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AN INTELLIGENT APPROACH TO DESIGN THREE-DIMENSIONAL AIRCRAFT SHEET METAL PART MODEL FOR MANUFACTURE

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ABSTRACT

Aircraft sheet metal part manufacturing is a knowledge-intensive process, and the manufacturability and manufacturing information are required to be considered in three-dimensional (3D) model by knowledge reuse. This paper presents a 3D model structure of the aircraft sheet metal part and an intelligent approach to design the model for manufacture combining intelligent manufacturability analysis with manufacturing information definition. Processability of part, formability of material and cost of fabrication are proposed to analyse the manufacturability of the part. Knowledge base for manufacturability analysis is established, and knowledge is reused to evaluate the part's manufacturability intelligently to meet the constraints of manufacturing conditions. Non-geometric information is defined in the 3D model to meet the needs of digital manufacturing and inspection using model-based technology. An example is given to describe the process of design for manufacture, which shows that the approach can realize the concurrent design and digital manufacturing of aircraft sheet metal.

Keywords: design for manufacture, intelligent manufacturability analysis, knowledge reuse.

1 INTRODUCTION

Sheet metal part is an important component of aircraft. Typical aircraft sheet metal parts include frame and rib parts, skins, panels, etc. Aircraft sheet metal parts and their manufacturing technology have such properties as complex structure, complex definition, difficult forming and difficult coordination.

Currently, digital design and manufacturing technology has been widely used in the development of aircraft products. Most of the manufacturing cost is defined during the design stage, and many of the quality characteristics are also fixed when the design stage is accomplished. So the different needs of the whole process should be considered for comprehensive descriptions. Related researches mainly focus on taking manufacturability analysis into design process by DFM(Design for manufacture) and MBD (Model Based Definition) technology.

In order to ensure the part's manufacturability and reduce design changes of sheet metal part, designers should consider the manufacturing requirements in design model. The manufacturability evaluating indexes should be decomposed in different design stages to analyse the part, which will make design and manufacture concurrent. DFM technology is one of the key technologies of concurrent engineering, its purpose is to fully consider the feasibility of downstream manufacturing sectors in the design stage (Ferrera et al. 2009). Li (2008) proposes a method of reading engineering information from the PDM system, interacting the parts classified information through the user interface, at last combining all kinds of information to analyse the manufacturability evaluating indexes for manufacturability analysis. Knowledge utilizing is to solve the manufacturing problem in manufacture engineering chain through using knowledge. In some manufacturing activities, such as process planning (Wang et al. 2007) and manufacturability analysis (Cochranea et al. 2008), knowledge retrieval is performed based on similarity of product or process. However, existing DFM methods mainly emphasis on the manufacturability analysis of the parts which are completely designed, it's not common to integrate DFM technology into the design process.

In order to meet the requirements of digital manufacturing and inspecting, designers should build 3D model for manufacturing. The 3D model should include non-geometric information expressed in traditional drawings, such as dimensions, tolerances and inspection information. MBD technology is based on the definition of the model (Lu et al. 2008 and Alemanni et al. 2011), Zhou et al. (2008) explain the meaning of MBD, propose a definition of digital coordinating products, 3D digital technology design, 3D data organization management and 3D digital process integration applications. Existing research about the MBD method mainly carried out from macroscopic views (Quintana et al. 2010). However, the 3D model of sheet metal part consists of geometric elements, manufacturing requirements, etc. So researching on the model with dimensions and tolerances needs further studied.

This paper proposes an intelligent approach to definite 3D sheet metal part model for manufacture. Three manufacturability evaluating indexes are proposed to evaluate the manufacturability of part based on the manufacturability knowledge base. Geometric information is defined in the guidance of DFM technology to meet the process constraints, non-geometric information is defined in the 3D model based on MBD technology to meet the needs of digital manufacturing and inspecting.

2 3D MODEL FOR MANUFACTURE OF SHEET METAL PART

Typical aircraft sheet metal parts have different structure features. Frame and rib parts consist of web, flange, joggle, lightening hole, etc. Skin and panel parts consist of matrix, gaps, stringers, etc. Figure 1 shows the 3D model of sheet metal part for manufacture, including geometric information and non-geometric information. Geometric information includes the shape of the parts and the dimensions transformation during manufacturing process. Non-geometric information includes annotations and attributes of parts.

