Manufacturing information interactions in data model driven design

R I M Young*, O Canciglieri Jr and **C A Costa**
Department of Manufacturing Engineering, Loughborough University, Loughborough, UK

Abstract: This paper presents a novel view of a software environment that has the potential to provide manufacturing information support to product design in line with the aims of concurrent engineering. The arguments developed should have significant consequences for future computer aided engineering (CAE) systems development and support the continuing globalization in business development. The approach taken has at the centre of its philosophy the need to provide designers with high-quality information on which to base their decisions. The concept of an information supported product design environment is not new, but a range of issues related to information interactions has yet to be resolved. This paper explores the use of information models to support functional and manufacturing interactions in design as well as the issues that are raised in attempting to support multiple views in design for manufacture. The design of injection moulded products is used as the focus against which the ideas in the paper are explored.

Keywords: information models, product range models, multi-viewpoint, design for manufacture

1 INTRODUCTION

Concurrent engineering is recognized as a major driver for business competitiveness. It is important that computer aids for product development should reflect and support the need for the multiplicity of inputs to the design process. This paper argues strongly in favour of information support systems in design and manufacture. These can offer flexibility, data integrity, support throughout the product life cycle, as well as being of modular construction and independent of specific vendors [**1**]. This is achieved by separating the information content from the software applications that use and generate the information, hence making any specific application easy to replace as long as the underlying information model is maintained. Such software applications have been termed data model driven applications.

The development of information supported systems can be viewed as having three key aspects to be addressed, these being the structure of the information, the management of the information and the functionality of the applications programs that use the information. Although these three areas cannot be completely separated, this paper is principally concerned with the first of these, termed information modelling.

If information models are to be effective in future computer aided engineering (CAE) systems to support product design, two of the key issues to be resolved are:

1. How to deal with multiple manufacturing views of products?
2. How to provide information structures that can support interactions between functional design and design for manufacture?

2 MULTIPLE VIEWS OF INFORMATION

The information model requirements to support manufacturing information interactions in product design are illustrated in Fig. 1. Product models provide the core information in data model driven systems [**2**, **3**], and it is becoming accepted that manufacturing models can be used to provide information concerning manufacturing capability [**4**]. In combination, these models provide the key sources of information to support design for manufacture applications. However, a critical issue that has not been resolved satisfactorily is how to link from a functional view of design to a manufacturing view of design [**5**]. A wide range of research has been pursued

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**Corresponding author: Department of Manufacturing Engineering, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK.*

in feature recognition and design by features in attempts to make this link [6]. However, design by features overconstrains the designer from a functional point of view while feature recognition provides the designer with no manufacturing focus. Work has investigated functional features in injection moulding but has not successfully linked this to manufacture [7]. The use of a product range model has the potential to overcome this problem and is applicable in variant design where there are common functional features with known options as to how each can be realized. Recent work has investigated architectures for product families [8].

Typically, design for manufacture software applications have been pursued from a single manufacturing viewpoint, e.g. design for machining or design for assembly. Each view taken requires its own structure of product information, which has largely been researched in the area of features technology. However, design for manufacture is typically not related to a single manufacturing process and software systems must be able to provide multi-process support. This need for multiple views of a product has been one of the critical drawbacks with traditional feature-based approaches. Figure 2 illustrates an example of an injection-moulded product where three views are considered: the design of a plastic consumer product, the design of the mould to make the plastic product and the manufacture of the mould. Each of these views needs to be addressed before the product can be manufactured successfully.

Data model driven systems have the potential to provide multi-process design for manufacture support. Manufacturing information on each specific manufacturing process can be stored in the manufacturing model. There is therefore the need for mechanisms to translate product information into a form that will enable the appropriate manufacturing information to be drawn from the manufacturing model. This can be achieved by utilizing product model structures that are supported by appropriate translation mechanisms. These translation mechanisms hold knowledge about the relationships between each significant pair of views, or domains, and therefore can act as a means of translating the information from within one domain into the appropriate form needed in another domain. Examples of domains related to the injection moulding are mouldability, the design of the mould, e.g. the cavity design, and the manufacture of the mould including machining, grinding, electric discharge machining (EDM) and assembly.

