Case Study of Capturing Certain CHM Process Capability On A CDF Product

B.1 The inputs enquiry for model implementation

The main page of this model persevered information enquiry export buttons. They will automatically save the enquiry information as a uniform data table.

For the chemical milling process inputs, this model set up five user forms to specific the required inputs for each step of the process flow. The information enquiry and process flow are list as follow:

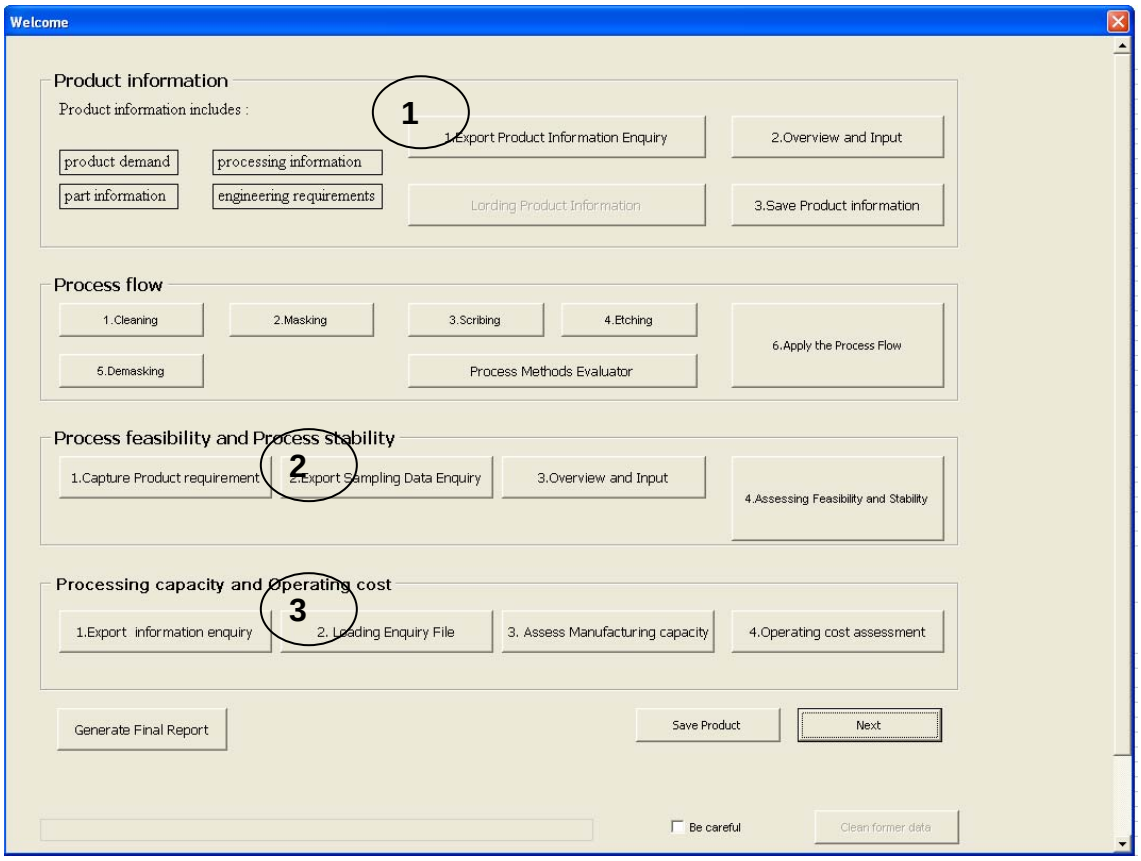
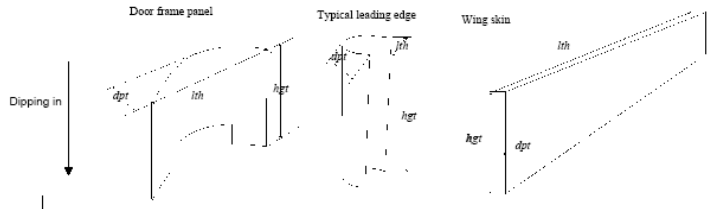


Figure B-1 Inputs and enquiries on main page

Product Name	CDF
Total Quantity (ships)	96
Total period (months)	12
Drawings:	DXXXXD8X02
Process specification:	AXXXXX49

Max.Depth.Part.material	2024T3 ACLAD	CDF_F
Maximum depth	4.6 mm	
Max.depth.thickness.LSL	1.4 mm	
Max.depth.thickness.USL	2.4 mm	
Surface finish_Max.Depth	0.9 micrometer	



Part information Part Name	Quantity per ship	Material	Thickness mm	Density g/cm^3	Length of contour m	Height of contour m	Depth of contour m
CDF_F	1	2024T3 ACLAD	6	2.78	2.5	1.7	0.6
CDF_A	1	2024T3 ACLAD	6	2.78	3.3	1.2	0.6

Engineering requirement Part Name	Surface finish_Max.D USL, micrometer	Max.Depth substrate LSL(mm)	Max.Depth substrate thickness USL(mm)
CDF_F	0.9	1.4	2.4
CDF_A	0.9	1.4	2.4

Processing information Part Name	Steps	Maximum Depth mm	Part surface (total) m^2	Etching surface m^2	Non-etching surface m^2	Total Scribing line length m	Weigth reduction kg
CDF_F	4	4.6	3.8	1.6	2.2	38	13
CDF_A	3	4.6	6.2	2.2	4	42	23

Figure B-2 Product information

the sample product should be the same material and the etching depth (or deeper)

New Product			Sample Product		
Part material	2024T3 ACLAD		Part material	2024T3 ACLAD	
Depth	4.60	mm	Max depth	4.6 mm	
Depth LSL	1.40	mm	Depth LSL	1.4 mm	
Depth USL	2.40	mm	Depth USL	2.4 mm	
Surface finish	0.90	micrometer	Surface finish	0.9 micrometer	

Depth

Subgro	Obs.1	Obs.2	Obs.3	Obs.4	Obs.5	Obs.6	Obs.7	Obs.8	Obs.9	Obs.10
1	1.67	1.58	1.60	1.80	1.74					
2	1.60	1.82	1.74	1.63	1.60					
3	1.50	1.70	1.65	1.68	1.70					
4	1.75	1.60	1.59	1.68	1.65					
5	1.60	1.74	1.60	1.68	1.86					
6	1.65	1.65	1.74	1.70	1.79					
7	1.75	1.70	1.60	1.68	1.90					
8	1.80	1.63	1.70	1.58	1.70					
9	1.92	1.79	1.80	1.75	1.65					
10	1.77	1.85	1.60	1.52	1.80					
11	1.88	1.82	1.74	1.63	1.77					
12	1.58	1.70	1.65	1.68	1.75					
13	1.55	1.60	1.59	1.68	1.75					
14	1.65	1.74	1.60	1.68	1.60					
15	1.89	1.65	1.75	1.81	1.70					
16	1.80	1.70	1.60	1.55	1.65					
17	1.88	1.73	1.80	1.89	1.75					
18	1.75	1.68	1.81	1.75	1.60					
19	1.59	1.59	1.70	1.68	1.65					
20	1.82	1.60	1.60	1.70	1.75					
21										
22										
23										
24										

Surface finish

Subgro	Obs.1	Obs.2	Obs.3	Obs.4	Obs.5	Obs.6	Obs.7	Obs.8	Obs.9	Obs.10
1	0.76	0.81	0.76	0.74	0.81					
2	0.74	0.79	0.76	0.81	0.79					
3	0.76	0.82	0.79	0.81	0.79					
4	0.76	0.81	0.79	0.76	0.83					
5	0.81	0.74	0.79	0.76	0.80					
6	0.81	0.84	0.76	0.84	0.76					
7	0.79	0.84	0.81	0.79	0.76					
8	0.81	0.84	0.81	0.86	0.79					
9	0.84	0.81	0.79	0.78	0.84					
10	0.81	0.84	0.79	0.81	0.86					
11	0.81	0.84	0.86	0.81	0.86					
12	0.84	0.81	0.81	0.79	0.86					
13	0.86	0.86	0.81	0.79	0.84					
14	0.81	0.84	0.81	0.86	0.81					
15	0.79	0.84	0.84	0.81	0.84					
16	0.88	0.81	0.83	0.81	0.84					
17	0.80	0.84	0.86	0.84	0.86					
18	0.74	0.79	0.74	0.80	0.79					
19	0.76	0.80	0.79	0.81	0.74					
20	0.77	0.84	0.78	0.76	0.83					
21										
22										
23										
24										

Figure B-3 Fsb & stb sampling data

Processing time referring data enquiry

There is a new product to assess the processing time and operation time, please fill in the following data to help us make a reasonable decision.

The required data are marked with color, the detail requests about the data enquiry are listed as Table 4 new product process flow , Table 5 processing time assessment and the" Product information.xls" file.
The more similar refering product is, the more accuracy result wold be gained for the new product. Thanks for your time!

fill datato cells the operation coefficient will be calculated automaticly

Table 1 Referring product information

Part.material			Part.material		
Depth	4.600	mm	Max.depth	4.2	mm
Depth LS	1.40	mm	Depth.LSL	1.4	mm
Depth US	2.40	mm	Depth USL	2.2	mm
Surface f	0.90	micromete	Surface finish	0.9	micrometer

Table 2 refering data and coefficient

Process flow		referring product data		Operation Coefficient, e_co = T_op/t_pc
		Time per batch by processing parameters, t_pc (unit: min)	actual operation time on facilities, T_op (unit: min)	
Cleaning		15	45	3.000
Masking	Coating	35	60	1.714
	Curing	60	90	1.500
Scribing		7.5	15	2.000
Etching		120	180	1.500
De-masking		7	12	1.714

Table 3 Process efficiency of the referring product

Operation time, T_op, (unit Hours)	Working hours occurpied, T, (unit: hours)	Process efficiency, e_p =T_op/T
84	240	35.0%

Figure B-4 Processing time referring data enquiry

CHM process flow

Process flow	Internal Specs Applied: LSL	USL	Product Specs LSL	USL	For assessing new product Remarks	
Cleaning						10
Specificatic Alkaline Cleaning	SXXXX301		AXXXXX49			
Method TURCO4215,60 - 70	10		Complying with			10
Time min	5	10				
Masking						
Specificatic Coating	SXXXXX301		AXXXXX49			
Method Material	Designation and		Complying with			
Thickness mil	8					8
Layers:	3					3
Interval time min	15					15
Method	Spraying		Complying with			
Coating Rate 1.5 min/m^2						1.5
Curing	AC 850					
Time min	90					90
Scribing						
Specificatic Scribing	SXXXXX301		AXXXXX49			
Method Manually Scribing			Complying with			
Scribing Rate 3 m/min						3
Etching						
Specificatic Alkaline Cleaning	SXXXXX301		AXXXXX49			
Method turco 4215, 60 - 70 C	10		Complying with		10	10
Time min	5	10				
Specificatic Pocket Etching	SXXXXX301		AXXXXX49			
Method NAOH,EDTA, 90 -			Complying with			
Etching rate 0.05 mm/min						0.05
Depth tolerance			Complying with			
± mm	0.1					
Surface finish					to be approv	0.9
micrometer		1.6		0.9		
Specificatic Desmuting	SXXXX481		Axxxxxx49			
Method Nitric acid,	1		Complying with			
Time min	0.5	1				
De-masking						
Specificatic Demasking Manually	SXXXXX301		AXXXXX49			
Stripping rate			Complying with			
2 min/m^2						2
Striping_for etching min/m^2	2					2
Sstep Interval time min	3					3

Figure B-5 The defined CHM process flow information

	facility type	working dimensions, m Length	Width	Depth	Gap	hours per month hrs	time capacity percenta	Time available hrs
Cleaning						Working 140	10%	14
	Cleaning T	10	2	2.4	0.4	Standby 140	10%	14
Masking						Working 240	20%	48
Coating	Painting Ro	10	5	3	1	Standby 216	20%	43.2
Curing	Heating Ro	10	4	3	0.5	Standby 216	20%	43.2
Scribing						Working 240	20%	48
	Manually scribing					Standby 240	20%	48
Etching						Working 240	20%	48
	Tanks	10	2	2.4	0.4	Standby 240	20%	48
De-masking						Working 240	10%	24
	Manually					Standby 240	10%	24

	Temperature accuracy Internal Facilities ± °C	Product specifications ± °C
Cleaning		
Aqueous Degreasing		
Alkaline Cleaning	2.8	Complying with
Deoxidizing		
Coversion Coating		
Masking		
Coating		
Curing	2.8	Complied with
Etching		
Alkaline Cleaning	2.8	Complying with
Pocket Etching	3	Complying with
Desmuting		
De-masking		
Chemically		

Figure B-6 The defined facilities information

B.2 The process capability report

The Report of Chemical Milling Process Capability on New Product

1 Introduction

This capability report of concerning chemical milling peocess is captured for the CDF product. The product recognition ws described as following tablle, and the genral process difficulty as well. The detail information of product could be accessed by the hyperlink on the right side.This report is mainly classified by five sections of Introduction, Process flow, Process feasibility and stability, Manufacturing capacity and Operating cost.However, more factors and process capability measures are applied during the model implementation.The details of capability are reported within each sections. Go for Product information

Product recognition			
Factors	Identified	unidentified	
Product	48	0	
Process	13	0	
Total	100%	61	0%

Process difficulty			
	Complying	22	96%
	Not Comply	0	0%
	To be approved	1	4%
	Total	23	100%
			Percentage

2 Process Flow

Go for more detail

The process flow is generated as follow:

CHM Process flow	Internal Specs	Product Specs	Remark
Cleaning			
Alkaline Cleaning TURCO4215,60 - 70	SXXXX301	Complying with AXXXXX49	
Masking			
Coating Curing tion and temperature fi	SXXXXX301	AXXXXX49	
Scribing			
Scribing Manually Scribing	SXXXXX301	Complying with AXXXXX49	
Etching			
Alkaline Cleaning turco 4215, 60 - 70 C	SXXXXX301	Complying with AXXXXX49	
Pocket Etching NAOH,EDTA, 90 -	SXXXXX301	Complying with AXXXXX49	to be approved as required
Desmuting Nitric Acid	SXXXXX301	Complying with AXXXXX49	
De-masking			
Demasking Manually	SXXXXX301	Complying with AXXXXX49	

The required process flow could be realized.The integrity of process system is confirmed.

The internal specifications covers entire chemical milling process flow. The systemic specifications are onfirmed.
There are 1process parameters to be approved, and 0 parameters not complying with product specifications. More detail refer process flow report by the hyperlink on the rightside. Go for more detail

The facilities meet the temperature accuracy required by new product.

Figure B-7 Section 1 and 2 of process capability report

3 process feasibility and stability

According to the assessment on quanlity measures of depth and surface finish, the concerning chemical milling process is considered as marginally having feasibility on the product.

The concerning chemical milling process is considered as having the process stability; 20 depth samples and20 surface finish samples are measured with the X-bar and R charts.; 0 of depth samples is/are out of control limits; and0 of surface finish samples is/are out of control limits..

Feasibility

Go for more detail

New product		Depth Cp=	1.82	Capable	Surface finish Cpku=	1.05	Marginally Capable
Material	2024T3 ACLAD	USL	2.4 mm		USL	0.9 µm	
etching de	4.6 mm	LSL	1.4 mm				

Sample product		Depth Cp=	1.82	Capable	Surface finish Cpku=	1.05	Marginally Capable
Material	2024T3 ACLAD	USL	2.4 mm				
etching de	4.6 mm	LSL	1.4 mm		USL	0.9 µm	
X double b	1.70 mm	Depth Cpk	1.08	Marginally Capable	X double b	0.81	
Sigma	0.09				Sigma	0.03	

Stability

Go for more detail

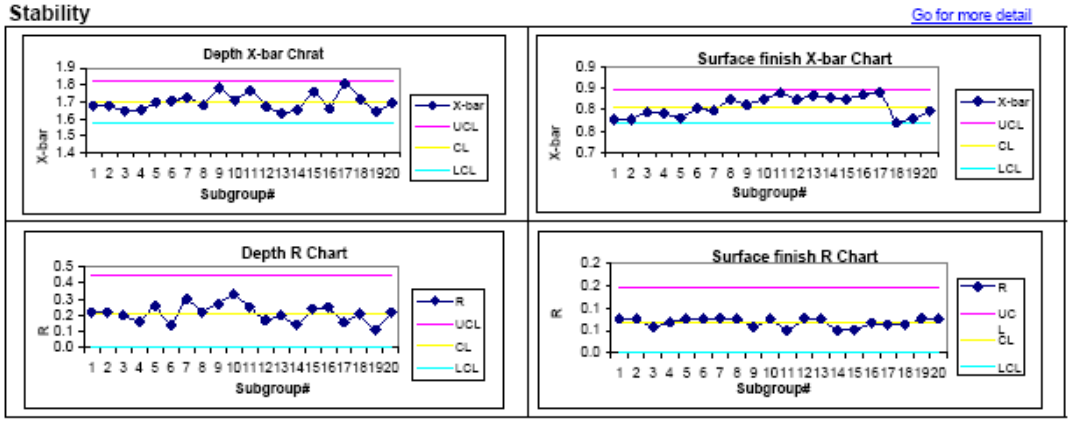


Figure B-8 The feasibility and stability of process capability report

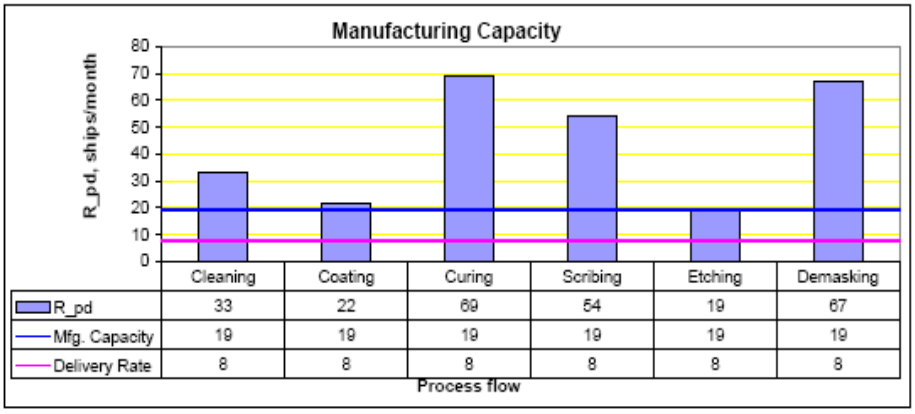
4 Manufacturing capacity

The concerning chemical milling process line could deliver the qualified product as required.
The required product delivery schedule chould be achieved with average delivery rate of 8ships/month. The required process efficent could be achieved.
The time request of the new product on the facilities could be achieved by present process, because the assessed manufacturing capacity (R_pd) is compling with the delivery rate (R_DL).

