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Supporting Multiple Views in Design for Manufacture

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Abstract

While concurrent engineering has become an accepted philosophy, its implementation leads to a need for radically different software support tools than those that are currently in the marketplace. This paper discusses the requirements for such tools, with emphasis on providing support in design for manufacture. The paper highlights recent progress in providing data driven design for manufacture support for injection moulded products based on the use of both Product and Manufacturing Models. This concept is then used to explore ideas which have the potential to provide design support where multiple manufacturing processes impinge on design decisions. The use of product range models, multiple view representations of product data and data interpretation mechanisms to release manufacturing information are discussed.

Keywords

Design for manufacture, product models, manufacturing models, information sharing.

1 INTRODUCTION

Providing designers with high quality information on which to base decisions is central to achieving good results. Although people are generally good at innovation in design and in the evolution of new design ideas they are not good at managing and remembering the many complex pieces of information which impinge on design decisions. The ideas presented in this

M. Mäntylä et al. (eds.), *Knowledge Intensive CAD*

paper have their emphasis in the provision of information support. This is believed to be a critical area of research if future Computer Aided Engineering systems are to provide an adequate support for design in a concurrent engineering environment.

While a range of work has addressed design for manufacture for single processes, this paper discusses research into software tools which can support design for manufacture where a number of manufacturing processes impinge on the design. The focus for the paper is the design of high volume customised products with particular emphasis in the area of net shaped products such as injection moulded products. Existing commercial tools which are offered in this area are typically based on post design analysis of finite element models. These are inappropriate for concurrent, multi-process, design for manufacture. Other research related to design for manufacture for injection moulding (Hanada, 1989) highlights the potential of multi-process design for manufacture in this application area.

Recent research in collaborative CAD environments for architectural design has identified the need for several models of a design object to support multi-disciplinary design (Rosenman & Gero, 1996). Other work from the same laboratory (Saad & Maher, 1996) has highlighted the need for a shared underlying representation which can support collaborative design. While their work focuses on multi-user environments, this paper argues a similar need for shared data representations to support design for multi-process manufacture.

It is argued that future design for manufacture support systems will comprise the following parts which require further investigation and research:

(a) Manufacturing information representations.

(b) Product data representations for multiple manufacturing viewpoints.

(c) Interpretation mechanisms between these viewpoints.

(d) Local strategists to act on the range of product and manufacturing information.

(e) Interaction mechanisms between design for function and design for manufacture which is some cases can be supported by Product Range Models.

2 INFORMATION MODELS TO SUPPORT DESIGN FOR MANUFACTURE

An important aspect of the approach described here is that it utilises the product model concept as a basis for data integration and data sharing. The paper builds on earlier work on information sharing in design and manufacture (Ellis et al, 1995) which explored the MOSES concept illustrated in figure 1. This work on Model Oriented Simultaneous Engineering Systems (MOSES) showed that two information models, one capturing product data and one capturing manufacturing process data, can be used to support product life cycle decision making. The approach taken is based on the use of object oriented databases providing supporting information to appropriate design support tools.

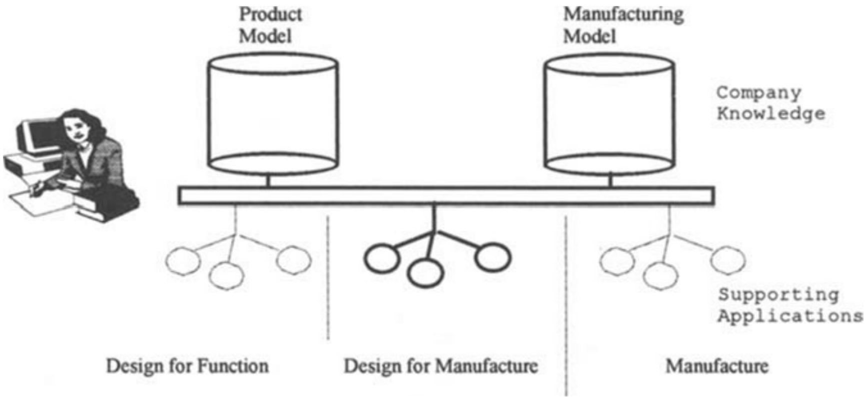


Figure 1 The MOSES Concept.