3 DATA INTERACTIONS IN INJECTION MOULDING DESIGN

3.1 The product range model

The aim of the product range model is to provide a support to design decision making. Design decisions in injection moulding can be categorized into two main areas, the first of these being the initial selection of the

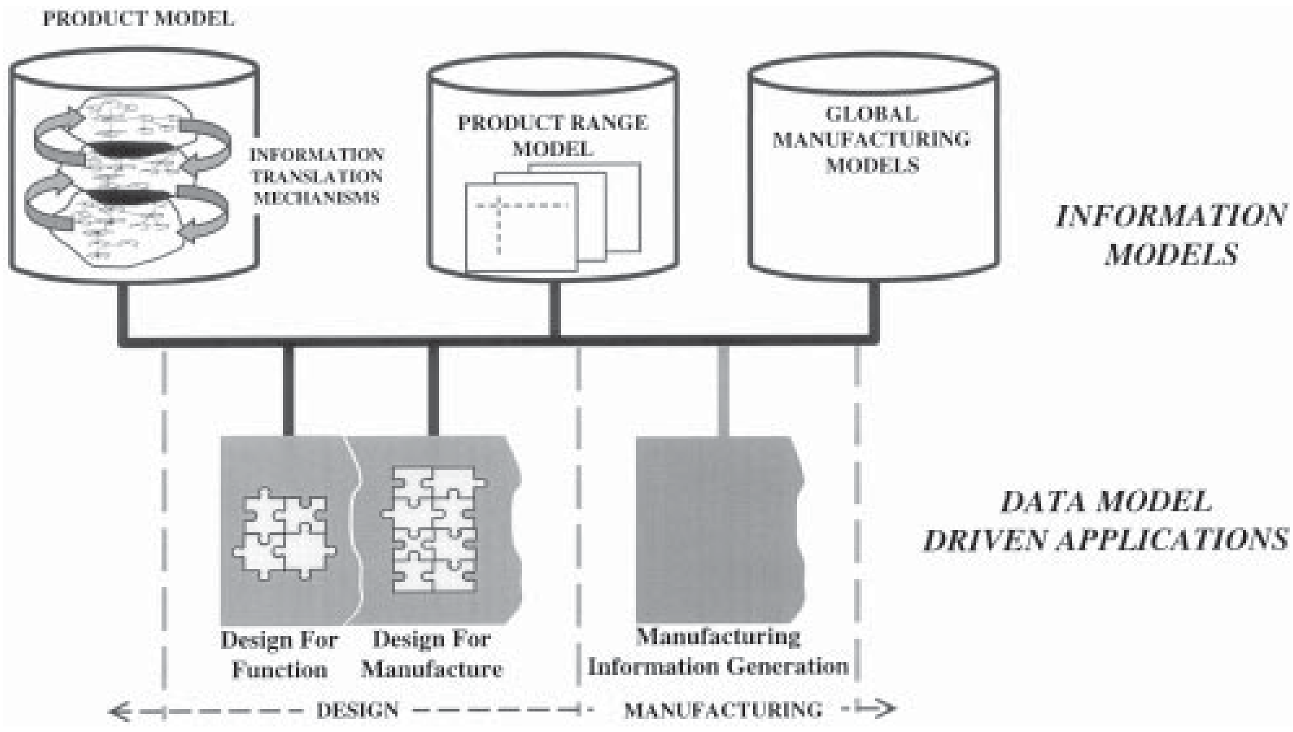

Fig. 1 Information models to support design for manufacture

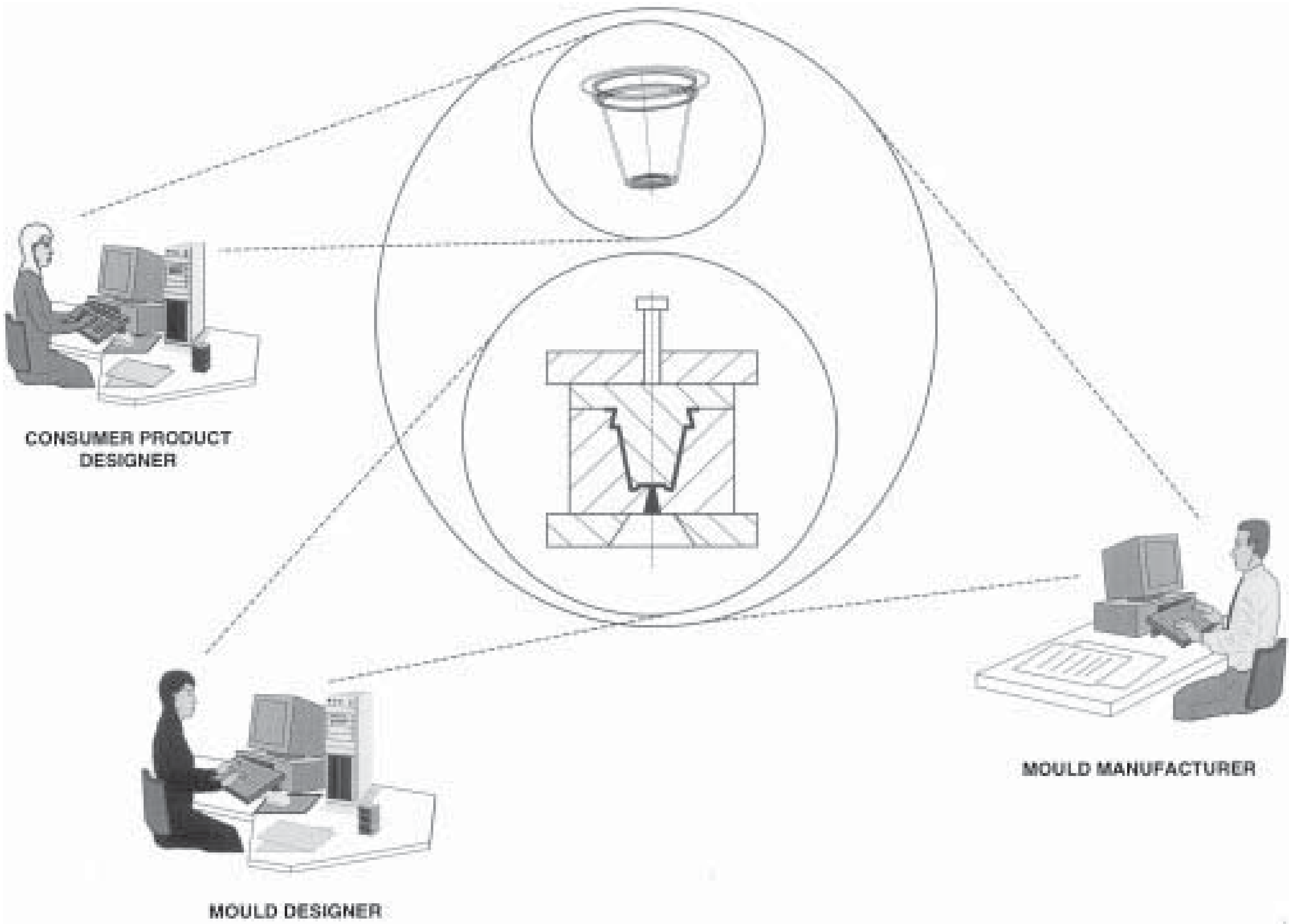

Fig. 2 An example of multiple views of a product

type of mould, e.g. two plate, three plate or runnerless, and the layout to use. The second area is in considering the systems to be used in cooling, feeding, venting and ejecting the mould. A range of alternative solutions can be defined to offer direct support to these functional needs of the design.

The product range model for injection moulding defines the relationships between moulding functions and their potential design solutions. The functions and subfunctions in the model allow the designer to search these potential design solutions. However, the suitability of each specific solution is influenced by decisions already made. For example, while the product range model should support all possible solutions, the choice of a particular cavity layout will restrict the range of valid options subsequently available. Similarly, the decision to use ejection pins through the core will limit the ease of cooling in the core.