To achieve the required delivered rate of new product, the minimum receiving rate is specified as below:

Delivery and Receiving rates requirements

CDF Product Delivery Rate:	Minimum Parts Reciving Rate		
	Part name	Product configuration quantity	Receiving Rate pieces/Month
8 Ships/month	CDF_F	1	8
	CDF_A	1	8
Product Q 96 ships Production 12 months			



Process efficient required by the new product

R_DL= 8 ships/month								
Monthly	Cleaning	Masking Coating	Masking Curing	Scribing	Etching	Demaskin	Total	Process efficient required, e_req
Total processing time per step, t_pc,hrs	0.14	1.125	0.42	0.44	1.64	0.21	31.80	$e_{req} = \frac{\sum_j t_{pc}^{0} \times R_{DL}}{\sum_j T^{max\ j}}$ 13.83%
Working hours avaliable,t^max, hrs	14	48	48	48	48	24	230	

Figure B-9 Manufacturing capacity of process capability report

5 Process economic

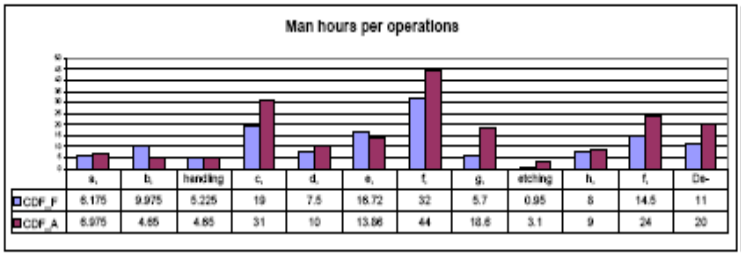
GO for details

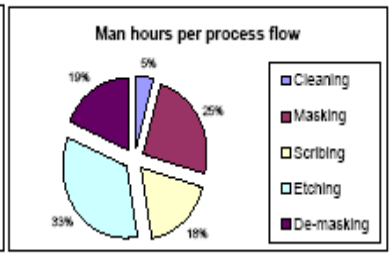
The process economic in this model is assessed with two indices: man hours and materials cost. Each of them is calculated per single ship of the new product. The man hours level and materials cost level mainly depends on the product features of part surface, etching depth, and etching steps.

The initial economic data base is adpoted from Harris(1974). If any particular data modification is to be applied, please go for the initial data table by the hyperlink on the rightside. The details of estimated man hours and materials cost are listed as follow: GO for det

Product Man hours estimation

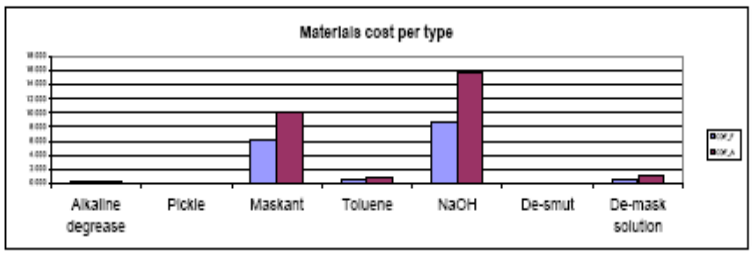
Process flow Man hours	Cleaning, min	Masking min	Scribing min	Etching min	De-masking min	Quantity per ship	Total hrs
CDF_F	6.175	34.2	24.22	46.65	25.5	1	
CDF_A	6.975	40.3	23.86	74.7	44	1	
Sub	13.15	74.5	48.08	121.35	69.5	2	5.44





Product material cost estimation

Process flow	Cleaning		Masking		Etching		De-masking	Sub.	Quantity per ship	Total £
Material	Alkaline	Pickle	Maskant	Toluene	NaOH	De-smut	De-mask			
CDF_F	0.135	0.014	6.269	0.563	8.814	0.019	0.636	16.449	1	44.615
CDF_A	0.220	0.022	10.228	0.919	15.594	0.026	1.156	28.166	1	



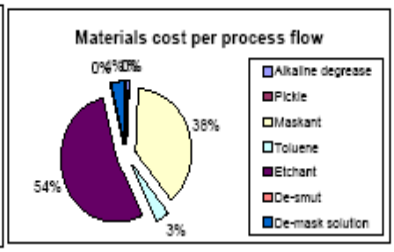
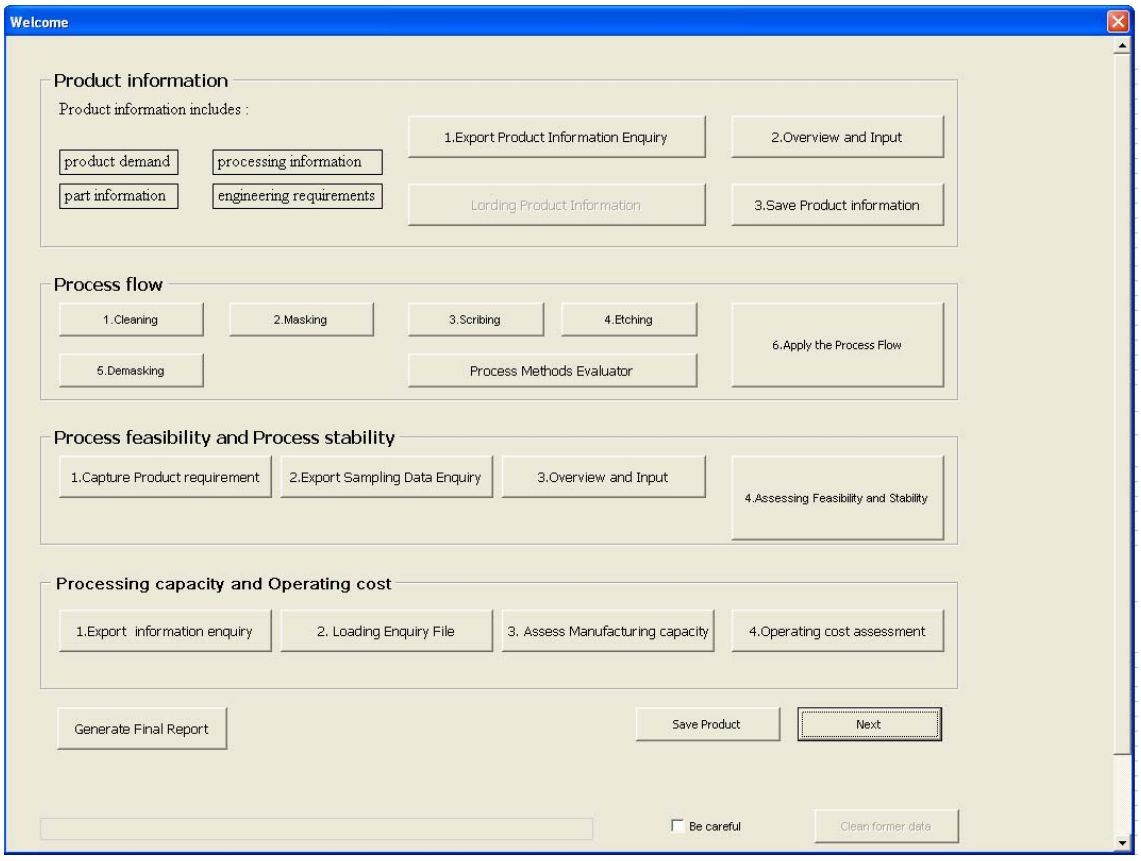


Figure B-10 Process economic of process capability report

Appendix C Source Codes of CHM process capability Capturing Model

This model was developed with MS Excel® VBA formation. There are total 8 user forms. Form1 includes all the buttons which implement the model functions including capturing product information, define process flow, assessing process feasibility and stability, calculating manufacturing capacity and assessing the process economic by man hours and material costs. Form2 to form6 are used as the interfaces of defining process flow. Form7 is used for debugging. Form 8 is an evaluation tool for process methods selection. The source codes and interface will be attached as follow:

