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Integrated digital design for manufacture for reduced life cycle cost

R. Curran[a,*], G. Gomis[a], S. Castagne[a], J. Butterfield[a], T. Edgar[b], C. Higgins[b], C. McKeever[c]

[a]*Centre of Excellence for Integrated Aircraft Technologies (CEIAT), School of Mechanical and Aerospace Engineering, Ashby Building, Queens University Belfast, Stranmillis Road, Belfast BT9 5AH, UK*
[b]*Northern Ireland Technology Centre, Queens University Belfast, Stranmillis Road, Belfast BT9 5AH, UK*
[c]*Bombardier Aerospace Belfast, Airport Road, Belfast, UK*

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Abstract

The main contribution of the work has been to present a methodology that facilitates the integration of design and manufacturing modelling at the concept design stage, including cost. In particular, the methodology allows the user to more readily exploit the digital manufacturing simulation capabilities offered through state-of-the-art software applications. The methodology is flexible and user driven, and advocates: (1) the definition of baseline design parameters in a configuration that is driven by direct operating cost (DOC), including manufacturing cost (MFC), (2) the automated generation of a digital design mock-up, and (3) detailed digital manufacturing simulation for in-depth investigation of cost-effective manufacturability. This has been coded into an industry standard modelling platform along with an interface to allow user manipulation, while iteration of the process is advocated in optimising the solution. The paper presents the collaborative application of this to the fuselage of a commercial regional jet. It is shown that a knowledge = -based engineering (KBE) approach can be encoded as a methodology for exploiting 3-D design modelling and manufacturing simulation capabilities. In addition, a novel aspect is the integration of cost into the development tool in order to generate cost-effective solutions, in terms of both MFCs and DOC.

Keywords: Digital manufacture; Cost modelling; DFM; Design integration; Cost optimisation

1. Introduction

Today's aerospace drivers are schedule, economics and performance; along with a number of additional aspects that enhance product quality and competitive advantage, including safety and environmental considerations (ACARE, 2003; AeIGT, 2003). These drivers need to be addressed in the context of a global and collaborative enterprise, not by disparate processes and tools that deliver a bespoke solution to an isolated problem but through a more radical holistic methodology enabled through integrated product life-cycle management (PLM). The work presented in this paper addresses the concurrent design integration of economic and performance aspects.

From an industrial point of view, design and manufacture lie at the very core of product

*Corresponding author. Tel.: +44 28 90 974190/335; fax: +44 28 90 382701.
E-mail address: t.curran@qub.ac.uk (R. Curran).

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realisation and, along with environmental characteristics, are the causal drivers for many characteristics and attributes that later define a product, including performance, cost and emergent behaviour (Pugh, 1992; Milhelm et al., 1993; Roy et al., 1999, 2002; Curran et al., 2005b). The design for manufacture (DFM) principle embodies the concurrent engineering philosophy through advocating the consideration of the downstream impact of decisions being made, in order to inform decision making at the time when the financial commitment and effort is being made (Curran et al., 2002). Consequently, we may propose that the underlying methodology proposed for integrated digital manufacturing should include the management of product, process and resource (PPR) data, a core theme of most PLM solutions. The optimisation of manufacturing processes in a virtual environment and the integration of that information into the design environment are two crucial factors. The authors believe that a complete digital design and manufacture modelling platform presents an integrating cost framework for all aspects of manufacture (materials, treatments, part fabrication, assembly, quality, tooling, and industrial engineering). Moreover, the DFM linkage can be seamless as design precisely defines the input data then required of the digital manufacturing process. Similarly, downstream life cycle phases such as test and certification, maintenance and operation, and disposal can be integrated into the conceptual design process (Mileham et al., 1993). In terms of the life cycle of the product, cost and economic impact are key industrial drivers and have been the focus of many challenging investigations (Arrow and Arrow, 1950; Levenson and Barro, 1966; Roy et al, 1999, 2002; Curran et al., 2005a).

This paper considers the development of a digital design and manufacturing modelling platform with integrated cost modelling capabilities, providing a truly collaborative methodology and concurrent engineering tool for aircraft life cycle cost reduction (Curran et al., 2006b). The application considered demonstrates the design of an aircraft fuselage panel, as part of research work that is being carried out in collaboration with Bombardier Aerospace Belfast. Consequently, the paper first considers the generation of an early conceptual design solution (Pugh, 1992) that is optimised for structural performance, manufacture and operational costs, where the geometry is generated automatically in a typical 3-D environment, thereby compressing much of the development cycle in a virtual engineering solution. The manufacturability is then simulated and investigated in more detail in order to fully optimise the assembly procedure, to ensure competitiveness and maximum profit levels for the producer. Although further iterations are not presented it is recommended that the results of the process should then be fed back into the design process to provide further DFM iterations and improvements through modifications that optimise detailed manufacturability issues.

2. Literature review

There are many research groups who are currently looking at developing a more integrated approach to design and digital manufacturing (Freedman, 1999; Olds, 1997; Singh, 2002). This is partly being driven by the fact that all major aerospace producers are now using digital design and manufacturing tools. According to a Dassault Systèmes press conference (Dassault, 2002) "DELMIA—the leading digital manufacturing tool from Dassault System—was selected to join the team developing the new A380, Airbus' 21st century super jumbo aircraft, for the final assembly processes in Airbus' new manufacturing facility in Hamburg, Germany". As well as Boeing (Boeing, 2005), Bombardier and Lockheed Martin, etc other industries are also taking an interest, such as MicroTurbo, Hitachi Zosen and Volkswagen who are all using the Dassault Platform as a PLM Solution.

Although digital design mock-up is now well established, championed for example by Dassault Aviation on their Falcon aircraft programme, digital manufacture is still an emerging software technology that has become a key component of product lifecycle management or PLM. A key component of this is the management and interrelation of product, process and resource data. For example, product information is defined within an engineering bill of material (E-BOM) each element of which is explicitly linked to the geometric solid model that constitutes part of the digital mock-up. The E-BOM is then used to generate the manufacturing bill of material (M-BOM) which is organised according to the work breakdown structure (WBS) which is defined by the production stages required to make the product. The resources required can then be associated with the production stages which means all of this information is held in an