This research has used the BOOCH object-oriented methodology to define information structures. The main structure of a product range model for injection moulding is shown in Fig. 3. The association of attributes and constraints with each design solution provides part of the solution to the narrowing of valid options as decisions are made. The relationship between this model, the product model and the manufacturing model is also being explored in order to provide improved support to design decision making.

3.2 Information structures and translation mechanisms

While the product range model can provide general design solutions for each design function, particular solutions need to be defined for each design case and multiple design for manufacture views need to be supported. Each view has its own, related, information which supports the decision-making process. Data structures can be defined that support each of the views independently, but for multi-viewpoint design for manufacture to be effective the relationships between the views must be supported. This has been achieved through the use of translation mechanisms.

Figure 4 illustrates three sets of data structures and two sets of translation mechanisms. Each data structure supports a single viewpoint domain while each of the

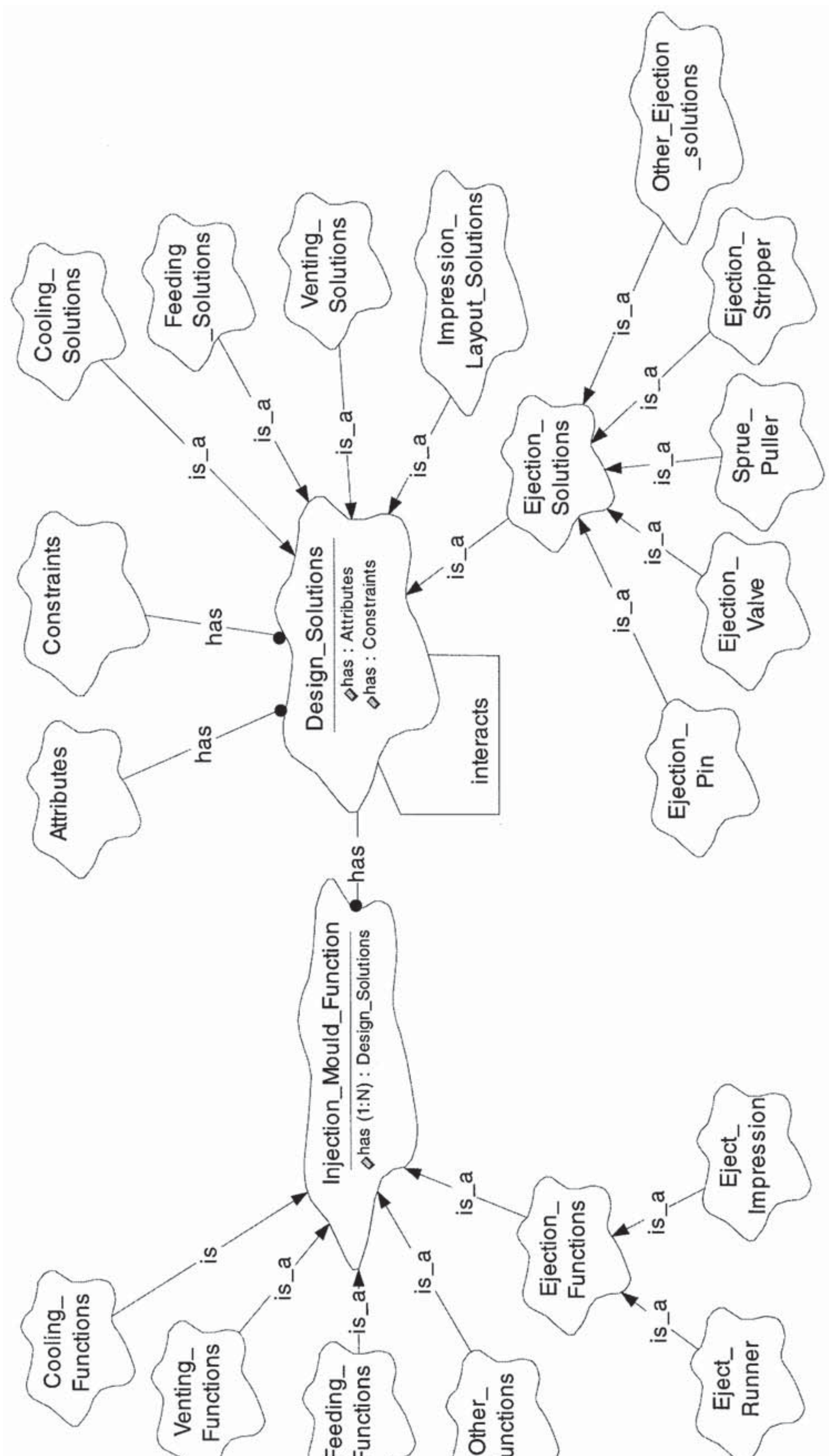

Fig. 3 The structure of a product range model for an injection mould

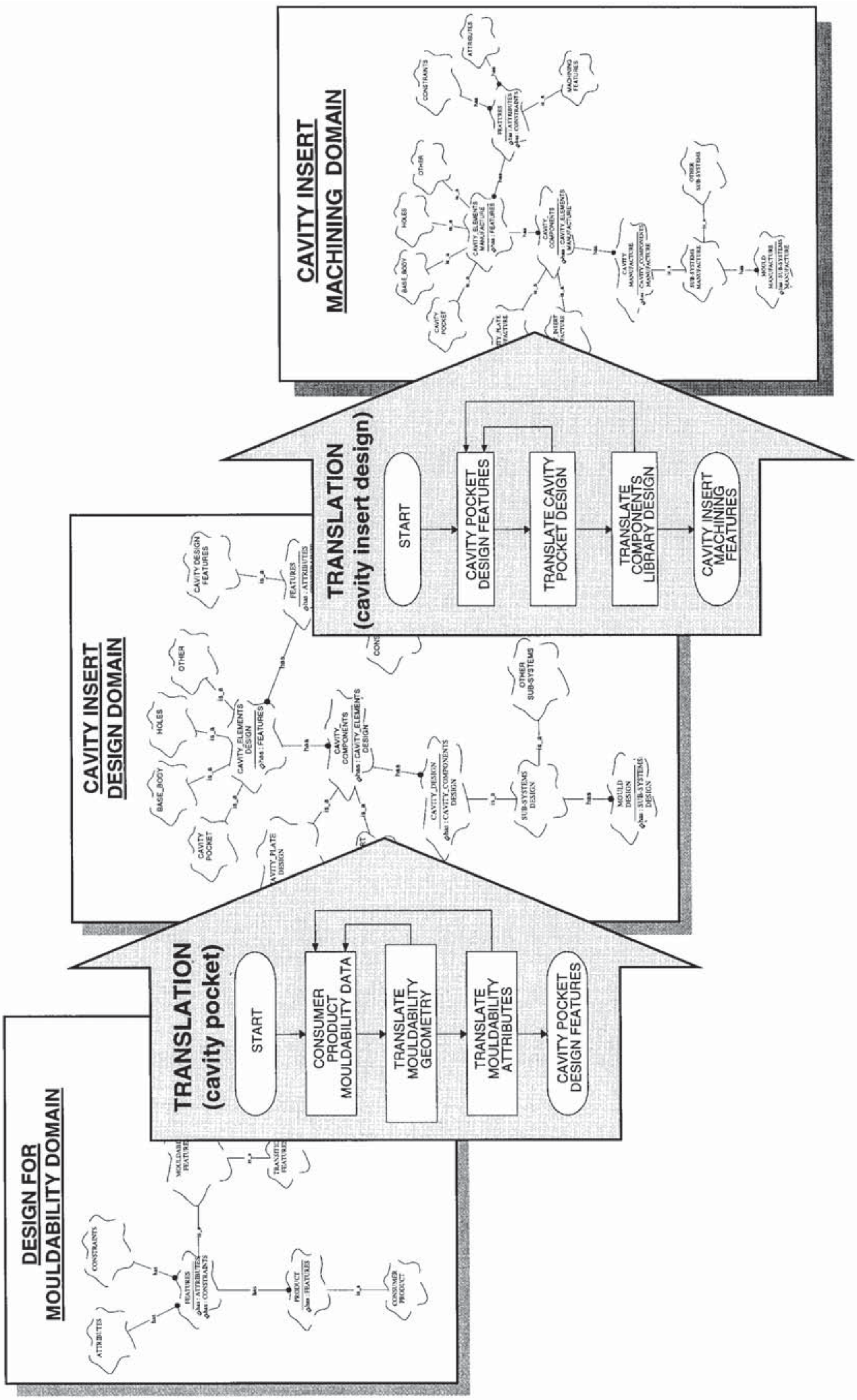

Fig. 4 Multiple data structures and data translations

defined translation mechanisms provides the link between two of the data structures. The viewpoints captured are each subsets of the views illustrated in Fig. 2, i.e. the mouldability view of the plastic product, the design of a mould cavity insert and the machining of a cavity insert.

