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MANUFACTURABILITY OF PRODUCT DESIGN REGARDING SUITABILITY FOR MANUFACTURING AND ASSEMBLY (DfMA)

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Abstract: *Manufacturability of product design significantly affect on overall quality, both in terms of functionality and utilization, so in terms of manufacturing and assembly. This paper presents systematization and analysis manufacturability of product design with a focus on DFMA methods.*
Keywords: *Manufacturability of product design, DfX, DfMA methods.*

Izrada dizajna proizvodna shodno pogodnosti za proizvodnju i montazu. *Tehnologičnost od dizajna proizvoda značajno utiče na ukupni kvalitet, kako u pogledu funkcionalnosti i korišćenja, tako i u pogledu proizvodnje i montaže. Ovaj rad predstavlja sistematizaciju i analizu tehnologičnosti pri dizajnu proizvoda sa fokusom na DFMA metode.*
Ključne reči: *tehnologičnost dizajna proizvoda, DfX, DfMA metode*

1. INTRODUCTION

Manufacturability of product design, primarily as a measure suitability for manufacturing is a very broad term and is difficult to uniquely define, because it depends on many influential elements, including the conditions in which the manufacturing process to implement.

Design of complex product is evaluated from standpoint of functionality, manufacturing, assembly, utilization and maintenance [11].

In this paper will be presented systematization of methods for analysis manufacturability of product design, with accent on manufacturability of product design regarding suitability for manufacturing and assembly (*DfMA - Design for Manufacturing and Assembly*). At the end of paper will show „DFMA" software on one specific example.

2. SYSTEMATIZATION METHOD'S FOR ANALYSIS MANUFACTURABILITY OF PRODUCT DESIGN - DfX TOOLS

Design for eXcellence (DfX) requires taking into account of all relevant design objectives and constraints in the early stages of design. DfX is general term, where „X" may represent manufacturing, assembly, quality, etc. [3].

There are various splitting DfX methods, and here will be displayed DfX methods for scope Design for Efficiency and Green Design, Fig. 1. DfX methods using three ranges of perception: 1) product scope, 2) system scope, 3) eco-system scope [6].

Product scope includes DfM (*Design for manufacturing*), DfA (*Design for Assembly*), DfQ (*Design for Quality*), DfR (*Design for Reliability*), DfD (*Design for Disassembly*), DfMa (*Design for Maintainability*) and DfO (*Design for Obsolescence*), and system scope includes DfSC (*Design for Supply Chain*), DfL (*Design for Logistics*) and DfN (*Design for Networks*).

Green Design includes DfRe (*Design for Recycle*), DfS (*Design for Sustainability*), DfE (*Design for Environment*) and DfLC (*Design for Life Cycle*).
Eco-system scope includes DfS, DfE and DfLC, and together with product scope DfRe [6].

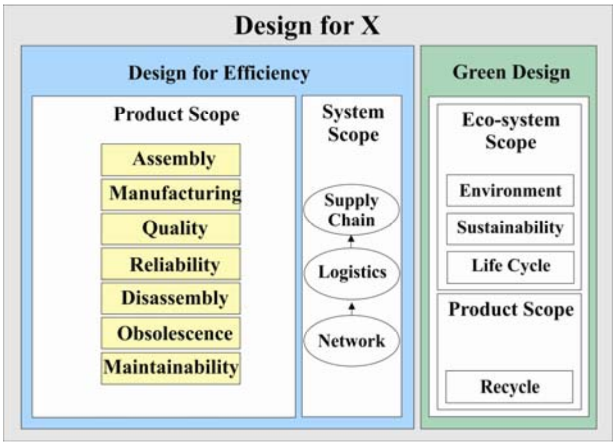

Fig. 1. Structure of DfX tools

The main purpose of design for efficiency is expressed as reducing costs and lead time of a product while sustaining or improving it's quality. Product scope focuses on the product aspects which enable efficiencies at the shop floor, while system scope concentrates on the integration and coordination of the value chain, starting with the design stage and ending with the delivery and maintenance system.

DfX concepts and methods have role in reducing the cost items. However, the actual percentage of each DfX concept can not be precisely measured because of the variety of the product type and required production system. Fig. 2 shows the possibilities of reducing price of product considering different sources of costs.

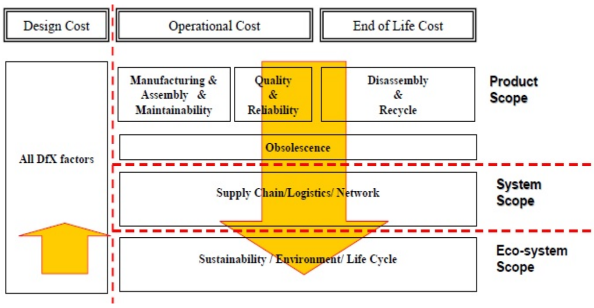

Fig. 2. The benefit of DfX factors in product costs [6]

3. DESIGN FOR MANUFACTURING AND ASSEMBLY (DfMA)

In the concept design for efficiency, design for manufacturing (DfM) and design for assembly (DfA) are methods that take into consideration first.