C.1 Userform1 Main page and source codes




```
Public Sub SelectFile()
Application.ScreenUpdating = False 'open excel file and read the sheet1 value
Dim Filename As String
Filename = Application.GetOpenFilename
Workbooks.Open Filename
```

```
'ThisWorkbook.Sheets(2).Range("b7: b8").Value = ActiveWorkbook.Sheets("Product information").Range("b7:
b8").Value
ActiveWorkbook.Close
Application.ScreenUpdating = True
End Sub

Private Sub CheckBox1_Click()
If CheckBox1.Value = True Then
cleanup.Enabled = True
Else
cleanup.Enabled = False
End If
End Sub

Private Sub cleanup_Click()
ClnDisp.Value = ""
ClnDisp.Value = "Cleaning start..."
Sheet8.Range("c6: j64").Value = Sheet8.Range("ac6: aj64").Value
ClnDisp.Value = ClnDisp.Value + "ch01..." + "Peocess Flow data Cleaned"
Sheet8.Range("c7: o51").Value = Sheet8.Range("ac7: aj51").Value
ClnDisp.Value = ClnDisp.Value + "ch 02..." + "Facility data Cleaned"
CheckBox1.Value = False
MsgBox "Cleaning done."
cleanup.Enabled = False
End Sub

Private Sub CommandButton1_Click()
UserForm1.Hide
UserForm2.Show
End Sub

Private Sub CommandButton11_Click()
Application.DisplayAlerts = False
Application.ScreenUpdating = False
Sheet10.Copy
ActiveWorkbook.SaveAs ThisWorkbook.Path & "\" & "Process Fsb and Stb Sampling Data" & ".xls"
ActiveWorkbook.Close
Application.ScreenUpdating = True
Application.DisplayAlerts = True
MsgBox "The equiry file has been saved as Process Fsb and Stb Sampling Data.xls"
End Sub

Private Sub CommandButton12_Click()
UserForm1.ScrollTop = 100
UserForm1.Hide
UserForm1.Show 0
If UserForm1.Height = 200 Then
UserForm1.Height = 550
End If
If UserForm1.Height = 550 Then
UserForm1.Height = 200
End If
Sheet10.Activate

'Application.ScreenUpdating = False 'open excel file and read the sheet1 value
Dim Filename As String
Filename = Application.GetOpenFilename
Workbooks.Open Filename
'Application.ScreenUpdating = True
End Sub

Private Sub CommandButton3_Click()
' 3.Save product information
UserForm1.Height = 550
UserForm1.Hide
UserForm1.Show

'get part names
Sheet8.Range("c94:c101").Value = Sheet2.Range("a41:a48").Value
Sheet8.Range("p94:p101").Value = Sheet2.Range("a41:a48").Value
'get product configuration information
Sheet8.Range("a94:a101").Value = Sheet2.Range("b21:b28").Value
```

```
'part surface for masking coating
Sheet8.Range("i94:i101").Value = Sheet2.Range("d41:d48").Value
'get scribing line length
Sheet8.Range("q94:q101").Value = Sheet2.Range("g41:g48").Value
'get etching depth
Sheet8.Range("w94:w101").Value = Sheet2.Range("c41:c48").Value
'get etching steps
Sheet8.Range("v94:v101").Value = Sheet2.Range("b41:b48").Value
'get non-etching surface
Sheet8.Range("ae94:ae101").Value = Sheet2.Range("f41:f48").Value
'get etching surface
Sheet8.Range("x94:x101").Value = Sheet2.Range("e41:e48").Value

'get the receiving and delivery rate for final report
Sheet3.Range("b90").Value = Sheet2.Range("b3").Value ' product name
Sheet3.Range("c97:c98").Value = Sheet2.Range("b4:b5").Value
Sheet3.Range("b92").Value = (Sheet2.Range("b4").Value / Sheet2.Range("b5").Value) 'R_DL
Sheet3.Range("e92:e99").Value = Sheet2.Range("a41:a48").Value ' parts names
Sheet3.Range("g92:g99").Value = Sheet2.Range("b21:b28").Value ' product configuration

Dim n As Integer
For n = 92 To 99
If Sheet2.Range("a" & (n - 71)).Value = "" Then
Exit For
End If
Sheet3.Range("i" & n).Value = (Sheet3.Range("g" & n).Value * Sheet3.Range("b92").Value)
Next n
MsgBox "minimum R_DL and r_rc are saved."
MsgBox "Product information saved."

'ThisWorkbook.Save
End Sub

Private Sub FebStbAssbutton_Click()
UserForm1.Hide
UserForm1.Show 0
UserForm1.Height = 550

'#########################################################################
'Process stability assessment
'Loading data

Dim i As Integer, t As Integer

' Loading sample product information

Sheet6.Range("j32:j33").Value = Sheet10.Range("L4:L5").Value
Sheet6.Range("j38").Value = Sheet10.Range("L7").Value
Sheet6.Range("j39").Value = Sheet10.Range("L6").Value
Sheet6.Range("j44").Value = Sheet10.Range("L8").Value
Sheet3.Range("C53:C54").Value = Sheet10.Range("L4:L5").Value
Sheet3.Range("f53").Value = Sheet10.Range("L7").Value
Sheet3.Range("f54").Value = Sheet10.Range("L6").Value
Sheet3.Range("j54").Value = Sheet10.Range("L8").Value

For i = 11 To 60
'if data cell = empty then stop loading in
If Sheet10.Range("b" & i).Value = "" Then
MsgBox (i - 11) & "rows of Depth data were collected."
Exit For
End If
'get DEPTH x bar from <<Fsb & stb sampling data>>
Sheet4.Range("b" & i).Value = WorksheetFunction.Average(Sheet10.Range("B" & i, "k" & i).Value)
'get DEPTH r bar from <<Fsb & stb sampling data>>
Sheet4.Range("H" & i).Value = WorksheetFunction.Max(Sheet10.Range("B" & i, "k" & i).Value) -
WorksheetFunction.Min(Sheet10.Range("B" & i, "k" & i))
Next i

For i = 11 To 60
'if data cell = empty then stop loading in
If Sheet10.Range("n" & i).Value = "" Then
MsgBox (i - 11) & "rows of Surface finish data were collected."
```

```
Exit For
End If

'get SURFACE FINISH x bar from <<Fsb & stb sampling data>>
Sheet4.Range("N" & i).Value = WorksheetFunction.Average(Sheet10.Range("N" & i, "W" & i).Value)
'get SURFACE FINISH R bar from <<Fsb & stb sampling data>>
Sheet4.Range("T" & i).Value = WorksheetFunction.Max(Sheet10.Range("N" & i, "W" & i)) -
WorksheetFunction.Min(Sheet10.Range("N" & i, "W" & i))
Next i
'get n value from sample size
Sheet4.Range("F4").Value = WorksheetFunction.Count(Sheet10.Range("b11:k11"))
Sheet4.Range("R4").Value = WorksheetFunction.Count(Sheet10.Range("N11:W11"))
'get k value from group size
Sheet4.Range("F5").Value = WorksheetFunction.Count(Sheet10.Range("b11:b60"))
Sheet4.Range("R5").Value = WorksheetFunction.Count(Sheet10.Range("N11:n60"))
'get x double bar value
Sheet4.Range("F7").Value = WorksheetFunction.Average(Sheet4.Range("b11:b60").Value)
Sheet4.Range("R7").Value = WorksheetFunction.Average(Sheet4.Range("n11:n60").Value)
'get r bar value
Sheet4.Range("F6").Value = WorksheetFunction.Average(Sheet4.Range("h11:h60").Value)
Sheet4.Range("R6").Value = WorksheetFunction.Average(Sheet4.Range("t11:t60").Value)
' lookup A2 VALUE
Sheet4.Range("H4").Value = WorksheetFunction.VLookup(Sheet4.Range("f4"), Sheet4.Range("aa11:ad19"), 2)
Sheet4.Range("t4").Value = WorksheetFunction.VLookup(Sheet4.Range("r4"), Sheet4.Range("aa11:ad19"), 2)
' lookup D3 value
Sheet4.Range("H5").Value = WorksheetFunction.VLookup(Sheet4.Range("f4"), Sheet4.Range("aa11:ad19"), 3)
Sheet4.Range("t5").Value = WorksheetFunction.VLookup(Sheet4.Range("r4"), Sheet4.Range("aa11:ad19"), 3)
' lookup D4 value
Sheet4.Range("H6").Value = WorksheetFunction.VLookup(Sheet4.Range("f4"), Sheet4.Range("aa11:ad19"), 4)
Sheet4.Range("t6").Value = WorksheetFunction.VLookup(Sheet4.Range("r4"), Sheet4.Range("aa11:ad19"), 4)
' calculate  cl = x double-bar
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
Sheet4.Range("D" & i).Value = Sheet4.Range("f7").Value
Next i
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
Sheet4.Range("p" & i).Value = Sheet4.Range("r7").Value
Next i
'calculate CL = Rbar
Sheet4.Range("j11").Value = Sheet4.Range("F6").Value
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
Sheet4.Range("j" & i).Value = Sheet4.Range("j11").Value
Next i
Sheet4.Range("v11").Value = Sheet4.Range("r6").Value
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
Sheet4.Range("v" & i).Value = Sheet4.Range("v11").Value
Next i
' calculate UCL = x double-bar + A2 * R bar
Sheet4.Range("c11").Value = Sheet4.Range("f7") + (Sheet4.Range("H4").Value * Sheet4.Range("F6").Value)
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
Sheet4.Range("c" & i).Value = Sheet4.Range("c11").Value
Next i
Sheet4.Range("o11").Value = Sheet4.Range("r7") + (Sheet4.Range("t4").Value * Sheet4.Range("r6").Value)
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
Sheet4.Range("o" & i).Value = Sheet4.Range("o11").Value
```

```
Next i
'calculate LCL = X double-bar - A2 * R bar
Sheet4.Range("e11").Value = Sheet4.Range("f7") - (Sheet4.Range("H4").Value * Sheet4.Range("F6").Value)
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
Sheet4.Range("e" & i).Value = Sheet4.Range("e11").Value
Next i
Sheet4.Range("q11").Value = Sheet4.Range("r7") - (Sheet4.Range("t4").Value * Sheet4.Range("r6").Value)
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
Sheet4.Range("q" & i).Value = Sheet4.Range("q11").Value
Next i
' calculate UCL = D4 * R bar
Sheet4.Range("I11").Value = Sheet4.Range("H6").Value * Sheet4.Range("F6").Value
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
Sheet4.Range("I" & i).Value = Sheet4.Range("I11").Value
Next i
Sheet4.Range("U11").Value = Sheet4.Range("T6").Value * Sheet4.Range("R6").Value
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
Sheet4.Range("U" & i).Value = Sheet4.Range("U11").Value
Next i
'CALCULATE LCL = D3 * Rbar
Sheet4.Range("k11").Value = Sheet4.Range("H5").Value * Sheet4.Range("F6").Value
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
Sheet4.Range("k" & i).Value = Sheet4.Range("k11").Value
Next i
Sheet4.Range("w11").Value = Sheet4.Range("t5").Value * Sheet4.Range("r6").Value
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
Sheet4.Range("w" & i).Value = Sheet4.Range("w11").Value
Next i
'Count the out_of_control points
'out of Ucl of depth x double bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("c" & i).Value < Sheet4.Range("b" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("B5").Value = t
'out of lcl of depth x double bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("e" & i).Value > Sheet4.Range("b" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("B6").Value = t
'Out of control limits of Depth X double chart
Sheet4.Range("B4").Value = Sheet4.Range("B5").Value + Sheet4.Range("B6").Value
```

```
'out of Ucl of depth R bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("i" & i).Value < Sheet4.Range("h" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("d5").Value = t
'out of Lcl of depth R bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("b" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("k" & i).Value > Sheet4.Range("h" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("d6").Value = t
'Out of control limits of Depth R chart
Sheet4.Range("d4").Value = Sheet4.Range("d5").Value + Sheet4.Range("d6").Value
' out of Ucl surface finish x double bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("n" & i).Value > Sheet4.Range("o" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("n5").Value = t
' out of lcl surface finish x double bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("n" & i).Value < Sheet4.Range("q" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("n6").Value = t
' out of control limits of surface finish X double bar chart
Sheet4.Range("n4").Value = Sheet4.Range("n5").Value + Sheet4.Range("n6").Value

' out of Ucl surface finish R bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("t" & i).Value > Sheet4.Range("u" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("p5").Value = t

' out of lcl surface finish R bar chart
t = 0
For i = 11 To 60
If Sheet4.Range("n" & i).Value = "" Then
Exit For
End If
If Sheet4.Range("t" & i).Value < Sheet4.Range("w" & i).Value Then
t = t + 1
End If
Next i
Sheet4.Range("P6").Value = t
```

```
' out of control limits of surface finish R bar chart
Sheet4.Range("P4").Value = Sheet4.Range("P5").Value + Sheet4.Range("P6").Value

'Process stability assessment
'if no point is out of control limits, process is considered as stable;
'or it would not be considered as a stable process.
If Sheet4.Range("B4").Value + Sheet4.Range("d4").Value + Sheet4.Range("n4").Value + Sheet4.Range("P4").Value = 0
Then
Sheet4.Range("A2").Value = "The concerning chemical milling process is considered as having the process stability"
Else
Sheet4.Range("A2").Value = "The concerning chemical milling process is considered as not having the process stability"
End If
Sheet4.Range("B2").Value = Sheet4.Range("F5").Value & " depth samples and" & Sheet4.Range("R5").Value & "
surface finish samples are measured with the X-bar and R charts."
Sheet4.Range("C2").Value = (Sheet4.Range("B4").Value + Sheet4.Range("d4").Value) & " " & "of depth samples is/are
out of control limits; and " & (Sheet4.Range("N4").Value + Sheet4.Range("P4").Value) & " " & "of surface finish samples
is/are out of control limits."
Sheet3.Range("b45").Value = Sheet4.Range("A2").Value & "; " & Sheet4.Range("B2").Value & "; " &
Sheet4.Range("C2").Value & "."

MsgBox "Process stability assessing....Done."

'##########################################################################################
'Process feasibility assessment
'Cp = (USL-LSL)/6S
'Cpk = MIN{(USL-X double bar)/3s, (X double bar - LSL)/3s}
's= R bar/d2

'x double bar
Sheet6.Range("h36").Value = Sheet4.Range("f7").Value
Sheet6.Range("J40").Value = Sheet4.Range("f7").Value
Sheet6.Range("h43").Value = Sheet4.Range("r7").Value
Sheet6.Range("j45").Value = Sheet4.Range("r7").Value
Sheet3.Range("c55").Value = Sheet4.Range("f7").Value
Sheet3.Range("j55").Value = Sheet4.Range("r7").Value
'R bar
Sheet6.Range("h37").Value = Sheet4.Range("f6").Value
Sheet6.Range("h44").Value = Sheet4.Range("r6").Value
'n
Sheet6.Range("h38").Value = Sheet4.Range("f4").Value
Sheet6.Range("h45").Value = Sheet4.Range("r4").Value
'd2
Sheet6.Range("h39").Value = WorksheetFunction.VLookup(Sheet6.Range("h38"), Sheet6.Range("ab26:ac34"), 2)
Sheet6.Range("h46").Value = WorksheetFunction.VLookup(Sheet6.Range("h45"), Sheet6.Range("ab26:ac34"), 2)
'sigma
Sheet6.Range("J41").Value = Sheet6.Range("h37").Value / Sheet6.Range("h39").Value
Sheet6.Range("J46").Value = Sheet6.Range("h44").Value / Sheet6.Range("h46").Value
Sheet3.Range("c56").Value = Sheet6.Range("J41").Value
Sheet3.Range("j56").Value = Sheet6.Range("J46").Value

'Cp of sample product
Sheet6.Range("J36").Value = (Sheet6.Range("J38").Value - Sheet6.Range("J39").Value) / (6 *
Sheet6.Range("J41").Value)
Sheet3.Range("f52").Value = Sheet6.Range("J36").Value
' assessing rules
If Sheet6.Range("j36").Value >= 2 Then
Sheet3.Range("g52").Value = "6 Sigma"
End If
If Sheet6.Range("j36").Value < 2 Then
Sheet3.Range("g52").Value = " Capable"
End If
If Sheet6.Range("j36").Value < 1.33 Then
Sheet3.Range("g52").Value = "Marginally Capable"
End If
If Sheet6.Range("j36").Value < 1 Then
Sheet3.Range("g52").Value = "Not Capable"
End If

'Depth Cp of the new product, assessing with the new USL and LSL
Sheet6.Range("m36").Value = (Sheet6.Range("m38").Value - Sheet6.Range("m39").Value) / (6 *
Sheet6.Range("J41").Value)
```

```
Sheet3.Range("f48").Value = Sheet6.Range("m36").Value
' assessing rules
If Sheet6.Range("m36").Value >= 2 Then
Sheet3.Range("g48").Value = "6 Sigma"
End If

If Sheet6.Range("m36").Value < 2 Then
Sheet3.Range("g48").Value = " Capable"
End If

If Sheet6.Range("m36").Value < 1.33 Then
Sheet3.Range("g48").Value = "Marginally Capable"
End If

If Sheet6.Range("m36").Value < 1 Then
Sheet3.Range("g48").Value = "Not Capable"
End If

' Depth Cpk for sample product
Sheet6.Range("j37").Value = WorksheetFunction.Min((Sheet6.Range("j38").Value - Sheet6.Range("j40").Value) / (3 *
Sheet6.Range("j41").Value), (Sheet6.Range("j40").Value - Sheet6.Range("j39").Value) / (3 *
Sheet6.Range("j41").Value))
Sheet3.Range("f55").Value = Sheet6.Range("j37").Value
' assessing rules
If Sheet6.Range("j37").Value >= 1.5 Then
Sheet3.Range("g55").Value = "6 Sigma"
End If
If Sheet6.Range("j37").Value < 1.5 Then
Sheet3.Range("g55").Value = " Capable"
End If
If Sheet6.Range("j37").Value < 1.33 Then
Sheet3.Range("g55").Value = "Marginally Capable"
End If
If Sheet6.Range("j37").Value < 1 Then
Sheet3.Range("g55").Value = "Not Capable"
End If

' surface finish Cpku
' sample product
Sheet6.Range("j43").Value = (Sheet6.Range("j44").Value - Sheet6.Range("j45").Value) / (3 *
Sheet6.Range("j46").Value)
Sheet3.Range("k52").Value = Sheet6.Range("j43").Value
' assessing rules
If Sheet6.Range("j43").Value >= 1.5 Then
Sheet3.Range("L52").Value = "6 Sigma"
End If
If Sheet6.Range("j43").Value < 1.5 Then
Sheet3.Range("L52").Value = " Capable"
End If
If Sheet6.Range("j43").Value < 1.33 Then
Sheet3.Range("L52").Value = "Marginally Capable"
End If
If Sheet6.Range("j43").Value < 1 Then
Sheet3.Range("L52").Value = "Not Capable"
End If

' the new product
Sheet6.Range("m43").Value = (Sheet6.Range("m44").Value - Sheet6.Range("j45").Value) / (3 *
Sheet6.Range("j46").Value)
Sheet3.Range("k48").Value = Sheet6.Range("m43").Value
' assessing rules
If Sheet6.Range("m43").Value >= 1.5 Then
Sheet3.Range("L48").Value = "6 Sigma"
End If
If Sheet6.Range("m43").Value < 1.5 Then
Sheet3.Range("L48").Value = " Capable"
End If
If Sheet6.Range("m43").Value < 1.33 Then
Sheet3.Range("L48").Value = "Marginally Capable"
End If
If Sheet6.Range("m43").Value < 1 Then
Sheet3.Range("L48").Value = "Not Capable"
```

```
End If

'assessing process feasibility
If Sheet6.Range("m37").Value >= 1.3 And Sheet6.Range("m43").Value >= 1.3 Then
Sheet3.Range("b44").Value = "According to the assessment on quanlity measures of depth and surface finish, the
concerning chemical milling process is considered as having feasibility on the product. "
End If

If Sheet6.Range("m37").Value < 1.3 Or Sheet6.Range("m43").Value < 1.3 Then
Sheet3.Range("b44").Value = "According to the assessment on quanlity measures of depth and surface finish, the
concerning chemical milling process is considered as marginally having feasibility on the product. "
End If

If Sheet6.Range("m37").Value < 1 Or Sheet6.Range("m43").Value < 1 Then
Sheet3.Range("b44").Value = "According to the assessment on quanlity measures of depth and surface finish, the
concerning chemical milling process is considered as marginally not having feasibility on the product. "
End If

'###############section 5.4###########################
'product recognition assessing
'product enineering requirements
Sheet3.Range("c5:g7").Value = ""


Sheet3.Range("c5").Value = WorksheetFunction.CountA(Sheet2.Range("b3:b5"))
Sheet3.Range("e5").Value = WorksheetFunction.CountBlank(Sheet2.Range("b3:b5"))
Sheet3.Range("c5").Value = Sheet3.Range("c5").Value + WorksheetFunction.CountA(Sheet2.Range("b13:b17"))
Sheet3.Range("e5").Value = Sheet3.Range("e5").Value + WorksheetFunction.CountBlank(Sheet2.Range("b13:b17"))

Dim counti As Integer
For counti = 21 To 28
If WorksheetFunction.CountA(Sheet2.Range("A" & counti, "h" & counti)) > 0 Then
Sheet3.Range("c5").Value = Sheet3.Range("c5").Value + WorksheetFunction.CountA(Sheet2.Range("A" & counti, "h" &
counti))
Sheet3.Range("e5").Value = Sheet3.Range("e5").Value + WorksheetFunction.CountBlank(Sheet2.Range("A" & counti,
"h" & counti))
Sheet3.Range("c5").Value = Sheet3.Range("c5").Value + WorksheetFunction.CountA(Sheet2.Range("A" & counti + 20,
"h" & counti + 20))
Sheet3.Range("e5").Value = Sheet3.Range("e5").Value + WorksheetFunction.CountBlank(Sheet2.Range("A" & counti +
20, "h" & counti + 20))
Sheet3.Range("c5").Value = Sheet3.Range("c5").Value + WorksheetFunction.CountA(Sheet2.Range("A" & counti + 10,
"d" & counti + 10))
Sheet3.Range("e5").Value = Sheet3.Range("e5").Value + WorksheetFunction.CountBlank(Sheet2.Range("A" & counti +
10, "d" & counti + 10))
End If

Next counti

MsgBox "Product recognition...enineering requirements...done."

'product recognition assessing
'product process requirements
' SPECIFIC SYSTEM
Dim ci As Integer, tr As Integer
For ci = 9 To 62
If Sheet8.Range("c" & ci).Value = "Specification" And WorksheetFunction.CountA(Sheet8.Range("f" & ci + 1, "i" & ci +
2)) > 0 Then
Sheet3.Range("c6").Value = Sheet3.Range("c6").Value + WorksheetFunction.CountA(Sheet8.Range("h" & ci))
Sheet3.Range("e6").Value = Sheet3.Range("e6").Value + WorksheetFunction.CountBlank(Sheet8.Range("h" & ci))
End If
' mark the missing specifications
If Sheet8.Range("c" & ci).Value = "Specification" And WorksheetFunction.CountA(Sheet8.Range("f" & ci + 1, "i" & ci +
2)) > 0 And Sheet8.Range("h" & ci).Value = "" Then
Sheet8.Range("h" & ci).Interior.Color = RGB(255, 0, 0)
End If
'assessing integrity of process system
If Sheet8.Range("c" & ci).Value = "Method" And WorksheetFunction.CountA(Sheet8.Range("f" & ci + 1, "i" & ci + 2)) > 0
And (Sheet8.Range("d" & ci).Value = "" Or Sheet8.Range("f" & ci).Value = "") And Sheet8.Range("h" & ci).Value <> ""
Then
Sheet8.Range("e2").Value = "The required process flow might not be realized completely. The integrity of process
system is not confirmed."
Else
```

```
Sheet8.Range("e2").Value = "The required process flow could be realized.The integrity of process system is confirmed."
End If

'adding the methods counting into product recognition in final report
If Sheet8.Range("c" & ci).Value = "Method" And WorksheetFunction.CountA(Sheet8.Range("f" & ci, "i" & ci + 1)) > 0
Then
Sheet3.Range("c6").Value = Sheet3.Range("c6").Value + WorksheetFunction.CountA(Sheet8.Range("h" & ci))
Sheet3.Range("e6").Value = Sheet3.Range("e6").Value + WorksheetFunction.CountBlank(Sheet8.Range("h" & ci))
End If
Next ci
MsgBox "assessing integrity of process system....done."

'systemic specifications assessing
If Sheet3.Range("e6").Value = 0 Then
Sheet8.Range("e1").Value = "The internal specifications covers entire chemical milling process flow. The systemic
specifications are onfirmed."
Else
Sheet8.Range("e1").Value = "The internal specifications might not cover each step of the required process flow. The
systemic specifications are not confirmed."
End If
MsgBox "systemic specifications assessing....done."
'process temperature accuracy
Dim di As Integer
For di = 36 To 51
If Sheet13.Range("f" & di).Value <> 0 Then
Sheet3.Range("c6").Value = Sheet3.Range("c6").Value + WorksheetFunction.CountA(Sheet8.Range("i" & di))
End If
Next di

'Product recognition...process requirements....done.
Sheet3.Range("d7").Value = WorksheetFunction.Sum(Sheet3.Range("c5:e6"))
Sheet3.Range("c7").Value = (Sheet3.Range("c5").Value + Sheet3.Range("c6").Value) / Sheet3.Range("d7").Value
Sheet3.Range("f7").Value = (Sheet3.Range("e5").Value + Sheet3.Range("e6").Value) / Sheet3.Range("d7").Value

MsgBox "Product recognition.......done."

MsgBox "Process feasibility assessing ......Done."
ThisWorkbook.Save
End Sub

Private Sub LoadEnquiry_Click()
UserForm1.ScrollTop = 400
UserForm1.Hide
UserForm1.Show 0
If UserForm1.Height = 200 Then
UserForm1.Height = 550
End If
If UserForm1.Height = 550 Then
UserForm1.Height = 200
End If
Sheet14.Activate

' select file and open
Dim Filename As String
Filename = Application.GetOpenFilename
Workbooks.Open Filename

End Sub

Private Sub LoadingNumAssess_Click()
Dim row As Variant, line As Variant, R As Integer, L As Integer
Dim i As Integer

'get loading number for Cleaning, get the processing time for single part
For i = 21 To 28
If Sheet2.Range("a" & i).Value = "" Then
Exit For
End If
row = ((Sheet13.Range("f10").Value - Sheet13.Range("h10").Value) / (Sheet2.Range("h" & i).Value +
Sheet13.Range("h10").Value))
line = ((Sheet13.Range("e10").Value - Sheet13.Range("h10").Value) / (Sheet2.Range("f" & i).Value +
Sheet13.Range("h10").Value))
```

```
If row < 1 Or line < 1 Then
Sheet13.Range("o10").Value = "Not meet"
MsgBox "Please check the Cleaning facility dimensions and product dimensions."
Else
Sheet13.Range("o10").Value = "Complying with"
End If

R = Int(row)
L = Int(line)
Sheet8.Range("d" & (i + 73)).Value = R * L
'Cleaning processing time equation
Sheet8.Range("e" & (i + 73)).Value = (Sheet8.Range("e91").Value / Sheet8.Range("d" & (i + 73)).Value)
Next i

'get loading number for Masking_Coating, single part processing time of coating
For i = 21 To 28
If Sheet2.Range("a" & i).Value = "" Then
Exit For
End If
row = ((Sheet13.Range("f13").Value - Sheet13.Range("h13").Value) / (Sheet2.Range("h" & i).Value +
Sheet13.Range("h13").Value))
line = ((Sheet13.Range("e13").Value - Sheet13.Range("h13").Value) / (Sheet2.Range("f" & i).Value +
Sheet13.Range("h13").Value))
If row < 1 Or line < 1 Then
Sheet13.Range("o13").Value = "Not meet"
MsgBox "Please check the Masking_Coating facility dimensions and product dimensions."
Else
Sheet13.Range("o13").Value = "Complying with"
End If

R = Int(row)
L = Int(line)
Sheet8.Range("H" & (i + 73)).Value = R * L

Dim nln As Variant, Rct As Variant, Surface As Variant, Tbt As Variant, Ld As Variant ' single part processing time start
nln = Sheet8.Range("i89").Value
Tbt = Sheet8.Range("i90").Value
Rct = Sheet8.Range("k90").Value
Surface = Sheet8.Range("i" & (i + 73)).Value
Ld = Sheet8.Range("H" & (i + 73)).Value

Sheet8.Range("j" & (i + 73)).Value = ((nln * (Rct * Surface * Ld + Tbt)) / Ld) ' single part processing time
Next i

'get loading number for Masking_Curing and single part processing time of curing
For i = 21 To 28
If Sheet2.Range("a" & i).Value = "" Then
Exit For
End If
row = ((Sheet13.Range("f14").Value - Sheet13.Range("h14").Value) / (Sheet2.Range("h" & i).Value +
Sheet13.Range("h14").Value))
line = ((Sheet13.Range("e14").Value - Sheet13.Range("h14").Value) / (Sheet2.Range("f" & i).Value +
Sheet13.Range("h14").Value))
If row < 1 Or line < 1 Then
Sheet13.Range("o14").Value = "Not meet"
MsgBox "Please check the Masking_Curing facility dimensions and product dimensions."
Else
Sheet13.Range("o14").Value = "Complying with"
End If

R = Int(row)
L = Int(line)
Sheet8.Range("m" & (i + 73)).Value = R * L

Sheet8.Range("n" & (i + 73)).Value = (Sheet8.Range("n91").Value / Sheet8.Range("m" & (i + 73)).Value) ' single part
processing time

Next i

'scribing facility assessing
For i = 21 To 28
```

```
If Sheet2.Range("a" & i).Value = "" Then
Exit For
End If

row = ((Sheet13.Range("f17").Value - Sheet13.Range("h17").Value) / (Sheet2.Range("h" & i).Value +
Sheet13.Range("h17").Value))
line = ((Sheet13.Range("e17").Value - Sheet13.Range("h17").Value) / (Sheet2.Range("f" & i).Value +
Sheet13.Range("h17").Value))

If Sheet13.Range("d17").Value = "Laser Scribing" And (row < 1 Or line < 1) Then
Sheet13.Range("o17").Value = "Not meet"
MsgBox "Please check the Scribing facility dimensions and product dimensions."
Else
Sheet13.Range("o17").Value = "Complying with"
End If

If Sheet13.Range("d17").Value = "Manually scribing" Then
Sheet13.Range("o17").Value = Sheet13.Range("d17").Value
End If

 ' single part processing time
Sheet8.Range("r" & (i + 73)).Value = (Sheet8.Range("q" & (i + 73)).Value / Sheet8.Range("r90").Value)

Next i

'get loading number for Etching
For i = 21 To 28

If Sheet2.Range("a" & i).Value = "" Then
Exit For
End If

row = ((Sheet13.Range("f20").Value - Sheet13.Range("h20").Value) / (Sheet2.Range("h" & i).Value +
Sheet13.Range("h20").Value))
line = ((Sheet13.Range("e20").Value - Sheet13.Range("h20").Value) / (Sheet2.Range("f" & i).Value +
Sheet13.Range("h20").Value))

If row < 1 Or line < 1 Then
Sheet13.Range("o20").Value = "Not meet"
MsgBox "Please check the Etching facility dimensions and product dimensions."
Else
Sheet13.Range("o20").Value = "Complying with"
End If

R = Int(row)
L = Int(line)

'#######
'accept experts comments, incorporated Loading limit for Etching tank
Dim LoadingLMT As Variant
If R > 2 Then
LoadingLMT = MsgBox("There usually is a limitation of 2 rows loading for etching tanks. That will help to enhance
spraying cleaning quality and minimum the influence of etcants remain. Press Yes the 2 Rows Loading limit will be
applied to the etching tank; Press No will ignore this limit.", vbYesNo, "Loading Limit for etching tank")
End If

If LoadingLMT = 6 Then
R = 2
MsgBox "The limit has been applied to the new product."
End If

If LoadingLMT = 7 Then
MsgBox "The 2 rows loading limit for etching has been ignored."
End If

'########
Sheet8.Range("u" & (i + 73)).Value = R * L
' single part processing time start
Dim Depth As Variant, R_etc As Variant, R_stp As Variant, Surf_etch As Variant, n_step As Variant, t_step As Variant,
Ld_etching As Variant
Depth = Sheet8.Range("w" & (i + 73)).Value
R_etc = Sheet8.Range("v90").Value
```

```
n_step = Sheet8.Range("v" & (i + 73)).Value
t_step = Sheet8.Range("i" & (i + 73)).Value
R_stp = Sheet8.Range("x90").Value
Surf_etch = Sheet8.Range("x" & (i + 73)).Value
Ld_etching = Sheet8.Range("u" & (i + 73)).Value

Sheet8.Range("y" & (i + 73)).Value = (((Depth / R_etc + n_step * t_step) / Ld_etching) + R_stp * Surf_etch) ' single part
processing time
Next i

'get loading number for DeMasking
For i = 21 To 28

If Sheet2.Range("a" & i).Value = "" Then
Exit For
End If
If Sheet13.Range("d23").Value = "Demasking Chemically" Then
row = ((Sheet13.Range("f23").Value - Sheet13.Range("h23").Value) / (Sheet2.Range("h" & i).Value +
Sheet13.Range("h23").Value))
line = ((Sheet13.Range("e23").Value - Sheet13.Range("h23").Value) / (Sheet2.Range("f" & i).Value +
Sheet13.Range("h23").Value))
End If

If row < 1 Then ' assess space request to facility
Sheet13.Range("o23").Value = "Not meet"
MsgBox "Please check the Demasking facility dimensions and product dimensions."
Else
Sheet13.Range("o23").Value = "Complying with"
End If

R = Int(row)
L = Int(line)

Sheet8.Range("aa" & (i + 73)).Value = R * L

If Sheet8.Range("aa" & (i + 73)).Value = 0 Then
Sheet8.Range("aa" & (i + 73)).Value = 0.0001
End If

If Sheet13.Range("d23").Value = "Demasking Chemically" Then 'chemically demasking processing time
Sheet8.Range("AF" & (i + 73)).Value = (Sheet8.Range("Ab91").Value / Sheet8.Range("aa" & (i + 73)).Value)
End If

If Sheet13.Range("d23").Value = "Manually" Then ' get THE MANUALLY processing time for single part
Sheet13.Range("o23").Value = Sheet13.Range("d23").Value
Sheet8.Range("AF" & (i + 73)).Value = (Sheet8.Range("AF90").Value * Sheet8.Range("AE" & (i + 73)).Value) ' single
part processing time
End If

Next i

'#######################################################
'single ship processing time
Dim k As Integer

Sheet8.Range("e103").Value = "" ' cleaning
Sheet8.Range("j103").Value = "" 'Coating
Sheet8.Range("n103").Value = "" 'curing
Sheet8.Range("r103").Value = "" 'scribing
Sheet8.Range("y103").Value = "" 'etching
Sheet8.Range("af103").Value = "" 'demasking

For k = 94 To 101
Sheet8.Range("e103").Value = ((Sheet8.Range("e" & k).Value * Sheet8.Range("a" & k).Value) +
Sheet8.Range("e103").Value)

Sheet8.Range("j103").Value = ((Sheet8.Range("j" & k).Value * Sheet8.Range("a" & k).Value) +
Sheet8.Range("j103").Value)

Sheet8.Range("n103").Value = ((Sheet8.Range("n" & k).Value * Sheet8.Range("a" & k).Value) +
Sheet8.Range("n103").Value)
```

```
Sheet8.Range("r103").Value = ((Sheet8.Range("r" & k).Value * Sheet8.Range("a" & k).Value) +
Sheet8.Range("r103").Value)

Sheet8.Range("y103").Value = ((Sheet8.Range("y" & k).Value * Sheet8.Range("a" & k).Value) +
Sheet8.Range("y103").Value)

Sheet8.Range("af103").Value = ((Sheet8.Range("af" & k).Value * Sheet8.Range("a" & k).Value) +
Sheet8.Range("af103").Value)

If Sheet8.Range("c" & (k + 1)).Value = "" Then
Exit For
End If

Next k

'#################################################################
'assess process parameters
' PROCESS PARAMETERS "to be approved" and "not complying" items counting
Sheet8.Range("o6").Value = WorksheetFunction.CountIf(Sheet8.Range("j9:j64"), "*to be approved*")
Sheet8.Range("p6").Value = WorksheetFunction.CountIf(Sheet8.Range("j9:j64"), "*not complying*")

MsgBox "Parameters checking done"
MsgBox "The process flow saved."
End Sub

Private Sub MfgCapacityENquiry_Click()

'copy process flow and product information to Process Statistical Data Enquiry
Sheet14.Range("c56:l116").Value = Sheet8.Range("c6:l66").Value
Sheet14.Range("e16:j20").Value = Sheet10.Range("h4:m8").Value
Sheet14.Range("i17:i20").Value = ""


Application.DisplayAlerts = False
Application.ScreenUpdating = False
Sheet14.Copy
ActiveWorkbook.SaveAs ThisWorkbook.Path & "\" & "Process Statistical Data Enquiry" & ".xls"
ActiveWorkbook.Close
Application.ScreenUpdating = True
Application.DisplayAlerts = True
MsgBox "The equiry file has been saved as Process Statistical Data Enquiry.xls"
End Sub

Private Sub Operatingcost_Click()
Dim i As Integer
For i = 2 To 9

If Sheet2.Range("a" & (i + 39)).Value = "" Then
Exit For
End If

'get part name
Sheet7.Range("e" & i).Value = Sheet2.Range("a" & (i + 39)).Value
Sheet7.Range("e" & (i + 50)).Value = Sheet2.Range("a" & (i + 39)).Value
Sheet7.Range("e" & (i + 40)).Value = Sheet2.Range("a" & (i + 39)).Value
Sheet7.Range("e" & (i + 90)).Value = Sheet2.Range("a" & (i + 39)).Value

'total surface
Sheet7.Range("g" & i, "j" & i).Value = Sheet2.Range("d" & (i + 39)).Value

'total surface for meterial cost
Sheet7.Range("g" & (i + 60), "j" & (i + 60)).Value = Sheet2.Range("d" & (i + 39)).Value

'weigth reduction for material cost
Sheet7.Range("k" & (i + 60)).Value = Sheet2.Range("h" & (i + 39)).Value

'total surface
Sheet7.Range("n" & i, "o" & i).Value = Sheet2.Range("d" & (i + 39)).Value

'scribing lines' length
Sheet7.Range("l" & i).Value = Sheet2.Range("g" & (i + 39)).Value
```

```
'etching surface
Sheet7.Range("m" & i).Value = Sheet2.Range("e" & (i + 39)).Value
'etching surface for material cost
Sheet7.Range("l" & (i + 60)).Value = Sheet2.Range("e" & (i + 39)).Value

' non- etching surface
Sheet7.Range("r" & i).Value = Sheet2.Range("f" & (i + 39)).Value
' non- etching surface for material cost
Sheet7.Range("m" & (i + 60)).Value = Sheet2.Range("f" & (i + 39)).Value

'etching step
Sheet7.Range("p" & i).Value = Sheet2.Range("b" & (i + 39)).Value

'template quantity
Sheet7.Range("k" & i).Value = 1
MsgBox "Men hours assessment......the template quantity per part type is set as 1."

'Loading number_Cleaning
Sheet7.Range("g" & (i + 20)).Value = Sheet8.Range("d" & (i + 92)).Value
'Loading number_Coating
Sheet7.Range("h" & (i + 20), "i" & (i + 20)).Value = Sheet8.Range("h" & (i + 92)).Value
Sheet7.Range("j" & (i + 20), "m" & (i + 20)).Value = 1
Sheet7.Range("o" & (i + 20), "p" & (i + 20)).Value = 1
Sheet7.Range("r" & (i + 20)).Value = 1

'loading number etching
Sheet7.Range("n" & (i + 20)).Value = Sheet8.Range("u" & (i + 92)).Value

If Sheet8.Range("f58").Value = "" Then
Sheet7.Range("q" & (i + 20)).Value = Sheet8.Range("aa94").Value
Else
Sheet7.Range("q" & (i + 20)).Value = 1
End If

Sheet7.Range("b" & (i + 30)).Value = Sheet2.Range("h" & (i + 19)).Value
Sheet7.Range("c" & (i + 30)).Value = Sheet2.Range("d" & (i + 19)).Value / 1000
Sheet7.Range("d" & (i + 30)).Value = Sheet2.Range("d" & (i + 39)).Value


'formed part parameters selection
If Sheet2.Range("h" & (i + 19)).Value > (Sheet2.Range("d" & (i + 19)).Value / 1000) And Sheet2.Range("d" & (i +
39)).Value < 1 Then

Sheet7.Range("g" & (i + 30), "r" & (i + 30)).Value = Sheet7.Range("g17:r17").Value
End If
If Sheet2.Range("h" & (i + 19)).Value > (Sheet2.Range("d" & (i + 19)).Value / 1000) And Sheet2.Range("d" & (i +
39)).Value > 5 Then
Sheet7.Range("g" & (i + 30), "r" & (i + 30)).Value = Sheet7.Range("g19:r19").Value
End If
If Sheet2.Range("h" & (i + 19)).Value > (Sheet2.Range("d" & (i + 19)).Value / 1000) And Sheet2.Range("d" & (i +
39)).Value <= 5 Then
Sheet7.Range("g" & (i + 30), "r" & (i + 30)).Value = Sheet7.Range("g18:r18").Value
End If

' flat part selection
If Sheet2.Range("h" & (i + 19)).Value <= (Sheet2.Range("d" & (i + 19)).Value / 1000) And Sheet2.Range("d" & (i +
39)).Value < 2 Then
Sheet7.Range("g" & (i + 30), "r" & (i + 30)).Value = Sheet7.Range("g14:r14").Value
End If

If Sheet2.Range("h" & (i + 19)).Value <= (Sheet2.Range("d" & (i + 19)).Value / 1000) And Sheet2.Range("d" & (i +
39)).Value > 5 Then
Sheet7.Range("g" & (i + 30), "r" & (i + 30)).Value = Sheet7.Range("g16:r16").Value
End If

If Sheet2.Range("h" & (i + 19)).Value <= (Sheet2.Range("d" & (i + 19)).Value / 1000) And Sheet2.Range("d" & (i +
39)).Value <= 5 Then
Sheet7.Range("g" & (i + 30), "r" & (i + 30)).Value = Sheet7.Range("g15:r15").Value
End If

'get the man hours
Dim j As Integer
```

```
For j = 7 To 18
Sheet7.Cells((i + 40), j) = Sheet7.Cells((i + 30), j) * Sheet7.Cells(i, j) / Sheet7.Cells((i + 20), j)
Next j
MsgBox "Men hours assessment....done."


'assess material cost
Dim k As Integer
For k = 7 To 13
Sheet7.Cells((i + 50), k) = Sheet7.Cells((i + 60), k) * Sheet7.Cells(75, k) * Sheet7.Cells(76, k)
Next k
MsgBox "Materials cost assessment....done."

Next i

'final report introduction
Sheet3.Range("b2").Value = "This capability report of concerning chemical milling peocess is captured for the " &
Sheet2.Range("b3").Value & " product." & Sheet8.Range("e3").Value & " The product recognition ws described as
following tablle, and the genral process difficulty as well. The detail information of product could be accessed by the
hyperlink on the right side.This report is mainly classified by five sections of Introduction, Process flow, Process
feasibility and stability, Manufacturing capacity and Operating cost.However, more factors and process capability
measures are applied during the model implementation.The details of capability are reported within each sections."
'final report process flow process parameters, systemic specifications and integrity of process
Sheet3.Range("b38").Value = "There are " & Sheet8.Range("o6").Value & "process parameters to be approved, and " &
Sheet8.Range("p6").Value & " parameters not complying with product specifications. More detail refer process flow
report by the hyperlink on the rightside."
Sheet3.Range("b37").Value = Sheet8.Range("e1").Value
Sheet3.Range("b36").Value = Sheet8.Range("e2").Value
'final report

End Sub

Private Sub ProcessCapacityAssessing_Click()

'Delivery rate = Q/P, product reuires rate
Sheet8.Range("e124").Value = (Sheet2.Range("b4").Value / Sheet2.Range("b5").Value)

'##################################
' cleaning process coefficient
Sheet8.Range("e105").Value = (Sheet14.Range("i29").Value / Sheet14.Range("f29").Value)
'single ship Operation time
Sheet8.Range("e108").Value = (Sheet8.Range("e105").Value * Sheet8.Range("e103").Value)
'available time capacity of facility
Sheet8.Range("e111").Value = Sheet13.Range("m10").Value
'Manufacturing capacity per step, R^j _pd
Sheet8.Range("e114").Value = Int(Sheet8.Range("e111").Value / (Sheet8.Range("e108").Value / 60))

' assess time request achievement of facility
If Sheet8.Range("e114").Value < Sheet8.Range("e124").Value Then
Sheet13.Range("q10").Value = "Not complying with"
Else
Sheet13.Range("q10").Value = "Complying with"
End If


'##################################
' Coating process coefficient
Sheet8.Range("j105").Value = (Sheet14.Range("i31").Value / Sheet14.Range("f31").Value)
'single ship Operation time
Sheet8.Range("j108").Value = (Sheet8.Range("j105").Value * Sheet8.Range("j103").Value)
'available time capacity of facility
Sheet8.Range("j111").Value = Sheet13.Range("m13").Value
'Manufacturing capacity per step, R^j _pd
Sheet8.Range("j114").Value = Int(Sheet8.Range("j111").Value / (Sheet8.Range("j108").Value / 60))

' assess time request achievement of facility
If Sheet8.Range("j114").Value < Sheet8.Range("e124").Value Then
Sheet13.Range("q13").Value = "Not complying with"
Else
Sheet13.Range("q13").Value = "Complying with"
End If
```