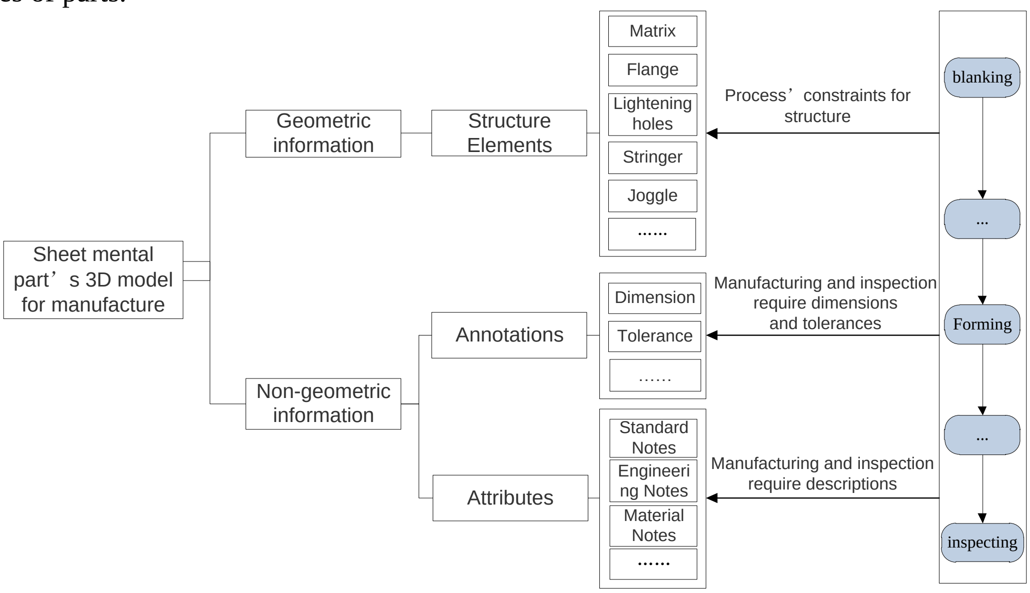

Figure 1: Information structure of the 3D model for manufacture

Annotations are divided into dimensions and tolerances. Dimensions mainly refer to the sizes of structure elements. Tolerances include the accurate information of structure elements and the accurate relative position between different structure elements. Attributes do not display as annotations in the 3D model, they exists as text descriptions of manufacturing and inspection information, which can be obtained by querying in the model. Some manufacturing information such as standard description, part management information, technical requirement, material description, approval or release information is suitable to be expressed as attributes, which contribute to the standard and orderly manufacture.

3 INTELLIGENT DESIGN FOR MANUFACTURE

3.1 Flow of intelligent design for manufacture

Figure 2 shows the intelligent design flow of frame and rib part. Considering the whole design process of part, the structure features are taken as the mainline and defined one by one. Geometrical information is defined within the manufacturing constraints. The constraints are supported by the knowledge base, which is built by process engineers for storing the knowledge including enterprise standard, specification, manual and experience. Moreover, with the support of tolerances and standards knowledge base, dimensions, tolerances, attributes, and other information are defined to meet manufacturing and inspecting needs. Intelligent manufacturability analysis of structure features and manufacturing information definition are combined.