DfM is actually a systematic approach that allows designers to predict the costs of manufacturing in the early stages of the design process, even when it is known only approximate geometry of the product that is being developed [8].

According [4] design for manufacturing was defined as an approach for designing a product so that the design quickly transitioned into production, the product is manufactured at a minimum cost, the product is manufactured with minimum effort in terms of processing and handling requirements, and the manufactured product attains designed level of quality. Fabricius [5] proposed a procedure of seven steps for design for manufacturing to enhance linkage between design and manufacturing using a three-dimension model. Stoll [10] is described 13 DfM guidelines that are strategy-based and practice oriented. These guidelines focus on three strategies relating to modular design, multi-use parts with standardization, and easy of assembly to increase to manufacturability.

In design for assembly (DfA) estimated design of product based on quantitative charasterictis of the product. The most important indicator of efficiency of design is assembly time. Assembly time of product reflects the difficulty of assembly process such as consolidation, adjustment, and alignment. So, DfA aims consolidate the components and functions in a smaller number of components, which affects on reducing assembly time and assembly costs.

DFMA is used for three main activities [2]:

- *As the basis for concurrent engineering studies to provide guidance to the design team in simplifying the product structure, to reduce manufacturing,*
- *As a benchmarking tool to study competitors products and quantify manufacturing and assembly difficulties and*
- *As a should-cost tool to help negotiate suppliers contracts.*

Three of most common DfMA methods by which they are developed appropriate software are [7]:

- *DFMA, Boothroyd Dewhurst Inc., USA, software developed according to the methodology developed by Boothroyd i Dewhurst,*
- *TeamSET, CSC Computer Sciences Ltd, UK, software developed according to the methodology Lucas-Hull and*
- *AEM Assembly Evaluation Method, Hitachi Corp., Japan, software developed according to the methodology Miyakawa and Ohashi.*

3.1 Boothroyd-Dewhurst method

Boothroyd-Dewhurst DfMA method evaluates the product based on design efficiency. The higher design efficiency-better product. Number of parts of the product has significant effect to the design efficiency value. If the product has many parts, the assembly time will be higher. Higher assembly time means lower design of efficiency. Also, higher assembly time directly means that the assembly cost is higher. Therefore, Boothroyd-Dewhurst DfMA recommends elimination of unnecessary part and combination of many parts into fewer components to reduce the number of parts in a product [7].

DfMA is a method for evaluating the manufacturability of part design and assembly design. It is a way to identify unnecessary parts in assembly, and determine the time of manufacture and assembly costs. The steps applying DfMA methods and corresponding software are shown in Fig. 3.

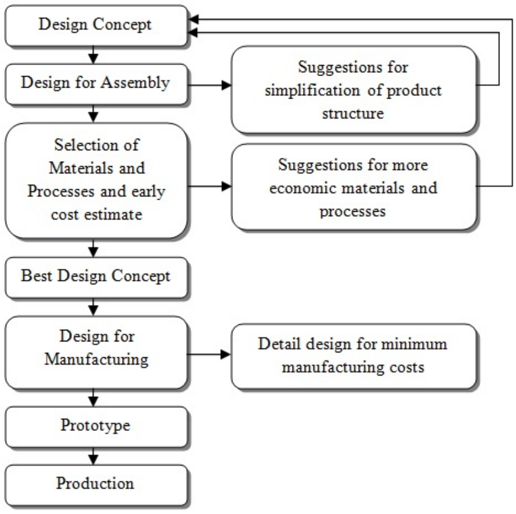

Fig. 3. The steps applying DfMA methods [6]

According Boothroyd claimed that product design for manufacture and assembly can be the key to high productivity an all manufacturing industries comparing to the automation. In his method, the concept of design for assembly was first indicated in the conceptual design phase to ensure the best design concept for materials and processes. Then, the concept was evaluated to minimize the manufacturing costs, which results in a slight increase the time in conceptual design phase. Considerable time savings would be achieved during preliminary design and detail design phases.