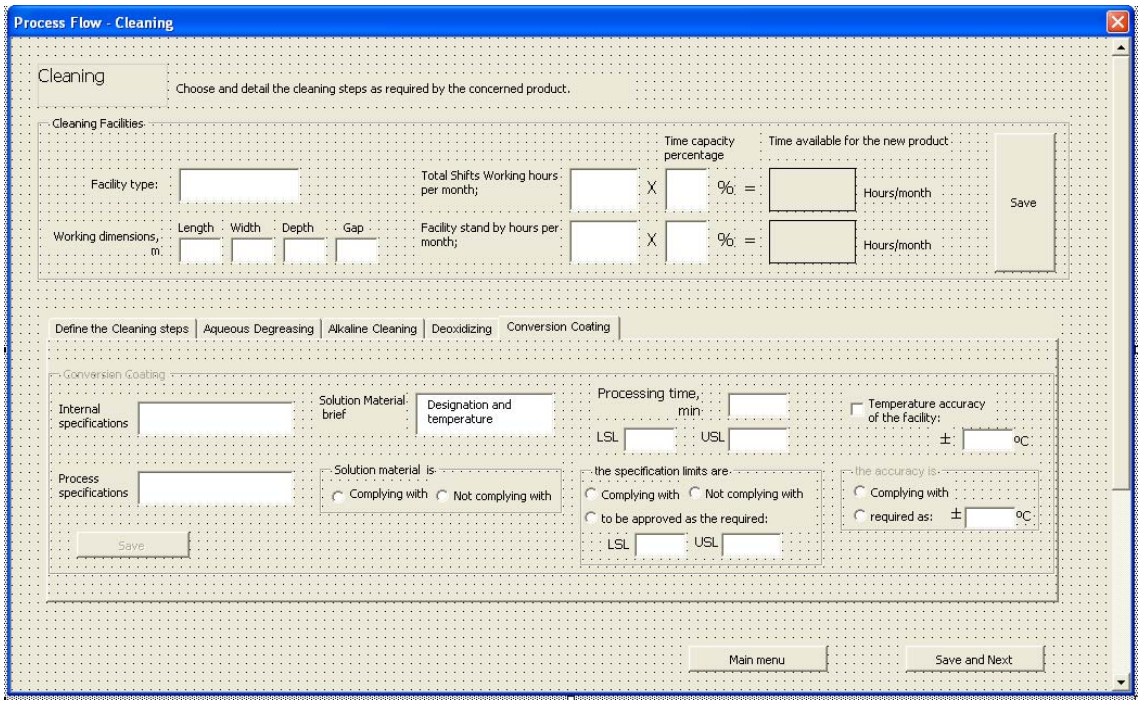
```
'################################
' curing process coefficient
Sheet8.Range("n105").Value = (Sheet14.Range("i33").Value / Sheet14.Range("f33").Value)
'single ship Operation time
Sheet8.Range("n108").Value = (Sheet8.Range("n105").Value * Sheet8.Range("n103").Value)
'available time capacity of facility
Sheet8.Range("n111").Value = Sheet13.Range("m14").Value
'Manufacturing capacity per step, R^j _pd
Sheet8.Range("n114").Value = Int(Sheet8.Range("n111").Value / (Sheet8.Range("n108").Value / 60))

' assess time request achievement of facility
If Sheet8.Range("n114").Value < Sheet8.Range("e124").Value Then
Sheet13.Range("q14").Value = "Not complying with"
Else
Sheet13.Range("q14").Value = "Complying with"
End If

'################################
' scribing process coefficient
Sheet8.Range("r105").Value = (Sheet14.Range("i35").Value / Sheet14.Range("f35").Value)
'single ship Operation time
Sheet8.Range("r108").Value = (Sheet8.Range("r105").Value * Sheet8.Range("r103").Value)
'available time capacity of facility
Sheet8.Range("r111").Value = Sheet13.Range("m17").Value
'Manufacturing capacity per step, R^j _pd
Sheet8.Range("r114").Value = Int(Sheet8.Range("r111").Value / (Sheet8.Range("r108").Value / 60))

' assess time request achievement of facility
If Sheet8.Range("r114").Value < Sheet8.Range("e124").Value Then
Sheet13.Range("q17").Value = "Not complying with"
Else
Sheet13.Range("q17").Value = "Complying with"
End If

'################################
' etching process coefficient
Sheet8.Range("y105").Value = (Sheet14.Range("i37").Value / Sheet14.Range("f37").Value)
'single ship Operation time
Sheet8.Range("y108").Value = (Sheet8.Range("y105").Value * Sheet8.Range("y103").Value)
'available time capacity of facility
Sheet8.Range("y111").Value = Sheet13.Range("m20").Value
'Manufacturing capacity per step, R^j _pd
Sheet8.Range("y114").Value = Int(Sheet8.Range("y111").Value / (Sheet8.Range("y108").Value / 60))

' assess time request achievement of facility
If Sheet8.Range("y114").Value < Sheet8.Range("e124").Value Then
Sheet13.Range("q20").Value = "Not complying with"
Else
Sheet13.Range("q20").Value = "Complying with"
End If

'################################
' demasking process coefficient
Sheet8.Range("af105").Value = (Sheet14.Range("i39").Value / Sheet14.Range("f39").Value)
'single ship Operation time
Sheet8.Range("af108").Value = (Sheet8.Range("af105").Value * Sheet8.Range("af103").Value)
'available time capacity of facility
Sheet8.Range("af111").Value = Sheet13.Range("m23").Value
'Manufacturing capacity per step, R^j _pd
Sheet8.Range("af114").Value = Int(Sheet8.Range("af111").Value / (Sheet8.Range("af108").Value / 60))
' assess time request achievement of facility
If Sheet8.Range("af114").Value < Sheet8.Range("e124").Value Then
Sheet13.Range("c4").Value = "The time request of new product on the facilities are likely not complying with, please
check the detail report facilities' assessment."
Sheet13.Range("q23").Value = "Not complying with"

Else
Sheet13.Range("C4").Value = "The time request of the new product on the facilities could be achieved by present
process, because the assessed manufacturing capacity (R_pd) is compling with the delivery rate (R_DL)."
Sheet13.Range("q23").Value = "Complying with"
End If
'final report facilities judgement.
```

```
Sheet3.Range("b86").Value = Sheet13.Range("C4").Value

'#################################################################
'Manufacturing capacity = min{R^j _pd}
Sheet8.Range("e120").Value = WorksheetFunction.Min(Sheet8.Range("af114").Value, Sheet8.Range("y114").Value,
Sheet8.Range("r114").Value, Sheet8.Range("n114").Value, Sheet8.Range("j114").Value, Sheet8.Range("e114").Value)
' assess time request achievement of facility
If Sheet8.Range("e120").Value < Sheet8.Range("e124").Value Then
Sheet13.Range("q17").Value = "Not complying with"
Else
Sheet13.Range("q17").Value = "Complying with"
End If

'#################################################################
'Process efficient in final report
Sheet3.Range("d121").Value = (Sheet8.Range("e103").Value / 60) ' cleaning t^t_pc for final report process efficient
Sheet3.Range("e121").Value = (Sheet8.Range("j103").Value / 60) '  t^t_pc for final report process efficient
Sheet3.Range("f121").Value = (Sheet8.Range("n103").Value / 60) '  t^t_pc for final report process efficient
Sheet3.Range("g121").Value = (Sheet8.Range("r103").Value / 60) '  t^t_pc for final report process efficient
Sheet3.Range("h121").Value = (Sheet8.Range("y103").Value / 60) '  t^t_pc for final report process efficient
Sheet3.Range("i121").Value = (Sheet8.Range("af103").Value / 60) '  t^t_pc for final report process efficient

Sheet3.Range("d122").Value = (Sheet13.Range("m9").Value) ' Working hours for final report process efficient
Sheet3.Range("e122").Value = (Sheet13.Range("m12").Value) '  t^t_pc for final report process efficient
Sheet3.Range("f122").Value = (Sheet13.Range("m12").Value) '  t^t_pc for final report process efficient
Sheet3.Range("g122").Value = (Sheet13.Range("m16").Value) '  t^t_pc for final report process efficient
Sheet3.Range("h122").Value = (Sheet13.Range("m19").Value) '  t^t_pc for final report process efficient
Sheet3.Range("i122").Value = (Sheet13.Range("m22").Value) '  t^t_pc for final report process efficient

' the required process efficient
Dim ttpc As Variant, ttwkhr As Variant
ttpc = (WorksheetFunction.Sum(Sheet3.Range("d121:i121").Value) * Sheet3.Range("c118").Value)
ttwkhr = WorksheetFunction.Sum(Sheet3.Range("d122:i122").Value)
Sheet3.Range("j121").Value = ttpc
Sheet3.Range("j122").Value = ttwkhr
Sheet3.Range("m121").Value = (ttpc / ttwkhr)

If Sheet8.Range("e120").Value >= Sheet8.Range("e124").Value Then
Sheet3.Range("b84").Value = "The required product delivery schedule chould be achieved with average delivery rate of
" & Sheet3.Range("b92") & "ships/month. The required process efficent could be achieved."
Else
Sheet3.Range("b84").Value = "The required product delivery schedule may not be achieved with average delivery rate
of " & Sheet3.Range("b92") & "ships/month. The required process efficent might not be achieved either."
End If

MsgBox "e_req assessing.....done."

'#################################################################
'assessing process difficulty
Sheet3.Range("k3").Value = WorksheetFunction.CountIf(Sheet8.Range("f9:j64"), "*Complying with*")
Sheet3.Range("k3").Value = Sheet3.Range("k3").Value + WorksheetFunction.CountIf(Sheet13.Range("i6:r54"),
"*Complying with*")

Sheet3.Range("k4").Value = WorksheetFunction.CountIf(Sheet8.Range("f9:j64"), "*Not Complying*")
Sheet3.Range("k4").Value = Sheet3.Range("k4").Value + WorksheetFunction.CountIf(Sheet13.Range("i6:r54"), "*Not
Complying*")

Sheet3.Range("k5").Value = WorksheetFunction.CountIf(Sheet8.Range("f9:j64"), "*to be approved*")
Sheet3.Range("k5").Value = Sheet3.Range("k5").Value + WorksheetFunction.CountIf(Sheet13.Range("i6:r54"), "*to be
approved*")
Sheet3.Range("k6").Value = WorksheetFunction.Sum(Sheet3.Range("k3:k5").Value)
Sheet3.Range("l3").Value = Sheet3.Range("k3").Value / Sheet3.Range("k6").Value
Sheet3.Range("l4").Value = Sheet3.Range("k4").Value / Sheet3.Range("k6").Value
Sheet3.Range("l5").Value = Sheet3.Range("k5").Value / Sheet3.Range("k6").Value
Sheet3.Range("l6").Value = Sheet3.Range("k6").Value / Sheet3.Range("k6").Value
MsgBox "Process difficulty checking....done."

'#################################
'facility space request checking
If WorksheetFunction.CountIf(Sheet13.Range("o9:o25"), "*Not complying*") > 0 Then
Sheet13.Range("c3").Value = "There is/are" & WorksheetFunction.CountIf(Sheet13.Range("o9:o25"), "*Not
complying*") & " of " & WorksheetFunction.CountA(Sheet13.Range("o9:o25")) & "facilities might not meet the new
```

```
product requests on working dimensions."
Else
Sheet13.Range("c3").Value = "The present facilities' working dimensions meet the space requests of new product."
End If
Sheet3.Range("b39").Value = Sheet3.Range("b39").Value + Sheet13.Range("c3").Value
MsgBox "facility space request checking.....done"

'################################
'facility temperature checking
If WorksheetFunction.CountIf(Sheet13.Range("i35:i53"), "*Not complying*") > 0 Then
Sheet13.Range("c2").Value = "There is/are" & WorksheetFunction.CountIf(Sheet13.Range("i35:i53"), "*Not complying*")
& " of " & WorksheetFunction.CountA(Sheet13.Range("i35:i53")) & "facilities might not meet the new product requests
on temperature accuracy."
Else
Sheet13.Range("c2").Value = "The facilities meet the temperature accuracy required by new product."
End If
'final reportgets facility accuracy
Sheet3.Range("b39").Value = Sheet13.Range("c2").Value
MsgBox "facility temperature checking........done."

'#################################
'#####section5.12###the qualified product####

If Sheet6.Range("m36").Value >= 1 And Sheet6.Range("m43").Value >= 1 And Sheet4.Range("B4").Value +
Sheet4.Range("d4").Value + Sheet4.Range("n4").Value + Sheet4.Range("P4").Value = 0 And
Sheet8.Range("e120").Value >= Sheet8.Range("e124").Value Then
Sheet8.Range("e3").Value = "The concerning chemical milling process line could deliver the qualified product as
required."
End If

If Sheet4.Range("B4").Value + Sheet4.Range("d4").Value + Sheet4.Range("n4").Value + Sheet4.Range("P4").Value > 0
Or Sheet6.Range("m36").Value < 1 Or Sheet6.Range("m43").Value < 1 Then
Sheet8.Range("e3").Value = "The concerning chemical milling process line migth not meet the new product
specifications. For detail see Feasibility and stability section."
End If

If Sheet8.Range("e120").Value < Sheet8.Range("e124").Value Then
Sheet8.Range("e3").Value = Sheet8.Range("e3").Value & " The delivery rate might not be achieved, see manufacturing
capacity section."
End If
Sheet3.Range("b82").Value = Sheet8.Range("e3").Value

MsgBox "the qualified product assessing.....done."
MsgBox "Manufacturing capacity assessing.....done."
End Sub

Private Sub ProMthdEvalu_Click()
MsgBox "This is a guidance of evaluating the optional process methods. It is not a necessary step for CHM process
capability capturing procedures. You can run and closed it at anytime. No data will be actually modified."
UserForm1.Hide
UserForm8.Show
End Sub

Private Sub viewinput_Click()
Dim Filename As String
Filename = Application.GetOpenFilename
Workbooks.Open Filename
'Workbooks("CHM Pro Capability Capturing Model.xlsm").Worksheets("Product").Range("a3:c17").Value =
Workbooks(Filename).Worksheets("Product information enquiry").Range("a3:c17").Value
'Workbooks("CHM Pro Capability Capturing Model.xlsm").Worksheets("Product").Range("a19:h28").Value =
Workbooks(Filename).Worksheets("Product information enquiry").Range("a19:h28").Value
'Workbooks("CHM Pro Capability Capturing Model.xlsm").Worksheets("Product").Range("a31:d38").Value =
Workbooks(Filename).Worksheets("Product information enquiry").Range("a31:d38").Value
'Workbooks("CHM Pro Capability Capturing Model.xlsm").Worksheets("Product").Range("a41:h48").Value =
Workbooks(Filename).Worksheets("Product information enquiry").Range("a41:d48").Value
UserForm1.Hide
UserForm1.Show 0
UserForm1.Height = 200
UserForm1.ScrollTop = 32
Sheet2.Activate
End Sub
Private Sub CommandButton5_Click()
```

```
UserForm1.Hide
UserForm2.Show
End Sub

Private Sub CommandButton6_Click()
UserForm1.Hide
UserForm3.Show
End Sub

Private Sub CommandButton7_Click()
UserForm1.Hide
UserForm4.Show
End Sub

Private Sub CommandButton8_Click()
UserForm1.Hide
UserForm5.Show
End Sub

Private Sub CommandButton9_Click()
UserForm1.Hide
UserForm6.Show
End Sub

Private Sub CptProductReqs_Click()
Sheet10.Range("I4:I8").Value = Sheet2.Range("b13: b17").Value
Sheet6.Range("M33:M34").Value = Sheet2.Range("b13: b14").Value
Sheet6.Range("M39").Value = Sheet2.Range("b15").Value
Sheet6.Range("M38").Value = Sheet2.Range("b16").Value
Sheet6.Range("M44").Value = Sheet2.Range("b17").Value
Sheet3.Range("C49").Value = Sheet2.Range("B13").Value
Sheet3.Range("c50").Value = Sheet2.Range("b14").Value
Sheet3.Range("F49").Value = Sheet2.Range("B16").Value
Sheet3.Range("F50").Value = Sheet2.Range("b15").Value
Sheet3.Range("j49").Value = Sheet2.Range("b17").Value
If Sheet3.Range("c50").Value = "" Then
MsgBox "Please check the Max.Depth information of the product."
End If
If Sheet3.Range("F50").Value = "" Then
MsgBox "Please check the Max.depth.thickness.LSL of the product."
End If
If Sheet3.Range("F49").Value = "" Then
MsgBox "Please check the Max.depth.thickness.USL of the product."
End If
If Sheet3.Range("j49").Value = "" Then
MsgBox "Please check the MSurface finish_Max.Depth of the product."
End If
MsgBox "Product's Depth, depth limits and surface finish limit have been captured."
End Sub

Private Sub ExportProductinf_Click()
Application.DisplayAlerts = False
Application.ScreenUpdating = False
Sheet11.Copy
ActiveWorkbook.SaveAs ThisWorkbook.Path & "\" & "Product information" & ".xls"
ActiveWorkbook.Close
Application.ScreenUpdating = True
Application.DisplayAlerts = True
MsgBox "The file has been saved as Product information.xls"
End Sub

Private Sub LordProductInfo_Click()
SelectFile
End Sub

Private Sub UserForm_Initialize()
UserForm1.ScrollTop = 0
Sheet8.Range("v1:v14").Value = "" ' clear rull data from process methods evaluator
End Sub
```

