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Integrated New Product Introduction Challenges in Aerospace Manufacturing Engineering

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Abstract

The key dynamic in supporting an efficient and effective integrated new product introduction process in the aerospace industry is the nature of the exchange of information between the functions of manufacturing engineering and design engineering. This paper describes a study of this dynamic with particular regard to the role the manufacturing function plays in developing a stable and robust manufacturing process for the product design intent. This study reports related work in this area and establishes the views concerning the new product introduction process of participants at a major aerospace manufacturer. It is found that integration between the manufacturing and design function driven by communication of qualitative data has brought benefit to the process in terms of quality cost and time. However, a stronger definition regarding the quality and usability of manufacturing process knowledge communicated to the design function is required for more effective and efficient new product introduction in the shortening timescales of the changing industrial environment.

Keywords:
New Product Introduction, Capability, Manufacturing Engineering, Aerospace Industry

1 INTRODUCTION

The development of highly complex products is traditionally achieved through the collaboration of multidisciplinary specialists throughout the product lifecycle. Understanding customer requirements and delivering product functionality that meets or exceeds them are achievements that bookend the programme of product development activities. Effective and efficient control of these activities provides a company operating in a highly competitive market with a profound advantage in delivering to customers a quality product in a shorter lead time.

New Product Introduction (NPI) is the business process that manages the delivery a cost effective product that meets customer requirements. It consists of the series of interacting decision making activities that bring a product concept to a state where a fully detailed design is defined and information is created that allows the product to be manufactured, assembled and tested [1]. Two key work owners are the Design Engineering and Manufacturing Engineering functions. Their efforts create mutually useful information regarding the product in development. Hence the transfer of information is an arbiter of effective processes in NPI. An integrated model of NPI supports the transfer of information to those activity owners that require it. The competition in the aerospace industry drives the need for New Product Introduction. Manufacturers of gas turbine engines are required to innovate new solutions to satisfy increasing demands from customers and regulators for ever more efficient engines that produce lower emissions, less noise and are sustainable commercial products. Adding to the challenge customer requirements give to product introduction are ever decreasing timescales for NPI activities.

Process efficiency is the capability demanded of NPI in the competitive environment. Efficiency improvements enable the programme of NPI tasks to be fully completed within a reduced timescale, while still satisfying customer requirements. This paper seeks to determine the challenges these industry realities present to the work of Manufacturing Engineering and the role of integration in the NPI process of a leading aerospace manufacturer. The responsibilities of the manufacturing engineering and the span of product introduction activities within the complete lifecycle provide the scope for this research.

The remainder of this paper is structured as follows: Section 2 describes the methodology undertaken in the research; Section 3 outlines the related work in this topic area; Section 4 describes the feedback on industrial practice from this research and Section 5 offers conclusions as to the challenges in new product introduction present in aerospace manufacturing and advocates future work.

2 METHODOLOGY

A series of interviews with key participants in the NPI process with the responsibilities of the manufacturing engineering function at the sponsoring company has been conducted. These interviews were approached in an open manner so as to capture knowledge of participants without presupposition as to the nature of the challenges experienced in the NPI process [2]. The opening question simply enquired as to the 'challenges' the interviewees could identify in the NPI work. By comparing feedback from interviews the gaps between aims of the process and reality and so the challenges in manufacturing engineering in fully achieving those aims would be shown. It was hoped that this manner of research could reveal new areas for more detailed future research.

Participating interviewees from the manufacturing engineering function included Product Introduction Team Leaders, Part Owners, a Manufacturing Technology Lead and a Process Excellence Manager. A Design Functional Coach from the design function was also interviewed to provide a balance of opinions. Interviewees where drawn from two supply chain unit production facilities. One performed precision casting and the other machining work. In this way a broad spectrum of opinion was hoped to be captured from these different processing specialisms with manufacturing.