The cavity pocket translation in Fig. 4 illustrates a procedure that takes information captured within the mouldability domain data structure and converts it into the form of information that can be held within the cavity insert design domain data structure. The cavity insert design translation procedure operates in a similar manner on its two data structures. These translation mechanisms effectively capture knowledge of the interrelationships between pairs of data views. Translation mechanisms can therefore only be effective when they are applied to particular known types of design.

4 DISCUSSION

This paper has provided a novel view of how data model driven systems can be enhanced to provide useful design and manufacture support. While product and manufacturing models can provide the main product and manufacturing information to support design decisions, they are inadequate on their own when dealing with the wide range of information views that are required in commercial systems.

This paper has argued that a link from design for function to design for manufacture can be achieved through the use of a product range model in variant design cases. Further, it has argued that multiple manufacturing views of a design can be supported through the use of appropriate data model structures in a product model combined with translation mechanisms to enable movement of data from one viewpoint to another. A further issue, yet to be fully resolved, is the relationship between knowledge contained in the translation mechanisms and knowledge within the supporting data driven applications.

The ideas presented in the paper have been explored and illustrated using injection moulding as a particular and appropriate case. The work is at the stage where the necessary data structures and translation mechanisms have been defined. An experimental object-oriented system is under development. While the problems of information interactions are complex, it is believed that their solution can offer major advantages in the commercial exploitation of future information systems.