C.2 Userform2 define the cleaning step of process flow




```
Private Sub Aq_TmpAcur_Click()
If Aq_TmpAcur.Value = True Then
AqTempAcur.Enabled = True
Frame5.Enabled = True
Else
AqTempAcur.Enabled = False
Frame5.Enabled = False
End Sub

Private Sub AqButton_Click()
Sheet8.Range("F10").Value = iptxt.Value
Sheet8.Range("h10").Value = pptext.Value
Sheet8.Range("d11").Value = AqSolution.Value
'Process flow information in final report
Sheet3.Range("c12").Value = AqSolution.Value
Sheet3.Range("e12").Value = iptxt.Value
Sheet3.Range("g12").Value = pptext.Value

Sheet8.Range("f12").Value = psl.Value
Sheet8.Range("g12").Value = psu.Value
Sheet8.Range("f11").Value = AqProcessing.Value

If mtdOptionButton1.Value = True Then
Sheet8.Range("h11").Value = mtdOptionButton1.Caption
End If

If mndOptionButton2.Value = True Then
Sheet8.Range("h11").Value = mndOptionButton2.Caption
End If

If cmpOptionButton4.Value = True Then
Sheet8.Range("k11").Value = AqProcessing.Value
End If

If ntcmpOptionButton3.Value = True Then
Sheet8.Range("j11").Value = ntcmpOptionButton3.Caption
Sheet8.Range("k11").Value = AqProcessing.Value
End If
```

```
If appOptionButton5.Value = True Then
Sheet8.Range("H12").Value = ppsl.Value
Sheet8.Range("I12").Value = ppsu.Value
Sheet8.Range("j10").Value = appOptionButton5.Caption
Sheet8.Range("k11").Value = WorksheetFunction.Average(WorksheetFunction.Max(ppsl.Value, psl.Value),
WorksheetFunction.Min(ppsu.Value, psu.Value))

End If

'Process flow information in final report
Sheet3.Range("g11").Value = Sheet8.Range("h11").Value
If cmpOptionButton4.Value <> True Then
Sheet3.Range("I12").Value = Sheet8.Range("J11").Value
End If

'temperature accuracy of facilities
If Aq_TmpAcur.Value = True Then
Sheet13.Range("F36").Value = AqTempAcur.Value
End If

If AqTempAcurComply.Value = True Then
Sheet13.Range("I36").Value = AqTempAcurComply.Caption
End If

If AqTempAcurComplyNot.Value = True Then
Sheet13.Range("H36").Value = AqTempAcurComplyNot.Caption
Sheet13.Range("I36").Value = AqTempAcur_Req.Value
Sheet13.Range("K36").Value = "NOT COMPLYING WITH"
End If
End Sub

Private Sub BacktoMain_Click()
UserForm2.Hide
UserForm1.Show
End Sub

Private Sub CheckBox1_Click()
If CheckBox1.Value = True Then
Frame3.Enabled = True
AqButton.Enabled = True
MultiPage1.Pages(1).Enabled = True
MultiPage1.Pages(1).Visible = True
End If
If CheckBox1.Value = False Then
Frame3.Enabled = False
AqButton.Enabled = False
MultiPage1.Pages(1).Enabled = False
MultiPage1.Pages(1).Visible = False
End If

End Sub

Private Sub CheckBox3_Click()
If CheckBox3.Value = True Then
Frame7.Enabled = True
ToggleButton1.Enabled = True
MultiPage1.Pages(2).Enabled = True
MultiPage1.Pages(2).Visible = True
End If
If CheckBox3.Value = False Then
Frame7.Enabled = False
ToggleButton1.Enabled = False
MultiPage1.Pages(2).Enabled = False
MultiPage1.Pages(2).Visible = False
End If
End Sub

Private Sub Alkaline_TmpAcur_Click()
If Alkaline_TmpAcur.Value = True Then
AlkalineTempAcur.Enabled = True
Frame11.Enabled = True
```

```
End If
If Alkaline_TmpAcur.Value = False Then
AlkalineTempAcur.Enabled = False
Frame11.Enabled = False
End If
End Sub

Private Sub CheckBox5_Click()
If CheckBox5.Value = True Then
Frame13.Enabled = True
ToggleButton2.Enabled = True
Frame13.Visible = True
MultiPage1.Pages(3).Enabled = True
MultiPage1.Pages(3).Visible = True

End If
If CheckBox5.Value = False Then
Frame13.Enabled = False
ToggleButton2.Enabled = False
Frame13.Visible = False
MultiPage1.Pages(3).Enabled = False
MultiPage1.Pages(3).Visible = False
End If
End Sub

Private Sub CleaningDefine_Click()

'Aq Cleaning including or not

If CheckBox1.Value = True Then
Sheet8.Rows(10).EntireRow.Hidden = False
Sheet8.Rows(11).EntireRow.Hidden = False
Sheet8.Rows(12).EntireRow.Hidden = False
Sheet3.Rows(11).EntireRow.Hidden = False
Sheet3.Rows(12).EntireRow.Hidden = False
Else
Sheet8.Rows(10).EntireRow.Hidden = True
Sheet8.Rows(11).EntireRow.Hidden = True
Sheet8.Rows(12).EntireRow.Hidden = True
Sheet3.Rows(11).EntireRow.Hidden = True
Sheet3.Rows(12).EntireRow.Hidden = True
End If

'Alkaline Cleaning including or not

If CheckBox3.Value = True Then
Sheet8.Rows(13).EntireRow.Hidden = False
Sheet8.Rows(14).EntireRow.Hidden = False
Sheet8.Rows(15).EntireRow.Hidden = False
Sheet3.Rows(13).EntireRow.Hidden = False
Sheet3.Rows(14).EntireRow.Hidden = False
Else
Sheet8.Rows(13).EntireRow.Hidden = True
Sheet8.Rows(14).EntireRow.Hidden = True
Sheet8.Rows(15).EntireRow.Hidden = True
Sheet3.Rows(13).EntireRow.Hidden = True
Sheet3.Rows(14).EntireRow.Hidden = True
End If

'Deoxid_Cleaning including or not

If CheckBox5.Value = True Then
Sheet8.Rows(16).EntireRow.Hidden = False
Sheet8.Rows(17).EntireRow.Hidden = False
Sheet8.Rows(18).EntireRow.Hidden = False
Sheet3.Rows(15).EntireRow.Hidden = False
Sheet3.Rows(16).EntireRow.Hidden = False
Else
Sheet8.Rows(16).EntireRow.Hidden = True
Sheet8.Rows(17).EntireRow.Hidden = True
Sheet8.Rows(18).EntireRow.Hidden = True
Sheet3.Rows(15).EntireRow.Hidden = True
```

```
Sheet3.Rows(16).EntireRow.Hidden = True
End If

'Convern_Cleaning including or not

If CheckBox7.Value = True Then
Sheet8.Rows(19).EntireRow.Hidden = False
Sheet8.Rows(20).EntireRow.Hidden = False
Sheet8.Rows(21).EntireRow.Hidden = False
Sheet3.Rows(17).EntireRow.Hidden = False
Sheet3.Rows(18).EntireRow.Hidden = False
Else
Sheet8.Rows(19).EntireRow.Hidden = True
Sheet8.Rows(20).EntireRow.Hidden = True
Sheet8.Rows(21).EntireRow.Hidden = True
Sheet3.Rows(17).EntireRow.Hidden = True
Sheet3.Rows(18).EntireRow.Hidden = True
End If

End Sub

Private Sub Deoxid_TmpAcur_Click()
If Deoxid_TmpAcur.Value = True Then
DeoxidTempAcur.Enabled = True
Frame17.Enabled = True

End If
If Deoxid_TmpAcur.Value = False Then
DeoxidTempAcur.Enabled = False
Frame17.Enabled = False
End If
End Sub

Private Sub CheckBox7_Click()
If CheckBox7.Value = True Then
Frame19.Enabled = True
ToggleButton3.Enabled = True
MultiPage1.Pages(4).Enabled = True
MultiPage1.Pages(4).Visible = True

End If
If CheckBox7.Value = False Then
Frame19.Enabled = False
ToggleButton3.Enabled = False
MultiPage1.Pages(4).Enabled = False
MultiPage1.Pages(4).Visible = False
End If
End Sub

Private Sub Convern_TmpAcur_Click()
If Convern_TmpAcur.Value = True Then
ConvernTempAcur.Enabled = True
Frame23.Enabled = True
End If
If Convern_TmpAcur.Value = False Then
ConvernTempAcur.Enabled = False
Frame23.Enabled = False
End If
End Sub

Private Sub ComboBox1_Change()
ComboBox1.AddItem ("Process Tanks")
ComboBox1.AddItem ("Painting")

End Sub

Private Sub CleaningFacSave_Click()
Sheet13.Range("J9").Value = WorkingHrs.Value
Sheet13.Range("K9").Value = (WorkingAval.Value / 100)
Sheet13.Range("M9").Value = (WorkingHrs.Value * WorkingAval.Value / 100)
WrkAvalDisp.Caption = (WorkingHrs.Value * WorkingAval.Value / 100)
```