3 RELATED WORK

The work of product introduction in complex industrial settings is a widely investigated field. A review of literature in this area reveals a broad consensus that advocates a concurrent engineering approach enabled through the collaboration of specialist functions [3]. This paradigm is associated with an efficient and effective product introduction process that achieves the goals of high quality, cost effective products in a compressed lead time. The key enabling dynamic inherent in this paradigm is that of exchange of knowledge and information. The methods of enhancing this ability within complex product development processes remain the focus of much of the related literature.

Concurrent Engineering (CE) has been established over the last two decades as the dominant paradigm for achieving high quality new product introduction in a shorter lead time [4-6].This is the practice of simultaneously executing stages of product introduction traditionally described in a linear manner, typically as follows; product need identification, concept selection and detailed design followed by manufacturing system design, production, service and end of life retirement. The effects of early simultaneous manufacturing engineering activity alongside design, and the level of influence given to manufacturing over design are widely investigated phenomena [7-9]. Collins et al (2002) conclude that when designs are new, high levels of manufacturing influence at early product concept stages have the greatest positive impact on performance [10]. They identify that late influence from manufacturing in fact has a weak negative influence. Principal reasons put forward are more accurate decision making and reduced time to market. Better informed early stage design decision making, benefiting from collaborative involvement of downstream functions avoids the financial and time costs of late engineering changes to resolve problems. Commencing downstream tasks earlier also reduces time to market. The manufacturing function can begin the long lead time work of acquiring process capability and identifying material supply chains in advance of final product design definition releases, thereby enabling more immediate production ramp-up.

Cross-functional integration is the widely advocated strategy for supporting CE [11; 12]. It enables specialist functions to relate relevant information to one another in a timely and constructive manner to complete better quality solutions that meet requirements and are achievable within stable manufacturing capabilities. Integration embodies an approach to overcome the boundaries to communication that exist between specialist functions. Functional specialisation develops in response to the technical complexity of products. While functional specialisation provides the depth of knowledge necessary for robust product development, boundaries between functions identified in cultural, language and technological terms present a challenge to the flow of knowledge and information that is necessary for an effective process. Payne et al (2002) and Bradfield and Gao (2007) emphasised that matrix management orientations are a commonly advocated organisational approach towards enabling collaborative integration within CE [13; 14]. It is an approach towards effective creation of cross functional teams that draw representatives from the specialist functions to collaboratively undertake a product introduction programme [13; 15; 16]. Teamwork is regarded as the means of ensuring full knowledge input from participants and that all requirements and constraints are agreed and understood by team members [17]. Beyond matrix management however, a growing body of literature identifies the role that the informal organisation plays [1; 18]. This is the network of relationships that grows organically in human organisations, crossing, and overcoming formal boundaries.

The principle of integration is the timely exchange of relevant information. It is identified that the products of product development are knowledge and information data [5]. Clark and Fujimoto (1991) propose five dimensions of integration that demonstrate the supportive role of integration on CE [19]. They are; timing of upstream/downstream tasks, richness of information media, frequency of transmission, direction of communication, and timing of upstream/downstream data flows. Two refer to timing of tasks and information exchange (i.e. sequentially). The other dimensions describe the nature of information exchange within integration. Rich exchanges of information are optimal in face-to-face meetings. Immediate dialogue enables short iteration cycles as opposed to bureaucratic document based communication. Physical collocation of teams is widely recommended in this regard [9]. However an increasing amount of work acknowledges the problems collocation presents in organisations that have adopted a global approach to product development to leverage economic opportunities such as cheaper labour [13; 20]. High frequency transmission progressively provides other functions with partial information rather than awaiting singular batch shots at the conclusion of major work packages. In this way upstream and downstream functions are able to simultaneously progress their activities. Clark and Fujimoto’s remaining dimension emphasises the importance of communicating in both upstream and downstream directions. The dimensions demonstrate that the nature of information exchange is just as important as the timing of the exchange. The nature of how information is actually exchanged between functions is key to an efficient and effective concurrent and integrated product introduction process. Design for Manufacture (DfM) is a commonly used method for the formal communication of manufacturing process capability or requirements to the design engineers. A data driven nature of this communication to benefit the product introduction process is emphasised [21]. In this way the design intent derived from customer requirements can be assured through the alignment of production requirements with capability.