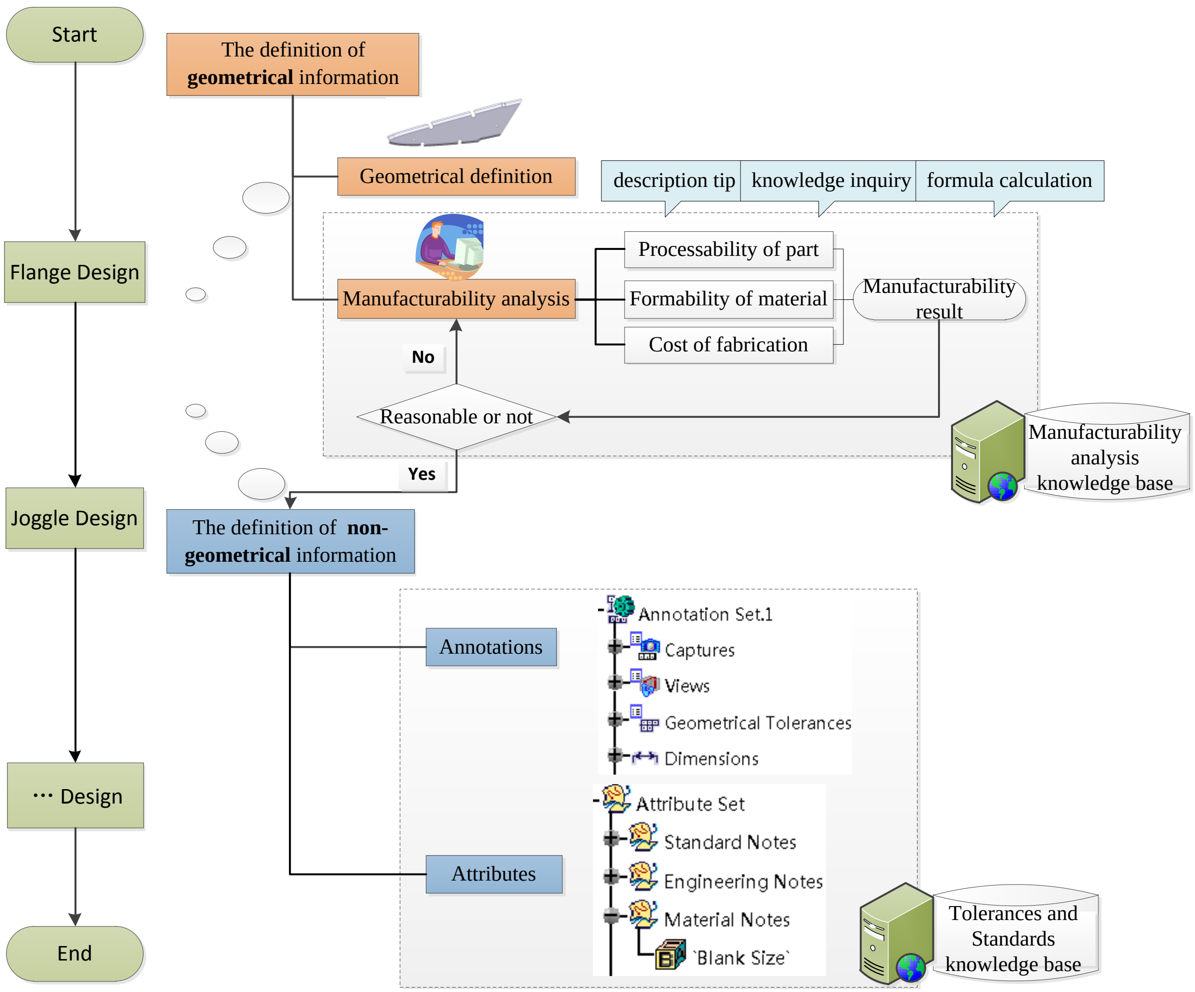

Figure 2: Intelligent design flow of frame and rib part.

During the stage of manufacturability analysis, the structural parameters of the part are acquired firstly, then the manufacturability evaluating indexes are calculated by the support of knowledge base. At last a conclusion is drawn to explain whether the manufacturing is feasible and economic. For the parts whose manufacture process are unreasonable, the manufacturability result is used for the modification of design.

Manufacturability evaluating indexes are established in this paper to evaluate whether the manufacturing process is reasonable. Table 1 shows the three kinds of manufacturability evaluating indexes of sheet metal part. The processability of part means that the dimensions of the sheet metal part should be in the range of the workbench and the forming force should be within the limit of the machine's existing capacity so that the part can be formed on the specified machine. The formability of material means that the forming parameters of structure elements should be within the forming limit of the given material so that the material will not be destroyed in the manufacturing. The cost of fabrication means that the structure elements should meet the standard requirements to reduce the quantity of special tooling so that the cost of fabrication can be controlled in a perfect range.

Table 1: Manufacturability evaluating indexes of sheet metal part.