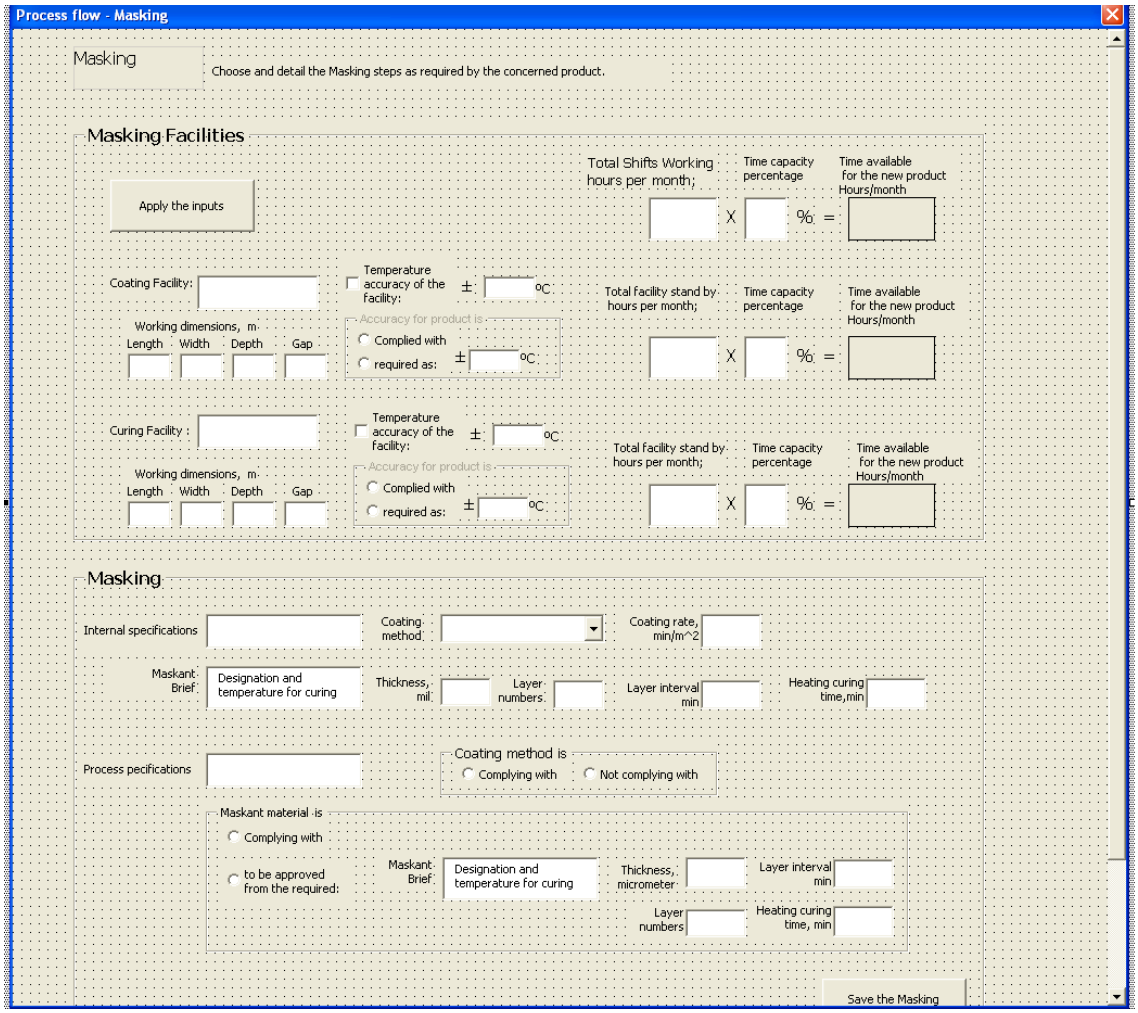
```
Sheet13.Range("D10").Value = CleanFactp.Value
Sheet13.Range("E10").Value = L.Value
Sheet13.Range("F10").Value = w.Value
Sheet13.Range("G10").Value = D.Value
Sheet13.Range("H10").Value = G.Value
Sheet13.Range("J10").Value = FacHrsStdby.Value
Sheet13.Range("K10").Value = (FacHrsAval.Value / 100)
Sheet13.Range("M10").Value = (FacHrsStdby.Value * FacHrsAval.Value / 100)
FacAvalDisp.Caption = (FacHrsStdby.Value * FacHrsAval.Value / 100)
End Sub

Private Sub CommandButton1_Click()
Sheet8.Range("k9") = Sheet8.Range("k11").Value + Sheet8.Range("k14").Value + Sheet8.Range("k17").Value +
Sheet8.Range("k20").Value
Sheet8.Range("e91") = Sheet8.Range("k9").Value
UserForm2.Hide
UserForm3.Show

End Sub

Private Sub Frame1_Click()
If OptionButton5.Value = fasle Then
AqProductTimeL.Value = fasle
AqProductTimeU.Value = fasle
End If

End Sub

Private Sub G_Change()
MsgBox "Gap means the safety margin between parts while they are loaded within same batch."
End Sub

Private Sub ToggleButton1_Click()
Sheet8.Range("F13").Value = TextBox20.Value
Sheet3.Range("e14").Value = Sheet8.Range("F13").Value 'intnl specs for final report
Sheet8.Range("h13").Value = TextBox21.Value
Sheet3.Range("g14").Value = Sheet8.Range("h13").Value 'Prod specs for final report
Sheet8.Range("d14").Value = TextBox19.Value
Sheet3.Range("c14").Value = Sheet8.Range("d14").Value 'Proc solutions for final report
Sheet8.Range("f15").Value = TextBox23.Value
Sheet8.Range("g15").Value = TextBox22.Value
Sheet8.Range("f14").Value = TextBox18.Value

If OptionButton20.Value = True Then
Sheet8.Range("h14").Value = OptionButton20.Caption
End If

If OptionButton19.Value = True Then
Sheet8.Range("h14").Value = OptionButton19.Caption
End If

Sheet3.Range("G13").Value = Sheet8.Range("h14").Value 'mthcomply for final report

If pslmtcomply.Value = True Then
Sheet8.Range("k14").Value = TextBox18.Value
End If

If pslmtntcply.Value = True Then
Sheet8.Range("j14").Value = pslmtntcply.Caption
Sheet8.Range("k14").Value = TextBox18.Value
End If

If lmttoapp.Value = True Then
Sheet8.Range("H15").Value = TextBox16.Value
Sheet8.Range("I15").Value = TextBox15.Value
Sheet8.Range("j13").Value = lmttoapp.Caption

Sheet8.Range("k14").Value = WorksheetFunction.Average(WorksheetFunction.Max(TextBox16.Value,
TextBox23.Value), WorksheetFunction.Min(TextBox15.Value, TextBox22.Value))
End If

If pslmtcomply.Value <> True Then
```

```
Sheet3.Range("i14").Value = Sheet8.Range("j14").Value 'process limits comply for final report
End If

'temperature accuracy of facilities
If Alkaline_TmpAcur.Value = True Then
Sheet13.Range("F37").Value = AlkalineTempAcur.Value
End If

If AlkalineTempAcurComply.Value = True Then
Sheet13.Range("I37").Value = AlkalineTempAcurComply.Caption
End If

If AlkalineTempAcurComplyNot.Value = True Then
Sheet13.Range("H37").Value = AlkalineTempAcurComplyNot.Caption
Sheet13.Range("I37").Value = AlkalineTempAcur_Req.Value
Sheet13.Range("K37").Value = "NOT COMPLYING WITH"
End If

End Sub

Private Sub ToggleButton2_Click()

Sheet8.Range("F16").Value = lpTextBox32.Value
Sheet3.Range("e16").Value = lpTextBox32.Value ' specs for final report
Sheet8.Range("h16").Value = ppTextBox33.Value
Sheet3.Range("g16").Value = ppTextBox33.Value 'specs for final report

Sheet8.Range("d17").Value = TextBox31.Value
Sheet3.Range("c16").Value = TextBox31.Value  'specs for final report

Sheet8.Range("f18").Value = plTextBox35.Value
Sheet8.Range("g18").Value = puTextBox34.Value
Sheet8.Range("f17").Value = aplTextBox30.Value

If OptionButton31.Value = True Then
Sheet8.Range("h17").Value = OptionButton31.Caption
End If

If mthOptionButton30.Value = True Then
Sheet8.Range("h17").Value = mthOptionButton30.Caption
End If

If slOptionButton27.Value = True Then
Sheet8.Range("k17").Value = aplTextBox30.Value
End If

If ntcmpOptionButton26.Value = True Then
Sheet8.Range("j17").Value = ntcmpOptionButton26.Caption
Sheet8.Range("k17").Value = aplTextBox30.Value
End If

If appOptionButton25.Value = True Then
Sheet8.Range("H18").Value = pslTextBox28.Value
Sheet8.Range("I18").Value = psuTextBox27.Value
Sheet8.Range("j16").Value = appOptionButton25.Caption

Sheet8.Range("k17").Value = WorksheetFunction.Average(WorksheetFunction.Max(pslTextBox28.Value,
plTextBox35.Value), WorksheetFunction.Min(psuTextBox27.Value, puTextBox34.Value))
End If

Sheet3.Range("g15").Value = Sheet8.Range("h17").Value
If slOptionButton27.Value <> True Then
Sheet3.Range("i16").Value = Sheet8.Range("j16").Value
End If


'temperature accuracy of facilities
If Deoxid_TmpAcur.Value = True Then
Sheet13.Range("F38").Value = DeoxidTempAcur.Value
End If

If DeoxidTempAcurComply.Value = True Then
```

```
Sheet13.Range("I38").Value = DeoxidTempAcurComply.Caption
End If

If DeoxidTempAcurComplyNot.Value = True Then
Sheet13.Range("H38").Value = DeoxidTempAcurComplyNot.Caption
Sheet13.Range("I38").Value = DeoxidTempAcur_Req.Value
Sheet13.Range("K38").Value = "NOT COMPLYING WITH"
End If

End Sub

Private Sub ToggleButton3_Click()
Sheet8.Range("F19").Value = ipTextBox44.Value
Sheet3.Range("e18").Value = ipTextBox44.Value ' spec for final report
Sheet8.Range("h19").Value = ppTextBox45.Value
Sheet3.Range("g18").Value = ppTextBox45.Value ' spec for final report

Sheet8.Range("d20").Value = mtdTextBox43.Value
Sheet3.Range("c18").Value = mtdTextBox43.Value ' spec for final report


Sheet8.Range("f21").Value = plTextBox47.Value
Sheet8.Range("g21").Value = puTextBox46.Value
Sheet8.Range("f20").Value = aplTextBox42.Value

If mtdOptionButton42.Value = True Then
Sheet8.Range("h20").Value = mtdOptionButton42.Caption
End If

If mtdOptionButton41.Value = True Then
Sheet8.Range("h20").Value = mtdOptionButton41.Caption
End If

If cmpOptionButton38.Value = True Then
Sheet8.Range("k20").Value = aplTextBox42.Value
End If

If notOptionButton37.Value = True Then
Sheet8.Range("j20").Value = notOptionButton37.Caption
Sheet8.Range("k20").Value = aplTextBox42.Value

End If

If appOptionButton36.Value = True Then
Sheet8.Range("H21").Value = pplTextBox40.Value
Sheet8.Range("I21").Value = ppuTextBox39.Value
Sheet8.Range("j20").Value = appOptionButton36.Caption

Sheet8.Range("k20").Value = WorksheetFunction.Average(WorksheetFunction.Max(pplTextBox40.Value,
plTextBox47.Value.Value), WorksheetFunction.Min(ppuTextBox39.Value, puTextBox46.Value))
End If

Sheet3.Range("g17").Value = Sheet8.Range("h20").Value ' spec for final report

If cmpOptionButton38.Value <> True Then
Sheet3.Range("i18").Value = Sheet8.Range("j20").Value ' spec for final report
End If

'temperature accuracy of facilities

If Convern_TmpAcur.Value = True Then
Sheet13.Range("F39").Value = ConvernTempAcur.Value
End If

If ConvernTempAcurComply.Value = True Then
Sheet13.Range("I39").Value = ConvernTempAcurComply.Caption
End If

If ConvernTempAcurComplyNot.Value = True Then
Sheet13.Range("H39").Value = ConvernTempAcurComplyNot.Caption
Sheet13.Range("I39").Value = ConvernTempAcur_Req.Value
Sheet13.Range("K39").Value = "NOT COMPLYING WITH"
```

```
End If
End Sub

Private Sub UserForm_()
'activesheet.rows(10).hiden = true
'activesheet.rows(10).hiden = fasle
End Sub

Private Sub UserForm_Initialize()
UserForm2.ScrollTop = 0
MultiPage1.Pages(1).Visible = False
MultiPage1.Pages(2).Visible = False
MultiPage1.Pages(3).Visible = False
MultiPage1.Pages(4).Visible = False
End Sub
```

C.3 Userform3 Define the masking step of process flow

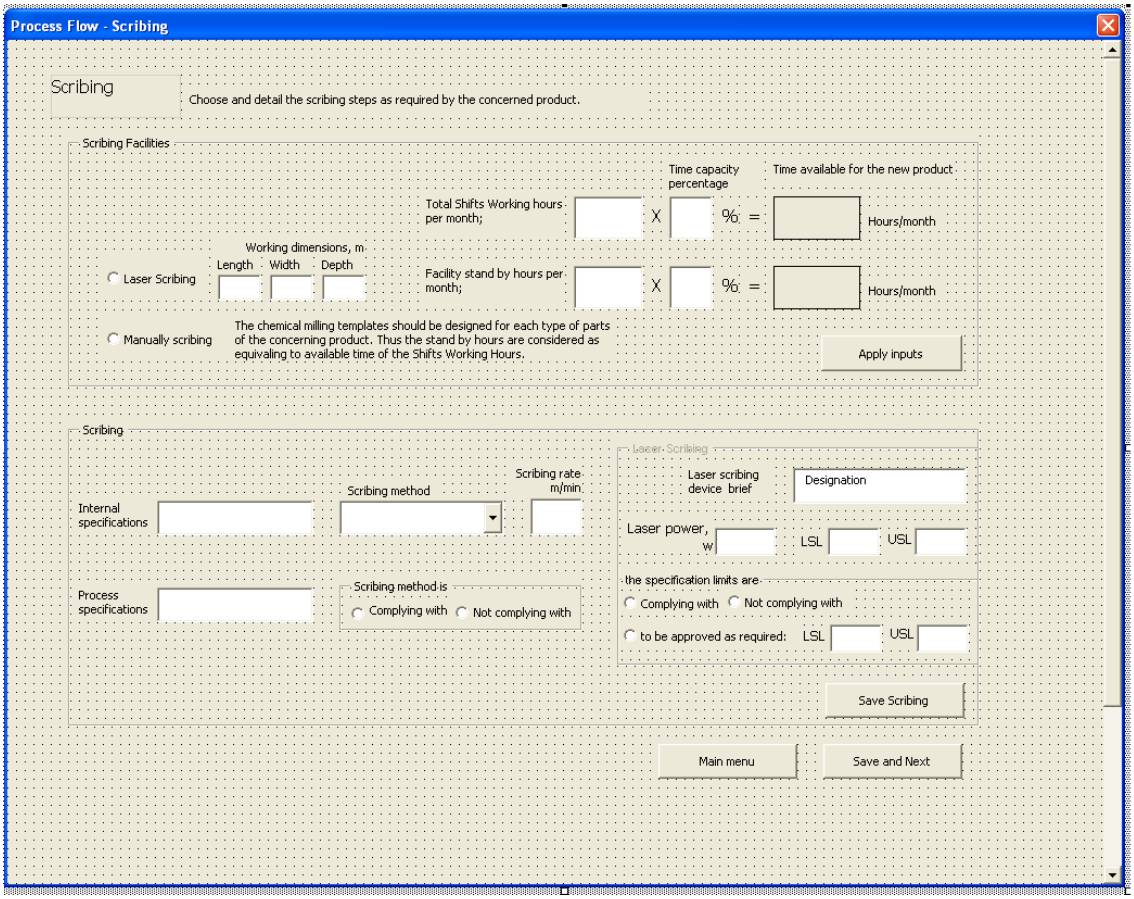



```
Private Sub BacktoMain_Click()
UserForm3.Hide
UserForm1.Show
End Sub

Private Sub Coating_TmpAcur_Click()
If Coating_TmpAcur.Value = True Then
Frame27.Enabled = True
```

```
CoatingTempAcur.Enabled = True
Else
Frame27.Enabled = False
CoatingTempAcur.Enabled = False
End If
End Sub

Private Sub CommandButton1_Click()
UserForm3.Hide
UserForm4.Show
End Sub

Private Sub Curing_TmpAcur_Click()
If Curing_TmpAcur.Value = True Then
Frame26.Enabled = True
CuringTempAcur.Enabled = True
Else
Frame26.Enabled = False
CuringTempAcur.Enabled = False
End If
End Sub

Private Sub Masking_Click()
Sheet8.Range("F23").Value = Iptext.Value
Sheet3.Range("e21").Value = Iptext.Value ' specs for final report
Sheet8.Range("H23").Value = PPtext.Value
Sheet3.Range("g21").Value = PPtext.Value ' specs for final report
Sheet8.Range("D32").Value = coatingrate.Value
Sheet8.Range("F24").Value = Maskantextbox.Value
Sheet3.Range("c21").Value = Maskantextbox.Value ' specs for final report
Sheet8.Range("F26").Value = thicknesstxt.Value
Sheet8.Range("F29").Value = Intervaltime.Value
Sheet8.Range("F27").Value = Layersnumber.Value
Sheet8.Range("F30").Value = Coatingmethod.Value
Sheet8.Range("F34").Value = CURINGTIMETextBox73.Value
Sheet8.Range("k32").Value = Sheet8.Range("f32").Value
Sheet8.Range("k90").Value = Sheet8.Range("f32").Value

If CoatMOptionButton16.Value = True Then
Sheet8.Range("H30").Value = CoatMOptionButton16.Caption
End If

If CoatmOptionButton17.Value = True Then
Sheet8.Range("H30").Value = CoatmOptionButton17.Caption
End If
Sheet3.Range("g20").Value = Sheet8.Range("H30").Value  ' specs for final report

If MsktOptionButton1.Value = True Then
Sheet8.Range("H24").Value = MsktOptionButton1.Caption
Sheet8.Range("k26").Value = Sheet8.Range("f26").Value
Sheet8.Range("k27").Value = Sheet8.Range("f27").Value
Sheet8.Range("k29").Value = Sheet8.Range("f29").Value
Sheet8.Range("k34").Value = Sheet8.Range("f34").Value
End If

If MSKTOptionButton2.Value = True Then
Sheet8.Range("J24").Value = MSKTOptionButton2.Caption
Sheet8.Range("H26").Value = PPMSKTthicknesstxt.Value
Sheet8.Range("k26").Value = Sheet8.Range("H26").Value
Sheet8.Range("h27").Value = ppLayersnumber.Value
Sheet8.Range("k27").Value = Sheet8.Range("H27").Value
Sheet8.Range("h29").Value = ppIntervaltime.Value
Sheet8.Range("k29").Value = Sheet8.Range("H29").Value
Sheet8.Range("h34").Value = ppcuringtime.Value
Sheet8.Range("k34").Value = Sheet8.Range("H34").Value
Sheet8.Range("h24").Value = ppmsktTextBox70.Value
Sheet3.Range("I20").Value = "to be approved with other maskants." ' specs for final report
End If

'get processing time assessing data
Sheet8.Range("i89").Value = Sheet8.Range("k27").Value
Sheet8.Range("i90").Value = Sheet8.Range("k29").Value
```

```
Sheet8.Range("n91").Value = Sheet8.Range("k34").Value
End Sub


Private Sub MaskingFacSave_Click()
Sheet13.Range("J12").Value = WorkingHrs.Value
Sheet13.Range("K12").Value = (WorkingAval.Value / 100)
Sheet13.Range("M12").Value = (WorkingHrs.Value * WorkingAval.Value / 100)
WrkAvalDisp.Caption = (WorkingHrs.Value * WorkingAval.Value / 100)

Sheet13.Range("D13").Value = Coating_Factp.Value
Sheet13.Range("E13").Value = Coating_L.Value
Sheet13.Range("F13").Value = Coating_W.Value
Sheet13.Range("G13").Value = Coating_D.Value
Sheet13.Range("H13").Value = Coating_G.Value
Sheet13.Range("J13").Value = Coating_FacHrsStdby.Value
Sheet13.Range("K13").Value = (Coating_FacHrsAval.Value / 100)
Sheet13.Range("M13").Value = (Coating_FacHrsStdby.Value * Coating_FacHrsAval.Value / 100)
Coating_FacAvalDisp.Caption = (Coating_FacHrsStdby.Value * Coating_FacHrsAval.Value / 100)

If Coating_TmpAcur.Value = True Then
Sheet13.Range("F42").Value = CoatingTempAcur.Value
End If

If CoatingTempAcurComply.Value = True Then
Sheet13.Range("I42").Value = CoatingTempAcurComply.Caption
End If

If CoatingTempAcurComplyNot.Value = True Then
Sheet13.Range("H42").Value = CoatingTempAcurComplyNot.Caption
Sheet13.Range("I42").Value = CoatingTempAcur_Req.Value
Sheet13.Range("K42").Value = "NOT COMPLYING WITH"
End If

Sheet13.Range("D14").Value = Curing_Factp.Value
Sheet13.Range("E14").Value = Curing_L.Value
Sheet13.Range("F14").Value = Curing_W.Value
Sheet13.Range("G14").Value = Curing_D.Value
Sheet13.Range("H14").Value = Curing_G.Value
Sheet13.Range("J14").Value = Curing_FacHrsStdby.Value
Sheet13.Range("K14").Value = Curing_FacHrsAval.Value
Sheet13.Range("M14").Value = (Curing_FacHrsStdby.Value * Curing_FacHrsAval.Value / 100)
Curing_FacAvalDisp.Caption = (Curing_FacHrsStdby.Value * Curing_FacHrsAval.Value / 100)

If Curing_TmpAcur.Value = True Then
Sheet13.Range("F43").Value = CuringTempAcur.Value
End If

If CuringTempAcurComply.Value = True Then
Sheet13.Range("I43").Value = CuringTempAcurComply.Caption
End If

If CuringTempAcurComplyNot.Value = True Then
Sheet13.Range("H43").Value = CuringTempAcurComplyNot.Caption
Sheet13.Range("I43").Value = CuringTempAcur_Req.Value
Sheet13.Range("K43").Value = "NOT COMPLYING WITH"
End If

End Sub

Private Sub UserForm_Initialize()
UserForm3.ScrollTop = 0
Coatingmethod.AddItem "Brushing"
Coatingmethod.AddItem "Spraying"
Coatingmethod.AddItem "Flow-coating"
Coatingmethod.AddItem "Dipping"
End Sub
```