A broad consensus regarding the approaches to product introduction in complex industrial settings can be determined from a review of the relevant literature. Communicating knowledge and information between specialist functions is repeatedly cited as vital not only for enabling an efficient, and effective, concurrent process for the industry, but in achieving a cost effective product of high quality that satisfies customer requirements.

4 INDUSTRY PRACTICE

In order to remain competitive in the aerospace industry it is incumbent upon the aerospace manufacturers to constantly seek opportunities for improving the design of their products to meet evolving industry and customer standards. The work of new product introduction is a vital process for achieving new components and complete product systems at the forefront of technical innovation whilst accomplishing stable and predictable manufacturing process capabilities. If components are intended for new products or are modifications to existing products they will be defined as 'new' and will hence such undergo the procedures of new product introduction. Concurrent and integrated work is the standard approach undertaken within the product introduction process. Integrated Project Teams (IPT) are formed in a cross functional manner to manage the development programme administered by a Product Introduction and Lifecycle Management model. At its top level the model describes the archetypal value adding development stages. At a decomposed level, it describes the relationship of respective function's individual (value adding) work packages to the high level project lifecycle and to other functional activities. Functional activity review meetings and formal product development stages scheduled throughout the process are occasions for specialist functions to meet together as IPTs and review product development progress against checklist criteria to ensure problems and risks in a programme are identified and measures put in place to address them. The administration of Product Introduction joins a company wide drive toward ever more controlled, stable, efficient and capable business processes. Its role is to publicise information and 'how to' guides supporting these company goals mandating the work of product introduction to functions including manufacturing and design. Written quality standards embody guides for product introduction practice. Conformance to these standards demonstrates understanding and verification for all design and specification requirements. Manufacturing undertakes a 'right first time' policy. This describes the condition wherein a manufactured component conforms to quality and functional standards without need for time consuming additional iterations of rework. Components that fail in this regard have the potential to adversely affect the goals of the complete product lifecycle.

Manufacturing Engineering responsibilities involve achieving a stable and cost effective production process including defining the assembly scheme, tool design and quality assurance processes ahead of the production ramp-up. This short list belies the complex multitude of activities and interactions that these responsibilities entail. An understanding of these is critical for the successful completion of the responsibilities within the design window. The production of an aerospace component was used as a case study in this research. The component, when completed represents two major stages of production, investment casting and machining, before the processed part can be assembled in the complete product. Defining each of these major processes for the components requires detailed work from manufacturing engineers to align the process with the goals of a controlled, stable, efficient and capable process. The two major stages of machining and casting respectively encompass a wide range of individual actions. The results of the interviews where summarised in through a mind mapping exercise (Figure 1). Here consistent terminology used in the interview responses was identified and grouped into themes. By this effort key topic areas relating to the challenges in the integrated approach to product introduction were synthesised from all the participants. The challenges identified are elaborated as follows:

4.1 The Challenge of Information Exchange

The common theme was information exchange between design and manufacturing, both in terms of quality, and understanding across functional boundaries. At the stage of the lifecycle where new products are beginning to be discussed at the level of component detail, manufacturing engineers can start the progressive work of defining manufacturing process capability for achieving final design intent. This can be commenced from a preliminary state. A capable process is one that delivers high levels of yield in production.