Progress is being made in understanding how product data can and should be represented to provide interchange standards between computer aided design systems through the work of STEP. Further, such product models have been shown to provide a successful route to the integration of a range of design and manufacturing software (Corrigall et al, 1992). Whilst the modelling of such product information is fundamental to the provision of information support for design, there is the need for a second model which can provide a representation of manufacturing capability and resource information. This is termed a Manufacturing Model and provides a source of manufacturing knowledge to support design and manufacturing decision making (Al-Ashaab 1994, Molina 1995).

The combined use of product and manufacturing models has the potential to provide the necessary information to support the full range of applications in product design and manufacture. This approach provides a highly flexible and extendible method of constructing CAE systems, enabling companies to capture their information assets within the data models and link these to the most appropriate third party software solutions available at any point in time.

3 A DESIGN FOR MANUFACTURE APPLICATION ENVIRONMENT

In an information supported system all software applications must rely on the information models as their source of information and as their output repository for information which may be used by designers or other applications. Once a Manufacturing Model has been defined a key requirement for any software support application is to be able to provide information inputs in a suitable form to access and use each type of information in the Manufacturing Model. Applications should also support the concurrent engineering philosophy and therefore must be active as early as possible in the product life cycle.

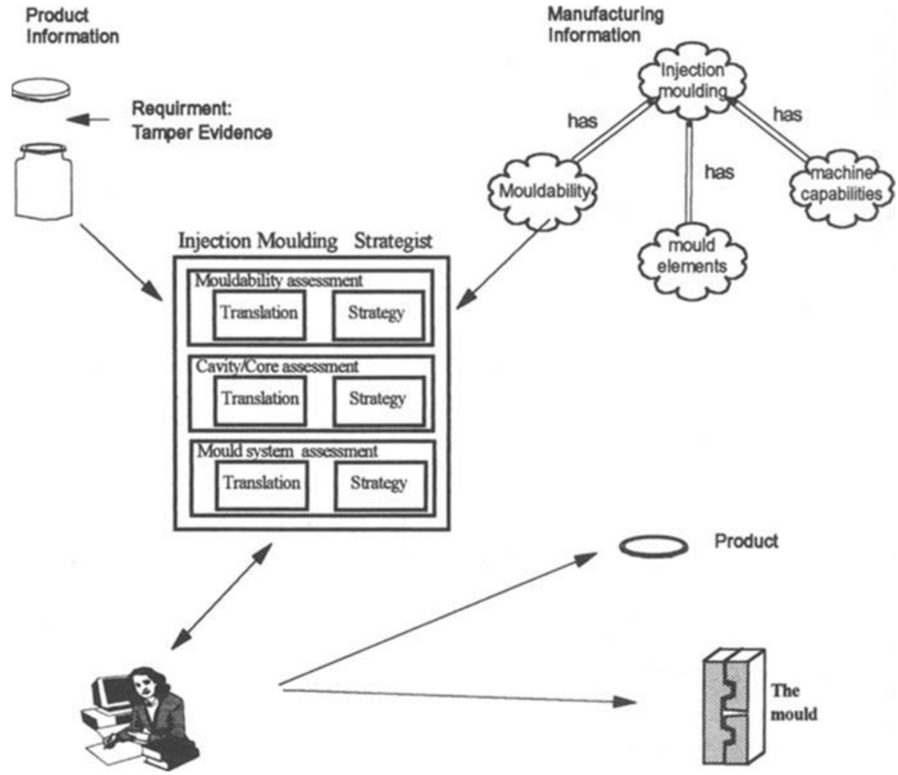


Figure 2 The PT-Plus Case Study.