C.4 Userform4 Define the scribing step of process flow

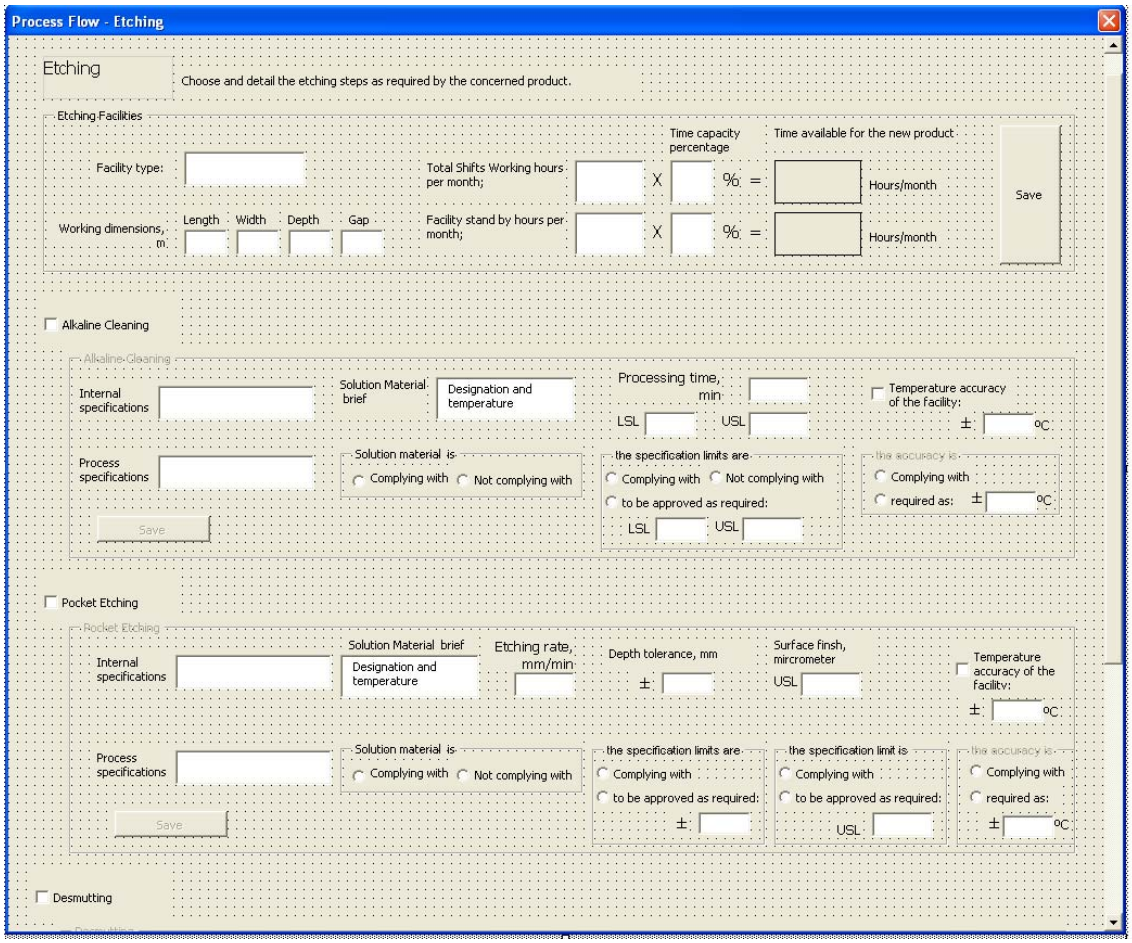



```
Private Sub BacktoMain_Click()
UserForm4.Hide
UserForm1.Show
End Sub

Private Sub CommandButton1_Click()
UserForm4.Hide
UserForm5.Show
End Sub

Private Sub ScribingFacSave_Click()
Sheet13.Range("J16").Value = WorkingHrs.Value
Sheet13.Range("K16").Value = (WorkingAval.Value / 100)
Sheet13.Range("M16").Value = (WorkingHrs.Value * WorkingAval.Value / 100)
WrkAvalDisp.Caption = (WorkingHrs.Value * WorkingAval.Value / 100)
If Scribingfac.Value = True Then
Sheet13.Range("d17").Value = "Laser Scribing"
Sheet13.Range("E17").Value = Scribing_L.Value
Sheet13.Range("F17").Value = Scribing_W.Value
Sheet13.Range("G17").Value = Scribing_D.Value
Sheet13.Range("J17").Value = Scribing_FacHrsStdby.Value
Sheet13.Range("K17").Value = (Scribing_FacHrsAval.Value / 100)
Sheet13.Range("M17").Value = (Scribing_FacHrsStdby.Value * Scribing_FacHrsAval.Value / 100)
Scribing_FacAvalDisp.Caption = (Scribing_FacHrsStdby.Value * Scribing_FacHrsAval.Value / 100)
End If
If ManuallyScribing.Value = True Then
Sheet13.Range("d17").Value = ManuallyScribing.Caption
Sheet13.Range("J17").Value = WorkingHrs.Value
Sheet13.Range("K17").Value = (WorkingAval.Value / 100)
Sheet13.Range("M17").Value = (WorkingHrs.Value * WorkingAval.Value / 100)
End If
End Sub
```

```
Private Sub Scribingsave_Click()

Sheet8.Range("F36").Value = Iptext.Value
Sheet3.Range("e24").Value = Iptext.Value ' spec for final report
Sheet8.Range("H36").Value = PPtext.Value
Sheet3.Range("g24").Value = PPtext.Value ' spec for final report

Sheet8.Range("D37").Value = Scribingmtd.Value
Sheet3.Range("c24").Value = Scribingmtd.Value ' spec for final report

Sheet8.Range("D39").Value = Scribingrt.Value
Sheet8.Range("k39").Value = Scribingrt.Value ' for assessing the processing time
Sheet8.Range("r90").Value = Scribingrt.Value ' for assessing the processing time

If ScribMth.Value = True Then
Sheet8.Range("H37").Value = ScribMth.Caption
End If

If ScribMthOptionButton13.Value = True Then
Sheet8.Range("H37").Value = ScribMthOptionButton13.Caption
End If
Sheet3.Range("g23").Value = Sheet8.Range("H37").Value  ' spec for final report

If Scribingmtd.Value = "Manually Scribing" Then
Sheet8.Rows(40).EntireRow.Hidden = True
Sheet8.Rows(41).EntireRow.Hidden = True
Else
Sheet8.Rows(40).EntireRow.Hidden = False
Sheet8.Rows(41).EntireRow.Hidden = False
End If


If Scribingmtd.Value = "Laser Scribing" Then
Sheet8.Rows(40).EntireRow.Hidden = False
Sheet8.Rows(41).EntireRow.Hidden = False
Sheet8.Range("D40").Value = Devicbrief.Value
Sheet13.Range("D17").Value = Devicbrief.Value
Sheet8.Range("F40").Value = LASERPW.Value
Sheet8.Range("F41").Value = LaserPsl.Value
Sheet8.Range("g41").Value = LaserpsU.Value
End If

If laserLimt.Value = True Then
Sheet8.Range("h40").Value = laserLimt.Caption
Sheet8.Range("k40").Value = LASERPW.Value
End If

If LaserlmtOptionButton3.Value = True Then
Sheet8.Range("h40").Value = LaserlmtOptionButton3.Caption
Sheet3.Range("i23").Value = "Specification limits are not complying with" ' information for final report
Sheet8.Range("k40").Value = LASERPW.Value
End If

If laserlmtOptionButton5.Value = True Then
Sheet3.Range("i23").Value = "Specification limits to be approved" ' information for final report
Sheet8.Range("J40").Value = laserlmtOptionButton5.Caption
Sheet8.Range("h41").Value = Laserppl.Value
Sheet8.Range("i41").Value = LaserppU.Value
Sheet8.Range("k40").Value = WorksheetFunction.Average(WorksheetFunction.Max(Laserppl.Value, LaserPsl.Value),
WorksheetFunction.Min(LaserpsU.Value, LaserppU.Value))
End If
End Sub

Private Sub LaserScringOptionButton13_Click()
If LaserScringOptionButton13.Value = True Then
Lasersave.Enabled = True
LaserFrame3.Enabled = True
End Sub

Private Sub Scribingmtd_Change()
If Scribingmtd.Value = "Laser Scribing" Then
```

```
LaserFrame29.Visible = True
LaserFrame29.Enabled = True
Else
LaserFrame29.Enabled = False
LaserFrame29.Visible = False
End If
End Sub

Private Sub UserForm_Initialize()
Scribingmtd.AddItem "Laser Scribing"
Scribingmtd.AddItem "Manually Scribing"
LaserFrame29.Visible = True
LaserFrame29.Enabled = True
Sheet8.Rows(40).EntireRow.Hidden = False
Sheet8.Rows(41).EntireRow.Hidden = False

UserForm4.ScrollTop = 0
'ThisWorkbook.Sheets(8).Rows(40).EntireRow.Hiden = False   object doesnot support
'ThisWorkbook.Sheets(8).Rows(41).EntireRow.Hiden = False object doesnot support
End Sub
```

C.5 Userform1 Define the Etching step of process




```
Private Sub BacktoMain_Click()
'back to first page
UserForm5.Hide
UserForm1.Show
```

```
End Sub

Private Sub CommandButton1_Click()
'page down
UserForm5.Hide
UserForm6.Show
End Sub

Private Sub dsmtcheck_Click()
If dsmtcheck.Value = True Then
dsmtFrame13.Enabled = True
dsmtsave.Enabled = True
End If
If dsmtcheck.Value = False Then
dsmtFrame13.Enabled = False
dsmtsave.Enabled = False
End If
End Sub

Private Sub dsmtsave_Click()
'save step
Sheet8.Range("F54").Value = dsmtinternalps.Value
Sheet3.Range("e31").Value = smtinternalps.Value  ' information for final report
Sheet8.Range("h54").Value = dsmtproductps.Value
Sheet3.Range("g31").Value = dsmtproductps.Value  ' information for final report
Sheet8.Range("d55").Value = dsmtsolutionmtl.Value
Sheet3.Range("c31").Value = dsmtsolutionmtl.Value  ' information for final report
Sheet8.Range("f55").Value = dsmtprocesstime.Value
Sheet8.Range("g56").Value = dsmtppsu.Value
Sheet8.Range("f56").Value = dsmtppsl.Value

If dsmtsolutioncmpl.Value = True Then
Sheet8.Range("h55").Value = dsmtsolutioncmpl.Caption
End If

If dsmtsolutionnncmpl.Value = True Then
Sheet8.Range("h55").Value = dsmtsolutionnncmpl.Caption
End If

Sheet3.Range("g30").Value = Sheet8.Range("h55").Value  ' information for final report
If dsmtpslmtcomply.Value = True Then
Sheet8.Range("j55").Value = dsmtprocesstime.Value
End If

If dsmtpslmtntcply.Value = True Then
Sheet8.Range("j55").Value = dsmtpslmtntcply.Caption
Sheet3.Range("i31").Value = "process limits not complying with"
End If

If dsmtlmttoapp.Value = True Then
Sheet8.Range("H56").Value = dsmtprodpsl.Value
Sheet8.Range("I56").Value = dsmtprodpsu.Value
Sheet8.Range("j54").Value = dsmtlmttoapp.Caption
Sheet8.Range("j56").Value = WorksheetFunction.Average(WorksheetFunction.Max(dsmtppsl.Value,
dsmtprodpsl.Value), WorksheetFunction.Min(dsmtppsu.Value, dsmtprodpsu.Value))
Sheet3.Range("i31").Value = "to be approved"
End If

'temperature accuracy of facilities
If Eth_Dsmt_TmpAcur.Value = True Then
Sheet13.Range("F47").Value = Eth_DsmtTempAcur.Value
End If

If Eth_DsmtTempAcurComply.Value = True Then
Sheet13.Range("I47").Value = Eth_DsmtTempAcurComply.Caption
End If

If Eth_DsmtTempAcurComplyNot.Value = True Then
Sheet13.Range("H47").Value = Eth_DsmtTempAcurComplyNot.Caption
Sheet13.Range("I47").Value = Eth_DsmtTempAcur_Req.Value
```

```
Sheet13.Range("K47").Value = "NOT COMPLYING WITH"
End If

End Sub

Private Sub EtchAlkaline_Click()

Sheet8.Range("F43").Value = internalps.Value
Sheet3.Range("e27").Value = internalps.Value  ' information for final report
Sheet8.Range("h43").Value = productps.Value
Sheet3.Range("g27").Value = productps.Value ' information for final report
Sheet8.Range("d44").Value = solutionmtl.Value
Sheet3.Range("c27").Value = solutionmtl.Value ' information for final report
Sheet8.Range("f44").Value = processtime.Value
Sheet8.Range("g45").Value = ppsu.Value
Sheet8.Range("f45").Value = ppsl.Value

If OptionButton20.Value = True Then
Sheet8.Range("h44").Value = OptionButton20.Caption
End If

If OptionButton19.Value = True Then
Sheet8.Range("h44").Value = OptionButton19.Caption
End If
Sheet3.Range("g26").Value = Sheet8.Range("h44").Value ' information for final report

If pslmtcomply.Value = True Then
Sheet8.Range("j44").Value = processtime.Value
End If

If pslmtntcply.Value = True Then
Sheet8.Range("j44").Value = pslmtntcply.Caption
End If

If lmttoapp.Value = True Then
Sheet8.Range("H45").Value = prodpsl.Value
Sheet8.Range("I45").Value = prodpsu.Value
Sheet8.Range("j43").Value = lmttoapp.Caption
Sheet8.Range("j45").Value = WorksheetFunction.Average(WorksheetFunction.Max(ppsl.Value, prodpsl.Value),
WorksheetFunction.Min(ppsu.Value, prodpsu.Value))
End If

If pslmtcomply.Value <> True Then
Sheet3.Range("g26").Value = Sheet8.Range("j44").Value
End If

'temperature accuracy of facilities
If Eth_Alkaline_TmpAcur.Value = True Then
Sheet13.Range("F46").Value = Eth_AlkalineTempAcur.Value
End If

If Eth_AlkalineTempAcurComply.Value = True Then
Sheet13.Range("I46").Value = Eth_AlkalineTempAcurComply.Caption
End If

If Eth_AlkalineTempAcurComplyNot.Value = True Then
Sheet13.Range("H46").Value = Eth_AlkalineTempAcurComplyNot.Caption
Sheet13.Range("I46").Value = Eth_AlkalineTempAcur_Req.Value
Sheet13.Range("K46").Value = "NOT COMPLYING WITH"
End If
End Sub


Private Sub etchingALKcheck_Click()

If etchingALKcheck.Value = True Then
alkFrame7.Enabled = True
EtchAlkaline.Enabled = True
End If

If etchingALKcheck.Value = False Then
alkFrame7.Enabled = False
```

```
EtchAlkaline.Enabled = False
End If
End Sub

Private Sub etchingCheckBox1_Click()
If etchingCheckBox1.Value = True Then
etchingframe.Enabled = True
etchingsave.Enabled = True
End If

If etchingCheckBox1.Value = False Then
etchingframe.Enabled = False
etchingsave.Enabled = False
End If
End Sub

Private Sub EtchingFacSave_Click()
Sheet13.Range("J19").Value = WorkingHrs.Value
Sheet13.Range("K19").Value = (WorkingAval.Value / 100)
Sheet13.Range("M19").Value = (WorkingHrs.Value * WorkingAval.Value / 100)
WrkAvalDisp.Caption = (WorkingHrs.Value * WorkingAval.Value / 100)

Sheet13.Range("D20").Value = Etching_Factp.Value
Sheet13.Range("E20").Value = Etching_L.Value
Sheet13.Range("F20").Value = Etching_W.Value
Sheet13.Range("G20").Value = Etching_D.Value
Sheet13.Range("H20").Value = Etching_G.Value
Sheet13.Range("J20").Value = Etching_FacHrsStdby.Value
Sheet13.Range("K20").Value = (Etching_FacHrsAval.Value / 100)
Sheet13.Range("M20").Value = (Etching_FacHrsStdby.Value * Etching_FacHrsAval.Value / 100)
Etching_FacAvalDisp.Caption = (Etching_FacHrsStdby.Value * Etching_FacHrsAval.Value / 100)
End Sub

Private Sub etchingsave_Click()
Sheet8.Range("F46").Value = ethps.Value
Sheet3.Range("e29").Value = ethps.Value ' information for final report
Sheet8.Range("h46").Value = productethps.Value
Sheet3.Range("g29").Value = productethps.Value ' information for final report
Sheet8.Range("d47").Value = ethmtl.Value
Sheet3.Range("c29").Value = ethmtl.Value ' information for final report
Sheet8.Range("d49").Value = ethrate.Value
Sheet8.Range("f51").Value = deptht.Value
Sheet8.Range("g53").Value = sfinish.Value
Sheet8.Range("k49").Value = ethrate.Value
Sheet8.Range("v90").Value = ethrate.Value ' for asseing the processing time
If ethantcmpl.Value = True Then
Sheet8.Range("h47").Value = ethantcmpl.Caption
End If

If etchantnncpl.Value = True Then
Sheet8.Range("h47").Value = etchantnncpl.Caption
End If

Sheet3.Range("g28").Value = Sheet8.Range("h47").Value ' information for final report
If depthtcpl.Value = True Then
Sheet8.Range("h50").Value = depthtcpl.Caption
End If

If depthtnncpl.Value = True Then
Sheet8.Range("H51").Value = ppdeptht.Value
Sheet8.Range("j50").Value = depthtnncpl.Caption
Sheet8.Range("k50").Value = ppdeptht.Value
End If

If sfcmply.Value = True Then
Sheet8.Range("h52").Value = sfcmply.Caption
End If

If sfnncmply.Value = True Then
Sheet8.Range("I53").Value = ppsfinish.Value
Sheet8.Range("J52").Value = sfnncmply.Caption
Sheet8.Range("k52").Value = ppsfinish.Value
```

```
End If

If depthtnncpl.Value = True Or sfnncmply.Value = True Then
Sheet3.Range("i29").Value = "to be approved as required" ' information for final report
End If

'temperature accuracy of facilities
If Ething_TmpAcur.Value = True Then
Sheet13.Range("F47").Value = EthingTempAcur.Value
End If

If EthingTempAcurComply.Value = True Then
Sheet13.Range("I47").Value = EthingTempAcurComply.Caption
End If

If EthingTempAcurComplyNot.Value = True Then
Sheet13.Range("H47").Value = EthingTempAcurComplyNot.Caption
Sheet13.Range("I47").Value = EthingTempAcur_Req.Value
Sheet13.Range("K47").Value = "NOT COMPLYING WITH"
End If
End Sub

Private Sub Eth_Alkaline_TmpAcur_Click()
If Eth_Alkaline_TmpAcur.Value = True Then
Eth_AlkalineTempAcur.Enabled = True
Frame11.Enabled = True
Else
Eth_AlkalineTempAcur.Enabled = False
Frame11.Enabled = False
End If
End Sub

Private Sub Eth_Dsmt_TmpAcur_Click()
If Eth_Dsmt_TmpAcur.Value = True Then
Frame17.Enabled = True
Eth_DsmtTempAcur.Enabled = True
Else
Eth_DsmtTempAcur.Enabled = False
Frame17.Enabled = False
End If

End Sub

Private Sub Ething_TmpAcur_Click()
If Ething_TmpAcur.Value = True Then
Frame5.Enabled = True
EthingTempAcur.Enabled = True
Else
EthingTempAcur.Enabled = False
Frame5.Enabled = False
End If
End Sub

Private Sub UserForm_Initialize()
UserForm5.ScrollTop = 0
End Sub
```