5 CONCLUSIONS

Data model driven concepts are important to future CAE systems development and such systems must be able to deal with information interactions if they are to be useful in commercial environments. Interactions between design for function and design for manufacture can be partially supported by the use of product range models. Multi-viewpoint design for manufacture requires the definition of multiple data structures and defined translation mechanisms that can provide the necessary link between pairs of information views.

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REFERENCES

1 **Ellis, T., Molina, A., Young, R. I. M.** and **Bell, R.** An information sharing platform for concurrent engineering. In *Integrated Manufacturing System Engineering* (Eds P. Ladet and F. Vernadat), 1995, pp. 262–277 (Chapman and Hall, London).
2 **Anderl, R.** Trends in product modelling. In Proceedings of 11th International Conference on *Engineering Design (ICED)*, 1997, Vol. 1, pp. 113–121.
3 **Krause, F.-L., Kimura, F., Kjellberg, T.** and **Lu, S. C.-Y.** Product modelling. *Ann. CIRP*, 1993, **42**(2), 695–707.
4 **Al-Ashaab, A. H.** and **Young, R. I. M.** Design for injection moulding in a manufacturing model environment. *J. Des. Mfg*, 1995, **5**, 45–55.
5 **Young, R. I. M.** Supporting multiple view in design for manufacture. In Proceedings of Second IFIP WG5.2 Workshop on *Knowledge Intensive CAD*, 1996, pp. 259–269 (Chapman and Hall, London).
6 **Allada, V.** and **Anand, S.** Feature base modelling approaches for integrated manufacturing: state of the art survey and future research directions. *Int. J. Computer Integrated Mfg*, 1995, **8**(6), 411–441.
7 **Wood, S. L.** and **Ullman, D. G.** The functions of plastic injection moulding features. *Des. Stud.*, 1996, **17**, 201–214.
8 **Erens, F.** and **Verhulst, K.** Architectures for product families. *Computers in Industry*, 1997, **33**, 165–179.