Our work on injection moulding has shown that a design for manufacture software support system, termed an injection moulding strategist, can provide design support by utilising information held in both a product model and a manufacturing model (Al-Ashaab 1994, Lee, 1996). A particular product case study, called PT-Plus, which is a tamper evident ring used in food packaging, has been used in exploring the research ideas, as shown in figure 2, and is used here to take these ideas further.

Knowledge about the injection moulding process has been stored in a manufacturing model and the requirements for the product have been captured in a product model as have alternative possible ways of meeting these requirements. An injection moulding strategist has been configured to provide the product designer with support to design both the product and the mould concurrently. Taking this approach it has been possible to provide advice to designers both on the design for manufacture of a product and the design of the mould needed to manufacture the product.

The strategist has been found to perform three key roles as illustrated in figure 2:

(a) to provide a structure against which concurrent interactions can take place;

(b) to capture the manufacturing strategy to be applied at each stage of the design for manufacture process;

(c) to provide the translation mechanisms which enables the product design data to be converted into the forms needed by the various classes of information contained in the manufacturing model.

4 DESIGN FOR FUNCTION AND DESIGN FOR MANUFACTURE INTERACTIONS.

The structure of the injection moulding strategist allows design for manufacture support to take place effectively. However, there is also a need to link to the functional requirements of the product if there is to be any concurrent interaction between design for function and design for manufacture. This leads into a critical problem of how to provide an environment which can allow designers to work with the functional needs of a product while still offering back advice on manufacture. This is recognised in the features community as a major problem requiring novel solutions (Allada and Anand, 1995).

It is possible, in high volume customised products, like the PT-Plus example, that the use of functional features, supported by a database containing knowledge of ranges of products, can be used as a mechanism to overcome the restrictions of traditional feature based design. This database, termed a Product Range Model, will enable designers to build product designs based on the functional needs of the product. This means that the designer has the flexibility of working within the general needs of the product functionality rather than being constrained to consider directly the manufacturing requirements of the product, as is typically the case in design by feature approaches.

A Product Range Model captures each of the functions which a product in a family can fulfil, along with the alternative ways in which each function can be achieved. The designer of a new product in the range is free to select from these alternatives. Product Range Models can be used to capture the functionality of products which are individual component products or of more complex product types. A simple illustration of a product range model database showing PT-Plus functions, linked to forms, which are in turn linked to mouldability features is shown in figure 3. This has been shown to be an effective means of linking between design for function and design for manufacture for this type of product.

Issues still to be addressed in constructing Product Range Models are:

(a) Can functional features within a product range be linked to multiple manufacturing processes in design for manufacture?

(b) Is there a limit to the complexity of functional interaction within a product range which invalidates the links to manufacturing which can been made?

(c) To what extent can sets of functional features, linked to existing product ranges, be extended to support new product ranges?