Content	Parameters as examples
Processability of part	length, width, height of part
Formability of material	limited bending radius, minimum thickness
Cost of fabrication	layout and dimension of structure elements

Manufacturability analysis of sheet metal part relates to many kinds of knowledge such as part features, standards, machine parameters, material forming limits and so on. Knowledge base for manufacturability analysis is established according to the three evaluating indexes. The technology of knowledge reuse is introduced to combine the knowledge base with existing general CAD systems.

3.2 Structure element design for manufacture

The intelligent design approach of 3D model for sheet metal part is divided into two stages, geometric definition and non-geometric definition. During the geometric definition stage, structure features are created through querying the knowledge base, which provides structural standards and sizes requirements. In the geometric model, designers could check the layout between structure features and the sizes which belong to the structure features. It turns to the non-geometric definition stage when the part meets the manufacturing requirements, and designers could define the dimensions and tolerances. Otherwise it will return back to the geometric definition and designers should find the reasons and redefine the geometric information. The intelligent design system of sheet metal part for manufacture is developed based on CATIA CAA. The system could standardize the design flow of part, and make the manufacturability analysis embedded in the design process which realizes part design quickly and concurrently. This intelligent design system consists of structure elements modules. The knowledge base is applied based on Web technology.

Flange design for manufacture is shown in Figure 3. A variety of parameters are evaluated to judge the manufacturability including bending radius, bending angle, flange height. For instance, the value of bending radius should be more than the minimum bending radius. Then bending coefficient is verified to complete the creation of geometric features. At last, dimensions and tolerances are defined to complete the definition of non-geometric information.

