Available online at www.sciencedirect.com
SCIENCE DIRECT™
Materials and Design 23 (2002) 651–656
Materials & Design
www.elsevier.com/locate/matdes

Towards more strategic product design for manufacture and assembly: priorities for concurrent engineering

K.L. Edwards*

School of Computing & Technology, University of Derby, Kedleston Road, Derby, DE22 1GB, UK

Received 11 January 2002; accepted 30 May 2002

Abstract

This paper investigates the strategic application of materials and manufacturing process information during the design process. Design For Manufacture and Assembly (DFMA) has become an important concurrent engineering imperative for cost effective product design. The basis of design for manufacture and assembly is a systematic procedure for analysing product designs based on the application of quantifiable data. The procedure generates a large amount of information and even in computerised form presents difficulties for decision-making except for the simplest of products. Guidelines encapsulating qualitative information on best design practice facilitate the procedure. Methods are described for effective integration of quantitative and qualitative materials, manufacturing and assembly process information during product design. A discussion is also included on the differences between designing for new products and in designing for changes in existing products.

Keywords: Design for manufacture; Design for assembly; Design for manufacture and assembly; New product development; Concurrent engineering

1. Introduction

Design For Manufacture (DFM) is a systematic procedure to maximise the use of manufacturing processes in the design of components and Design For Assembly (DFA) is a systematic procedure to maximise the use of components in the design of a product. To be effective in product design, the procedures are often combined as Design For Manufacture and Assembly (DFMA). The aim of DFMA is to maximise the use of manufacturing processes and minimise the number of components in an assembly or product. DFMA is a systematic procedure for analysing proposed designs from the perspective of assembly processes. To obtain the maximum benefit from DFMA, the procedure is applied as early as possible in the design process and used within a concurrent engineering teamwork environment. In conjunction with the procedure, designers can make use of DFMA guidelines to help manage and reduce the large amount of information involved. DFMA guidelines are statements (rules of thumb, tips, aids, hints, suggestions, etc.) of good design practice that have been empirically derived from past experience.

The normal result of DFMA, as an integral part of the design process, is simpler and more reliable products that are less expensive to manufacture and assemble. However, products designed in this way tend to have a smaller number of complex components, making maintenance and upgrading difficult and expensive. The emphasis on reducing manufacturing costs has, therefore, been at the detriment of in-service costs. This may not be a particular problem for mass-produced (typically minimal maintenance, low priced, short life span) products such as the majority of domestic appliances. It is important, however, for more expensive products such as motorcars and aeroplanes, that maintenance is required in order to ensure their expected life spans. Over the years, long life products such as motorcars have also seen the growing trend towards using components that cannot be maintained. This has kept the cost of maintenance low but is wasteful of resources.

*Corresponding author. Tel.: +44-1332-591-729; fax: +44-1332-622-739.

E-mail address: k.l.edwards@derby.ac.uk (K.L. Edwards).

0261-3069/02/$ - see front matter © 2002 Elsevier Science Ltd. All rights reserved.
PII: S0261-3069(02)00050-X

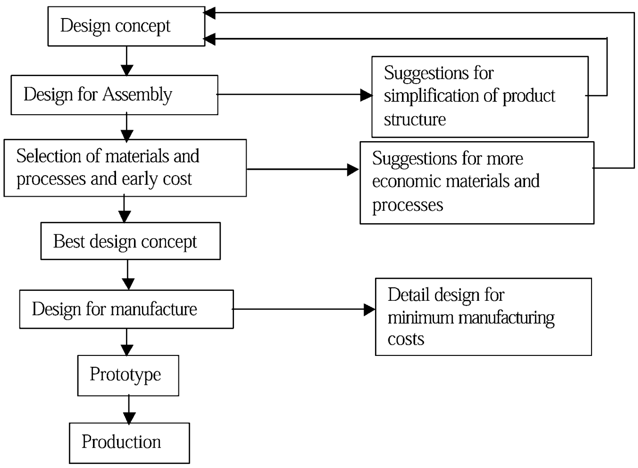

Fig. 1. Typical stages in a DFMA procedure (courtesy of Boothroyd and Dewhurst [2]).

With regard to the practice of designing for future upgrading, this is presently limited for most products but seen regularly in industrial electronics for example to facilitate future improvements in functionality and performance and in large made-to-order products such as ships which regularly receive refits. In the future, government legislation, particularly environmental protection and the need to control the use of precious resources, might change this situation. Manufacturers will be forced to provide alternative uses for the materials and components used in their products' manufacture when they reach the end of their design lives. This is already being seen with motorcar manufacturers but little has been done so far for mass produced consumer products. To be effective, consumers will need to play their part and accept higher prices for their products. In return the products will last longer, but contain more adjustable and/or replaceable components to maintain appropriate function, and upgrades of components and/or subassemblies to provide improvements. DFMA procedures will need to reflect the changing situation, adapting to compromise, and handling larger amounts of diverse information.

2. Design for manufacture and assembly process

The DFMA procedure can typically be broken down into two stages as shown in Fig. 1. Initially, Design for assembly is conducted, leading to a simplification of the product structure and economic selection of materials and processes. After iterating the process, the best design concept is taken forward to Design for Manufacture, leading to detailed design of the components for minimum manufacturing costs. The procedure is cost driven and importantly depends on the product design already existing. The procedure outlined, and there are many variations [1], optimises the original product design to produce a new and improved design. Most of the DFMA procedures today are computerised and DFMA can be done very quickly, once essential data is entered, allowing 'what if' scenarios to be conducted. DFMA procedures can be supported with guidelines, which are often supplemented by the experience of the designer. The importance of the contribution from guidelines cannot be over emphasised. In fact some DFMA is done purely through experience, with little or no support from a systematic procedure or formal guidelines. This approach is highly dependent on the knowledge and experience of the individual designer or collective design knowledge and experience of the company concerned.

Most of the pioneering and ongoing research in the field known today as DFMA can be attributed to Boothroyd and Dewhurst [2]. The procedure-based process analyses product designs by performing: a functional analysis; a manufacturing analysis; a handling analysis; and a fitting analysis. Each analysis stage generates cost indices, allowing problematic areas to be easily identified and priorities for redesign to be suggested. Repeating parts or all of the process will test the design change effectiveness. An alternative to the structured approach is the integration of all relevant areas and a greater emphasis on supporting the design process [3]. The latter approach is inherently more conducive to supporting directly concurrent team working. The two approaches, although only subtly different when combined, provide structured integration. A benefit of this is the mapping of product, process and people and as a consequence consideration of life cycle aspects.

3. Selecting appropriate manufacturing and assembly processes

A typical product contains many components, each requiring a variety of processes. There is usually more than one method of manufacturing a component from a given material. There are many classifications of processing methods for materials, but hierarchically can be divided into the following categories:

- casting;
- forming and shaping;
- machining;
- joining; and
- finishing

The selection of the most appropriate manufacturing process is dependent on a large number of factors but the most important considerations are shape complexity and material properties. DFM needs to take into consideration all the above and more in order to support decision making and provide this information in a timely and appropriate manner. Ultimately, most information can be reduced to a cost, the paramount driver to economical design. DFM converts most manufacturing