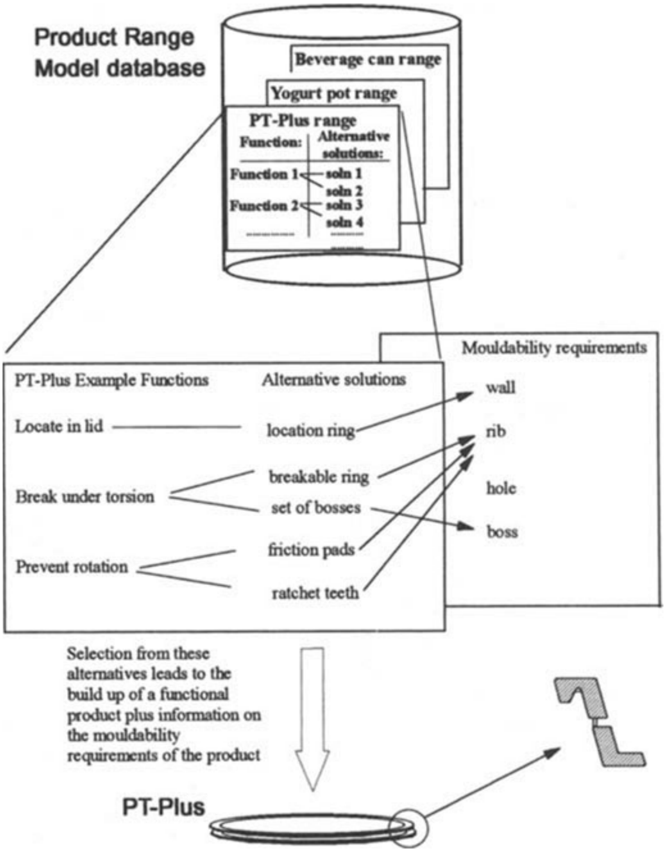
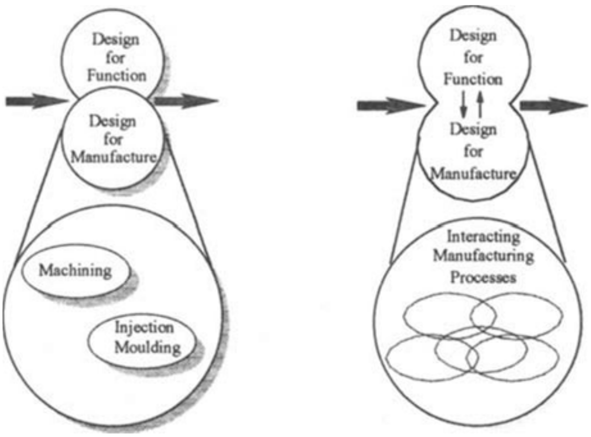


Figure 3 Linking Functional Design to Design for Manufacture through Product Range Models

5 INFORMATION SHARING IN DESIGN FOR MULTI-PROCESS MANUFACTURE

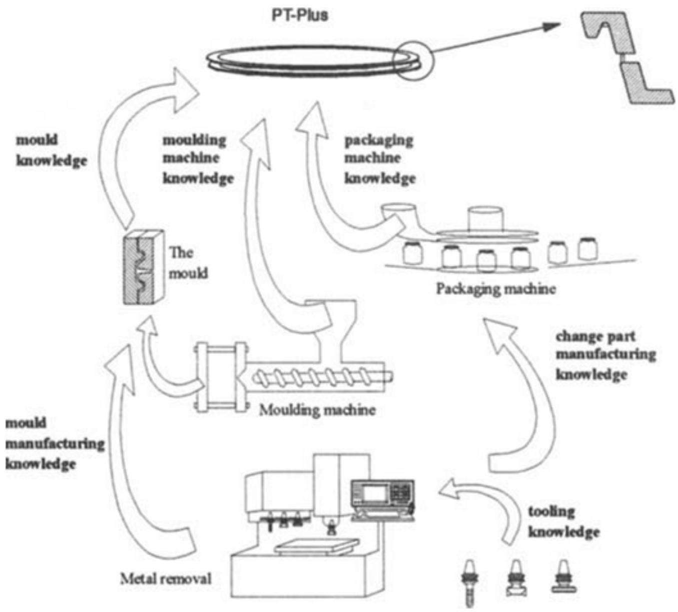
The majority of design for manufacture research to date has focused on a single manufacturing process e.g. design for assembly, design for machining, or design for injection moulding. When we consider real design problems there are many manufacturing processes involved and each must be able to offer its knowledge input to support design decisions. The distinction between design for manufacture for single processes and for multiple processes is drawn in figure 4.



(a) Design using a single manufacturing process

(b) Design using multiple, interacting, manufacturing processes

Figure 4 Single and multi-process design for manufacture



The majority of products require multiple processes in their manufacture and each can influence the design of the product. Systems must therefore be able to provide support which meets this need. If we again consider the PT-Plus example, its design, as shown in figure 5, is influenced by the mould, the injection moulding machine to be used, the packaging machine through which the component is fed as well as the mould manufacturing processes of machining, EDM, grinding, etc. The influences of each must be known and fed back to the designer when significant.