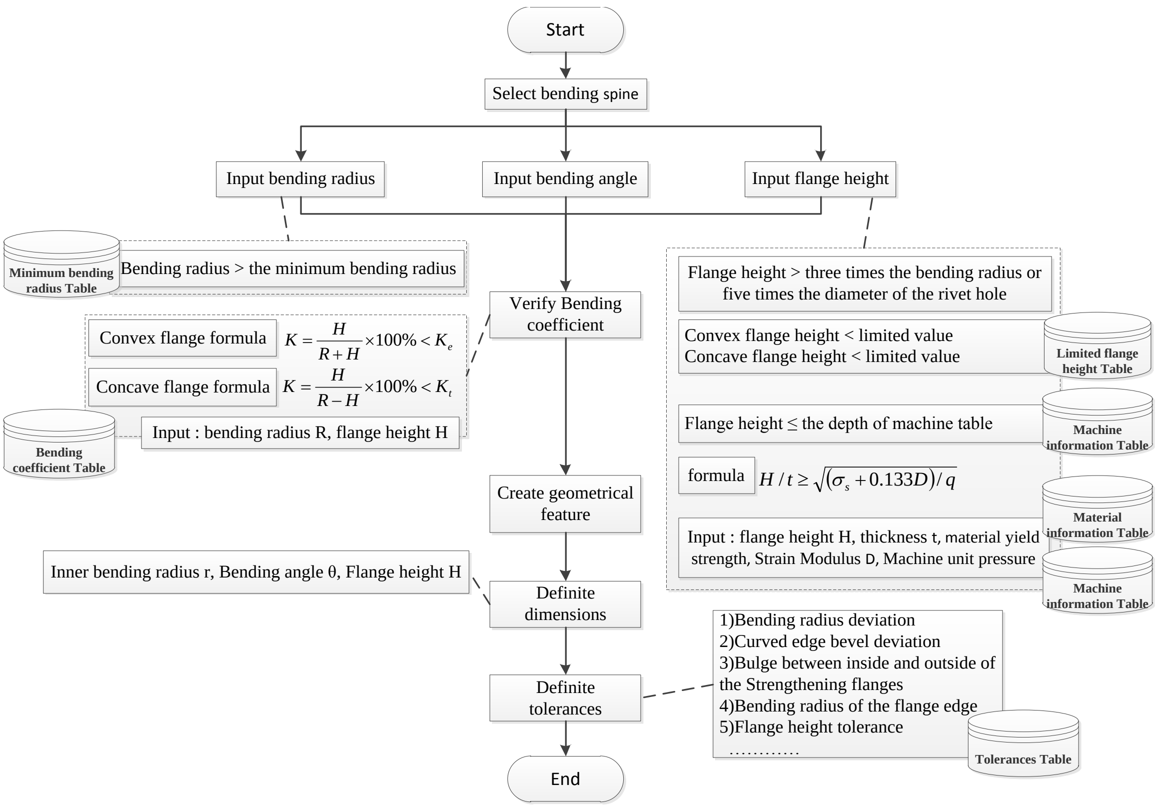

Figure 3: Flange design for manufacture

Figure 4 shows that flange parameters such as bending radius, flange height and bending coefficient are evaluated in the intelligent design system to realize the design for manufacture. As for bending coefficient analysis, designers could click on the 'Calculate' button to get result directly as bending radius and flange height have been automatically extracted in the TXT box. And a web page appears as 'Bending coefficient Table' button is clicked. The page provides the standard bending coefficient value, which could be compared with the calculating result. Similarly, another web page will provide the tolerances requirements when clicking on ' Tolerances Table '.

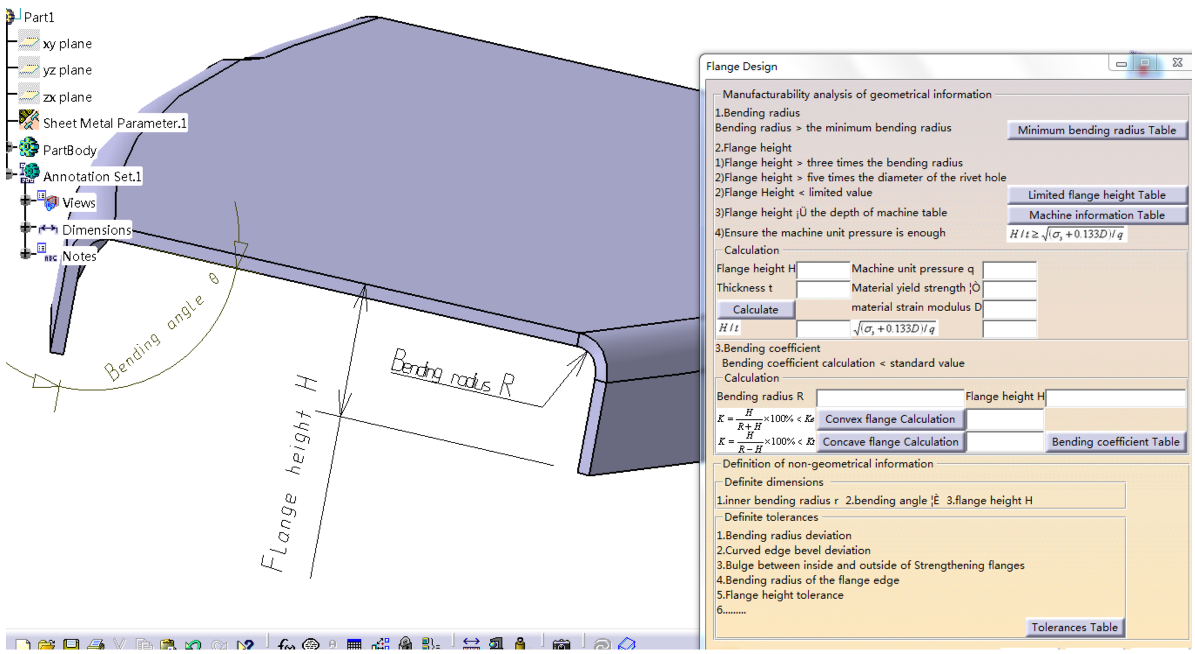

Figure 4: Flange design in the system

4 CONCLUSION

In this study, an intelligent approach is proposed to design 3D aircraft sheet metal part model for manufacture. Advanced technologies such as DFM and MBD are applied to integrate the design process with manufacturing information. This approach can realize the concurrent design and digital manufacturing. An example is used to verify the effectiveness and practicability of the approach. With the achievement of this study, the design of sheet metal part will be more efficient and accurate. Geometric information is created with the constraints of manufacturability and it will reduce the rework of design. Detailed non-geometric information is defined in 3D model to suffice the digital intelligent manufacture of new aircraft products.

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