DfM is reported as a valuable dynamic here. DfM can be the forum from the earliest stages of component design for negotiating design parameters to enable a fully optimised product solution. Manufacturing can demonstrate a quantifiable capability can be achieved in a certain tolerance band and request design changes to tolerances to match, thereby reducing risk of low production yield downstream. Improving or acquiring process capability deemed vital to the design intent can also be identified and demonstrated early in the process through this exchange. Accurate, unambiguous data regarding process capability was repeatedly voiced as the vital element in this exchange. Historically danger lies in a manufacturing engineer basing decisions of whether a design feature could be manufactured on qualitative information. The design engineering view advanced in interviews is that accurate, data driven DfM exchanges enable equally accurate design decisions to be made, thereby limiting potential need for redesign iterations late in the process. DfM is the system where accurate exchange of process data is manifested to the benefit of the right first time policy. For manufacturing the benefit lies in the ability to accurately predict production yields, and work this into cost models for the process. The data driven improvement in DfM is beginning to manifest itself in current projects that are approaching production ramp-up. A component currently in development achieved zero defects in a batch produced in an early proving run of a production process. Additionally machining development time on a current project was reported to have been halved from recent historic levels. The principle benefits of information exchange between design and manufacturing that is accurate and data driven are observable in both effectiveness, and efficiency. Better quality components result and wasteful iterations are removed from the process.

Here the key challenge on the part of manufacturing is the accurate capture of processing capability data. It was expressed that while the capture of data is well established in manufacturing, its translation into a useful format remained a challenge. A useful format was suggested as one that aligns with the management of information and data within the design function. Indeed it is suggested that the process of casting presents unique challenges in capturing its capability. Dynamics such as