The value of the manufacturing model concept is that it provides the means by which the capability of each of these processes can be captured independently. It is up to the design for manufacture support applications to be able to access the information in such a model in order to identify any significant information which should be fed back to the design team.

While the capability of each process can be captured in a manufacturing model, the more critical problem is to provide a data input to the manufacturing model, in the appropriate form for each manufacturing process. There is therefore a need to provide a view of product data in a suitable form for each process. It is proposed that this can be provided from a product model if it can capture the different facets of product data needed for each manufacturing process's viewpoint, as illustrated in figure 6. In addition, there is then a further need for a translation process which can maintain the different faceted views of the product data as it is manipulated by the various design for manufacture applications.

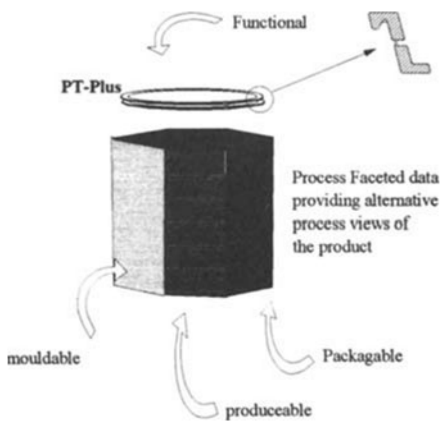


Figure 6 Process Faceted Data for the PT-Plus Example

An overall view of the elements of a data driven design for multi-process manufacture environment is shown in figure 7, highlighting the need for a product range model, process faceted data, and a faceted data generator , or data translator, in addition to the multiple levels of expertise needed to support each manufacturing process.

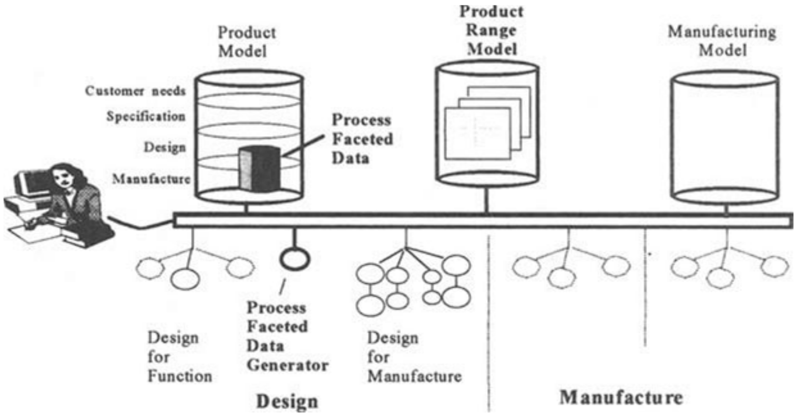


Figure 7 Design for Multi-process Manufacture

6 DISCUSSION

This paper has discussed the need for radically different design support tools to support knowledge intensive engineering activities. It has highlighted the importance of providing information support to design teams and the role which both product and manufacturing models can offer in doing this. The need for further research into such models is needed as is the critical need to understand how application environments can utilise the information contained in these model to better support designers. This raises issues both in terms of the structure of such environments and the information translation techniques which are needed.

The use of a Product Range Model to provide support in the interactions between design for function and design for manufacture has been highlighted as has its potential to provide a more effective design support tool in feature based design systems. A potential route to providing design for multi-process manufacture support, utilising these concepts, has been indicated and research is currently being pursued by the author to investigate these ideas further.

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BIOGRAPHY

Bob is currently a lecturer in the Department of Manufacturing Engineering at Loughborough University of Technology. His research interests are in integrated design and manufacture, and software support for concurrent engineering. Prior to joining Loughborough in 1985 he worked for some 10 years in industry, being mainly concerned with the design and development of new products and processes. Bob's recent research publications have addressed issues in product modelling, features technology, process planning, design for manufacture and modelling manufacturing information.