C.6 Userform6 Define the demasking step of process flow

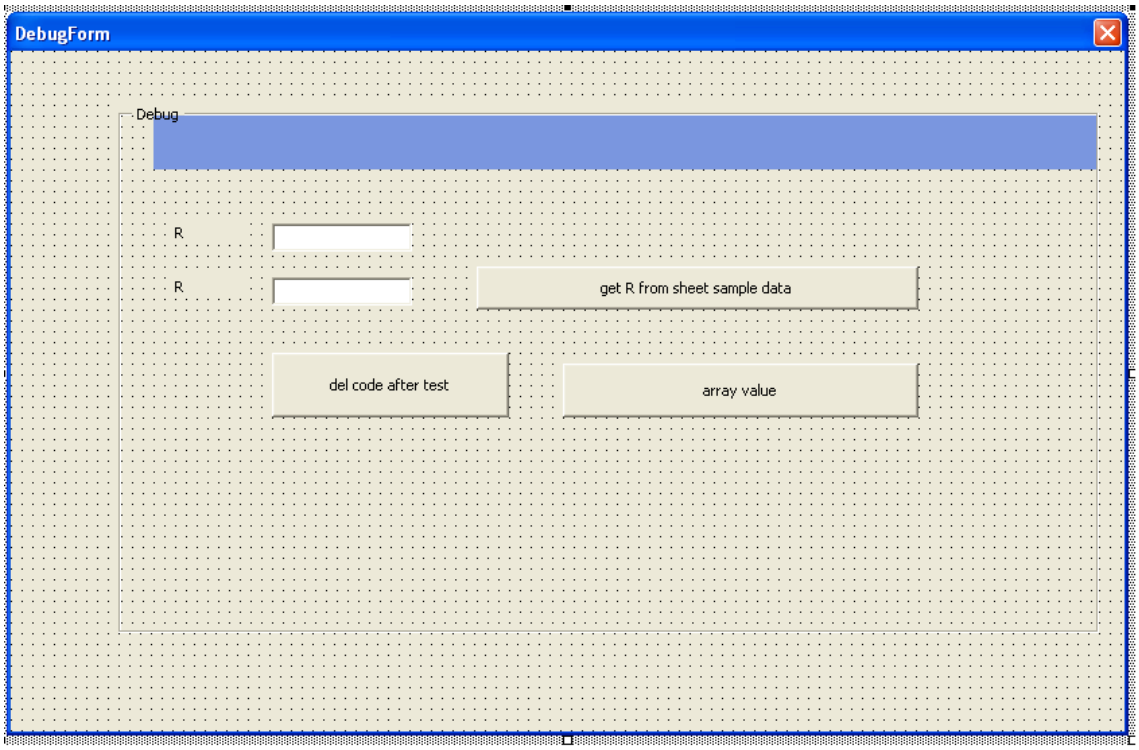
```
Private Sub BacktoMain_Click()
UserForm6.Hide
UserForm1.Show
End Sub

Private Sub CommandButton1_Click()
UserForm6.Hide
UserForm1.Show
```

```
End Sub

Private Sub DeMskChem_TmpAcur_Click()
If DeMskChem_TmpAcur.Value = True Then
DeMskChemTempAcur.Enabled = True
Frame5.Enabled = True
Else
DeMskChemTempAcur.Enabled = False
Frame5.Enabled = False
End If
End Sub

Private Sub DeMskFacSave_Click()
Sheet13.Range("J22").Value = WorkingHrs.Value
Sheet13.Range("K22").Value = (WorkingAval.Value / 100)
Sheet13.Range("M22").Value = (WorkingHrs.Value * WorkingAval.Value / 100)
WrkAvalDisp.Caption = (WorkingHrs.Value * WorkingAval.Value / 100)

' save the facility information for chemically demasking

If DeMskChem.Value = True Then
Sheet13.Range("D23").Value = DeMskChemFactp.Value
Sheet13.Range("E23").Value = DeMskChem_L.Value
Sheet13.Range("F23").Value = DeMskChem_W.Value
Sheet13.Range("G23").Value = DeMskChem_D.Value
Sheet13.Range("H23").Value = DeMskChem_G.Value
Sheet13.Range("J23").Value = DeMskChem_FacHrsStdby.Value
Sheet13.Range("K23").Value = (DeMskChem_FacHrsAval.Value / 100)
Sheet13.Range("M23").Value = (DeMskChem_FacHrsStdby.Value * DeMskChem_FacHrsAval.Value / 100)
DeMskChem_FacAvalDisp.Caption = (DeMskChem_FacHrsStdby.Value * DeMskChem_FacHrsAval.Value / 100)
End If

' save the facility information for manually demasking

If DeMskManu.Value = True Then
Sheet13.Range("D23").Value = DeMskManu.Caption
Sheet13.Range("J23").Value = WorkingHrs.Value
Sheet13.Range("K23").Value = (WorkingAval.Value / 100)
Sheet13.Range("M23").Value = (WorkingHrs.Value * WorkingAval.Value / 100)
End If
End Sub

Private Sub DMSKmtd_Change()
If DMSKmtd.Value = "Demasking Chemically" Then
dmskchmframe.Visible = True
dmskchmframe.Enabled = True

strplabel.Visible = False
strplabel.Enabled = False
strprate.Enabled = False
strprate.Visible = False
End If

If DMSKmtd.Value = "Demasking Manually" Then
dmskchmframe.Visible = False
dmskchmframe.Enabled = False

strplabel.Visible = True
strplabel.Enabled = True
strprate.Enabled = True
strprate.Visible = True
End If
End Sub



Private Sub dsmksaveButton_Click()
If DMSKmtd.Value = "Demasking Manually" Then
Sheet8.Range("F58").Value = DSMKinternalps.Value
Sheet8.Range("h58").Value = DSMKproductps.Value
Sheet8.Range("D58").Value = DMSKmtd.Value
Sheet8.Range("D60").Value = strprate.Value
```

```
Sheet8.Range("k60").Value = strprate.Value
Sheet8.Range("af90").Value = strprate.Value

dmskchmframe.Enabled = False
dmskchmframe.Visible = False

Sheet8.Rows(61).EntireRow.Hidden = True
Sheet8.Rows(62).EntireRow.Hidden = True
Sheet8.Rows(63).EntireRow.Hidden = True
Sheet8.Rows(64).EntireRow.Hidden = True

Sheet3.Range("c33").Value = "Demasking Manually" ' information for final report
End If

If DMSKmtd.Value = "Demasking Chemically" Then
dmskchmframe.Enabled = True
dmskchmframe.Visible = True
Sheet8.Rows(61).EntireRow.Hidden = False
Sheet8.Rows(62).EntireRow.Hidden = False
Sheet8.Rows(63).EntireRow.Hidden = False
Sheet8.Rows(64).EntireRow.Hidden = False
Sheet8.Range("F61").Value = DSMKinternalps.Value
Sheet8.Range("h61").Value = DSMKproductps.Value
Sheet3.Range("c33").Value = "Demasking Chemically"
End If

Sheet3.Range("e34").Value = DSMKinternalps.Value ' information for final report
Sheet3.Range("g34").Value = DSMKproductps.Value

If DMSKmtd.Value = "Demasking Manually" And DSMKMthCMPL.Value = True Then
Sheet8.Range("h59").Value = DSMKMthCMPL.Caption
End If

If DMSKmtd.Value = "Demasking Manually" And DSMKMthCMPLnot.Value = True Then
Sheet8.Range("h59").Value = DSMKMthCMPLnot.Caption
End If

If DMSKmtd.Value = "Demasking Manually" Then
Sheet3.Range("g33").Value = Sheet8.Range("h59").Value
Sheet13.Rows(51).EntireRow.Hidden = True
Else
Sheet13.Rows(51).EntireRow.Hidden = False
End If


If DMSKmtd.Value = "Demasking Chemically" And DSMKMthCMPL.Value = True Then
Sheet8.Range("h62").Value = DSMKMthCMPL.Caption
End If

If DMSKmtd.Value = "Demasking Chemically" And DSMKMthCMPLnot.Value = True Then
Sheet8.Range("h62").Value = DSMKMthCMPLnot.Caption
End If

If DMSKmtd.Value = "Demasking Chemically" Then
dmskchmframe.Enabled = True
dmskchmframe.Visible = True
Sheet8.Range("d62").Value = dmskchmSOLUTION.Value
Sheet8.Range("F63").Value = dmskProcessing.Value
Sheet8.Range("k63").Value = dmskProcessing.Value
Sheet8.Range("AB91").Value = dmskProcessing.Value
Sheet8.Range("f64").Value = dmskProL.Value
Sheet8.Range("g64").Value = dmskProu.Value
Sheet3.Range("c34").Value = dmskchmSOLUTION.Value
End If

If dmsksolutioncmpl.Value = True Then
Sheet8.Range("h62").Value = dmsksolutioncmpl.Caption
End If

If dmsksolutionnncmpl.Value = True Then
Sheet8.Range("h62").Value = dmsksolutionnncmpl.Caption
End If
```

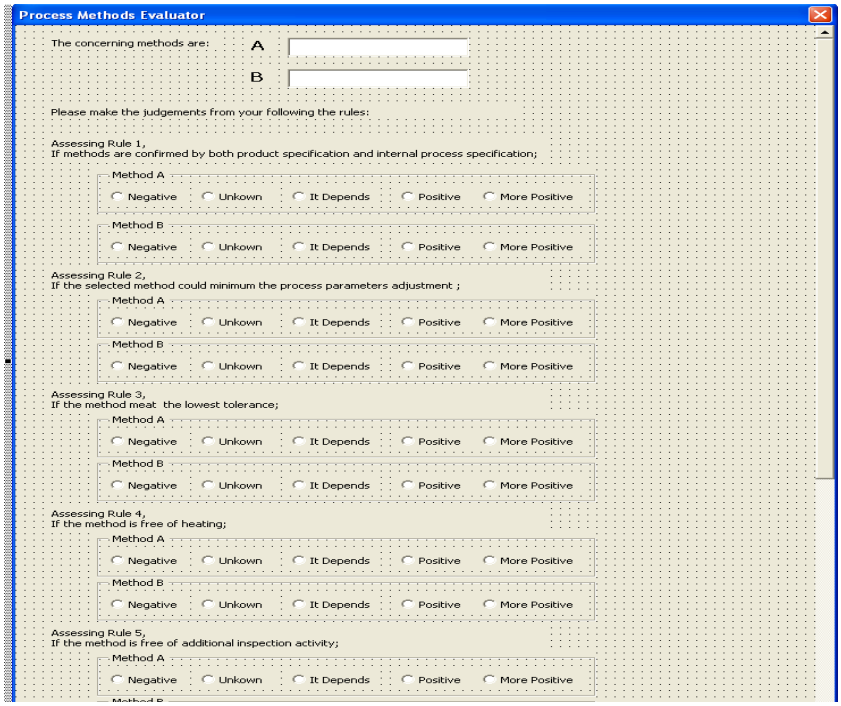
```
If DMSKpslmtcomply.Value = True Then
Sheet8.Range("H63").Value = DMSKpslmtcomply.Caption
Sheet8.Range("K63").Value = dmskProcessing.Value
Sheet8.Range("AB91").Value = dmskProcessing.Value
End If

If DMSKpslmtntcply.Value = True Then
Sheet8.Range("H63").Value = DMSKpslmtntcply.Caption
Sheet8.Range("k63").Value = dmskProcessing.Value
Sheet8.Range("AB91").Value = Sheet8.Range("k63").Value
End If

If DMSKlmttoapp.Value = True Then
Sheet8.Range("H64").Value = DMSKprodpsl.Value
Sheet8.Range("I64").Value = DMSKprodpsu.Value
Sheet8.Range("j61").Value = DMSKlmttoapp.Caption
Sheet8.Range("K63").Value = WorksheetFunction.Average(WorksheetFunction.Max(DMSKprodpsl.Value,
dmskProL.Value), WorksheetFunction.Min(dmskProu.Value, DMSKprodpsu.Value))
Sheet8.Range("AB91").Value = Sheet8.Range("k63").Value
End If

If dmsksolutionnncmpl.Value = True Then
Sheet3.Range("i34").Value = "Solution material is" & dmsksolutionnncmpl.Caption  ' for final report
End If

If DMSKpslmtntcply.Value = True Then
Sheet3.Range("i34").Value = "specifications limits are not complying with"
End If

If DMSKlmttoapp.Value = True Then
Sheet3.Range("i34").Value = "specifications limits are to be approved"
End If

'temperature accuracy of facilities
If DeMskChem_TmpAcur.Value = True Then
Sheet13.Range("F46").Value = DeMskChemTempAcur.Value
End If

If DeMskChemTempAcurComply.Value = True Then
Sheet13.Range("I46").Value = DeMskChemTempAcurComply.Caption
End If

If DeMskChemTempAcurComplyNot.Value = True Then
Sheet13.Range("H46").Value = DeMskChemTempAcurComplyNot.Caption
Sheet13.Range("I46").Value = DeMskChemTempAcur_Req.Value
Sheet13.Range("K46").Value = "NOT COMPLYING WITH"
End If
End Sub

Private Sub etchingstrip_save_Click()
Sheet8.Range("f65") = etchingstriping.Value
Sheet8.Range("k65") = etchingstriping.Value
Sheet8.Range("x90") = etchingstriping.Value
Sheet8.Range("k66") = Intervalsteptime.Value
Sheet8.Range("f66") = Intervalsteptime.Value
Sheet8.Range("x91") = Intervalsteptime.Value
End Sub

Private Sub UserForm_Initialize()
DMSKmtd.AddItem "Demasking Chemically"
DMSKmtd.AddItem "Demasking Manually"
strplabel.Visible = True
strplabel.Enabled = True
strprate.Enabled = True
strprate.Visible = True
dmskchmframe.Visible = True
dmskchmframe.Enabled = True
UserForm6.ScrollTop = 0
End Sub
```

C.7 Userform7 Debug userform




```
' source code input as functions debug
```

C.8 Userform8 Process methods evaluator



```
Private Sub CommandButton2_Click()
UserForm8.Hide ' close Process methods evaluator and back to main page
UserForm1.Hide
UserForm1.Show
Sheet8.Range("v1:v14").Value = "" ' clear rull data
End Sub

Private Sub GetEvaluation_Click()
Sheet8.Range("v1:v14").Value = ""
'v1:v7 stands for marks of method A
'v8:v14 stands for marks of method B
Dim i As Integer, j As Integer, k As Integer
For i = 1 To 70
j = i / 5
k = i Mod 5

If k = 0 Then
k = 5
End If

If UserForm8.Controls("OptionButton" & i).Value = True Then
Sheet8.Range("v" & j).Value = k
End If

Next i

Dim marka As Integer, markb As Integer, eva As Variant
marka = WorksheetFunction.Sum(Sheet8.Range("v1:v7").Value)
markb = WorksheetFunction.Sum(Sheet8.Range("v8:v14").Value)

If marka > markb Then
eva = "Method A" & " " & TextBoxA.Text
Else
eva = "Method B" & " " & TextBoxB.Text
End If

Disply.Caption = "Method A got " & marka & " " & "marks from the evaluation; and Method B got " & markb & "" &
"marks. " & eva & "is recommended."

If marka = markb Then
Disply.Caption = "The methods A and B get same marks from the evaluation. You may select from them as you prefer."
End If

'Sheet8.Range("v1:v14").Value = "" ' clear rull data

End Sub
```