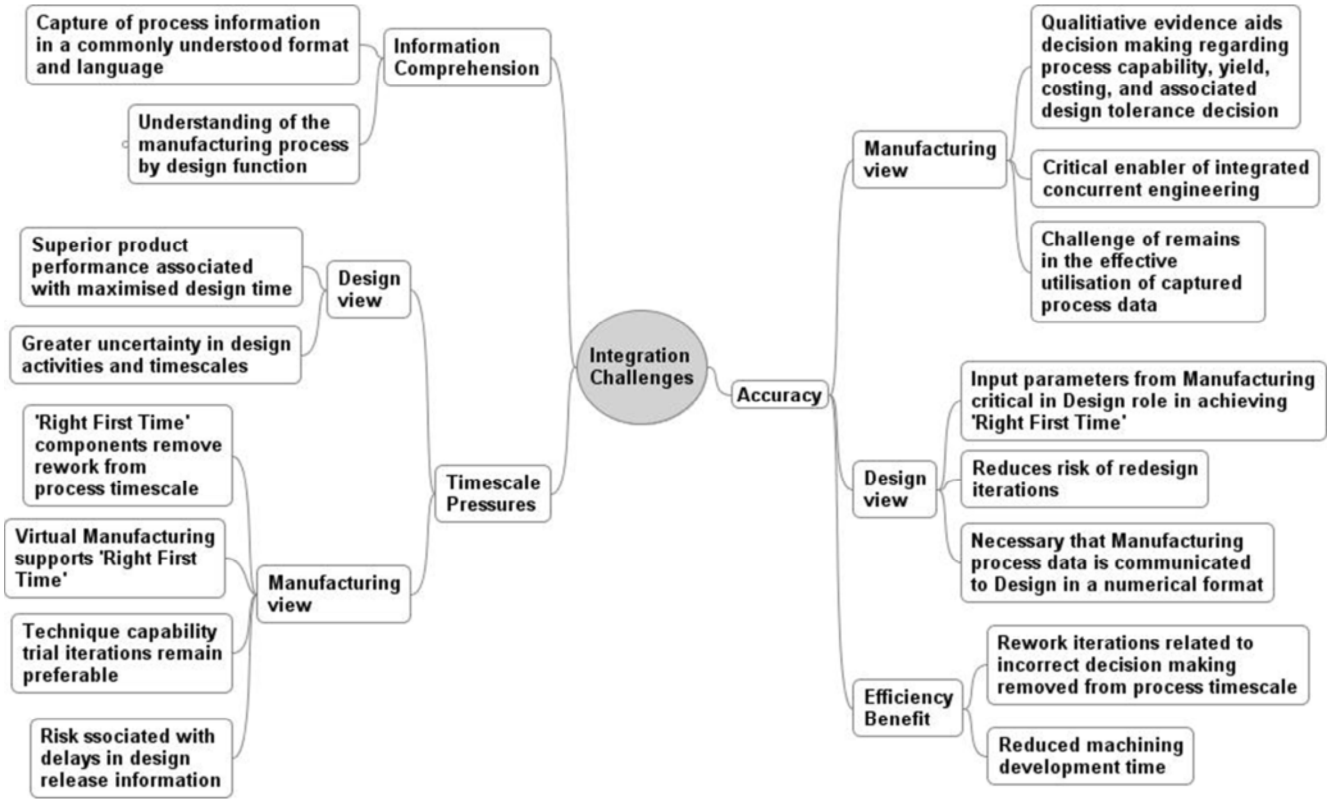

Figure 1: Challenges in the integrated approach to product introduction

material properties of the cast material are more difficult to capture than machined dimensions. Further, a limited understanding of some of the activities of Manufacturing Engineering by Design Engineers is cited as a barrier to efficient interaction between the two.

4.2 The Challenge of Innovation

Advancing functional performance is vital for technological innovation that meets or exceeds customer requirements. Manufacturing capability must also advance to support it with a stable and controlled process. Design tolerances on components are reported to be increasingly sensitive with each innovation on efficiency and weight reduction. Competitors within the industry can be expected to be similarly driven to meet customer requirements. Tightening tolerances present a direct challenge to stable process capability and with that, manufacturing costs. The challenge of this work is added to by the compression of the time available in the project.

4.3 The Challenge of Timescale Compression

Ever decreasing time scales in which to complete the necessary product introduction work of manufacturing engineers is a major challenge driven by competitive factors in the aerospace industry. Key Manufacturing Engineering activities such as acquisition of physical process capability often have long and constraining lead times. Virtual techniques have been successfully developed to direct the definition of the manufacturing process to a more optimum level before any metal is cut on expensive tooling. For instance, in the casting process these techniques have been reported to have helped achieve production yields in new components at levels usually expected in mature production process. However limits to virtual manufacturing techniques are cautioned.

Not all physical aspects of the process can be predicted virtually. Hence it remains important to maintain physical trials and iterations of casting techniques to achieve a stable process. However an increasing pressure to immediate produce component parts for complete engine development limits this opportunity. As such the attainment of ‘right first time’ can be undermined and parts continue through the lifecycle at risk of future rework process iterations becoming necessary.

An attempt was made to identify whether the compression of timescales was equally distributed across the two functions of manufacturing and design. On one hand it was advised that the demands of individual projects and programmes are often too unique to provide such a generalisation. However, a common view expressed by manufacturing participants was that it was their work that often suffered due to late releases in design information. A design engineering view suggests that maximising the time available to design benefits a product that better matches customer requirements, which may add weight to the view that it is within manufacturing activities that timescale compressions may be felt most acutely.

5 CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

This paper presents new product introduction challenges with particular focus on integration of the manufacturing function in the process. The research results support the view expressed in literature concerning the benefit integration of design and manufacturing functions has on the quality of the product being developed, and the effectiveness and efficiency of the product introduction process. The benefit derived from the recommended practices of rich and high quality exchanges of information are borne out in the aerospace company studied.

The responsibilities of the manufacturing engineering function can be seen to be supported by integration. Developing robust and stable production process, sustainable supply chains and accurate cost models benefits from the knowledge gained about the product in question from Design Engineers tasked to define it.

However, there is an indication that more needs to be done to clarify and define the extent of knowledge about manufacturing process that is necessary to improve design and the product introduction. It is identified that: (1) a definition of the manufacturing process knowledge required by the design function is necessary regarding the usability, clarity and quality of process data; (2) this definition must capture an understanding of the variety of processes used; (3) the definition must recognise the complexity of process specialisation within the manufacturing engineering function; and (4) innovative design requirements must be aligned with an evolving manufacturing process capability in this definition.

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