This method, namely software can be divided into three main stages [9]:

1) Selection of workpiece

Selection the best type of raw material or workpiece as the first step in applying DfMA depends of many *factors that affect their choice, such as:*

- *Mechanical and chemical properties of the workpiece material,*
- *Selection standard workpiece and*
- *Application of near net production technology.*

2) Selection machining processes and systems

At determining the most appropriate machining processes and systems should be taken into consideration:

- *Type of production,*
- *Type and shape of workpiece,*
- *Economically tolerance of product,*
- *Opportunities machining systems,*
- *Appropriate tools and supplies, etc.*

3) *Assembly of the product*

During assembly of product, provides the greatest possibility of applying DfMA methods. Proper use of DfMA principles allows produce a high quality products. This principles are based on:

- *Reducing the number of parts in the assembly,*
- *Implementation of symmetric parts when product design allows it,*
- *Easy design of products,*
- *Ensure self fixturing,*
- *Avoid parts that can tangle, etc.*

3.2 Lucas-Hull method

Lucas Organization and University of Hull United Kingdom are the two groups behind the development of the Lucas design for assembly (DfMA) method. Lucas DfMA evaluation method takes into consideration the crucial aspects of assemblability and component manufacture [7].
Algorithmic structure of this method is given in Fig. 4.

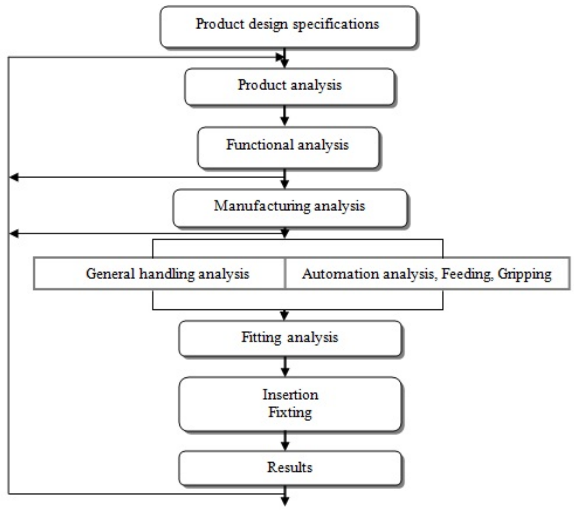

Fig. 4. Lukas-Hull DfMA method [7]

3.3 Hitachi metod (AEM)

Assemblability Evaluation Method (AEM) was developed by Hitachi in 1976 for better assemblability of product by improving design of product. AEM identifies the weakness of the design at the early stage of the design process. The design quality is being evaluated based on two indicators that are [7]:

- ***'E'*** refers to an assemblability evaluation score ratio. It determines the difficulty of the operations and
- ***'K'*** refers to an assembly cost ratio. It is used to project elements of assembly cost.

Description of algorithmic structure for assessing suitability for assembly by Hitachi at given in Fig. 5.

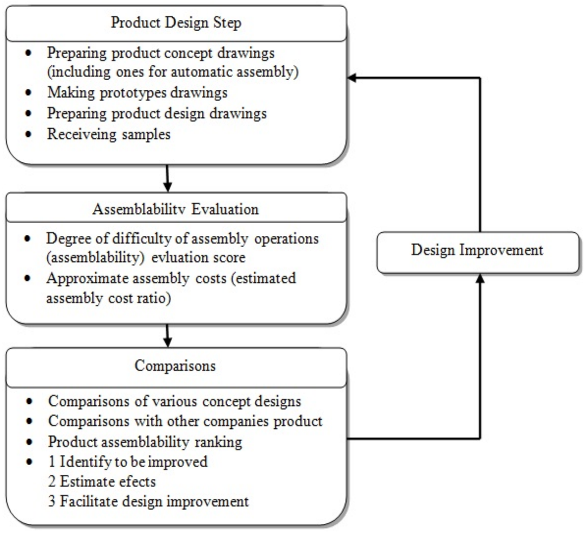

Fig. 5. Assessment of suitability for assembly and redesign [7]

4. REVIEW OF SOFTWARE SOLUTIONS

In the previous section presents the most common software for DfMA, while in this paper provides a brief overview of software *DfM Cost 2.2 i DfMA 9.4 by Boothroyd Dewhurst Inc.*, in one example. It is also important to note that this is a trial DfMA software was obtained in order to explore it's possibilities.

It is recommended that first determine the manufacturing costs for various components using DfM aplication, and then apply DfA aplication to determine assembly costs. In Fig. 6 shown estimation of the manufacturing costs of the example of cylinder, and Fig. 7 shown estimation assembly costs for example piston assembly [1].

User interface Concurrent Cost 2.2 and Design for Assembly 9.4 consists of three areas:

1. *Tree model,*
2. *Fields to define certain data and*
3. *Fields for display estimates costs.*

In DfM aplications Concurrent Cost 2.2, under tree model are shown corresponding machining processes some parts of the product, while in the field to define the data, enter data, such as part name, part number, life volume, selection workpiece and it's dimension, selection processes and materials, etc. Selection processes and materials (material-process or process-material) is essential. If you select material first software will show the possible processes for the selected material, and if you select process first, software will show the possible materials for the process. Fields for display estimates costs shows individual costs element, such as cost of material, cost adjustment, tooling cost, etc., and finally total cost.

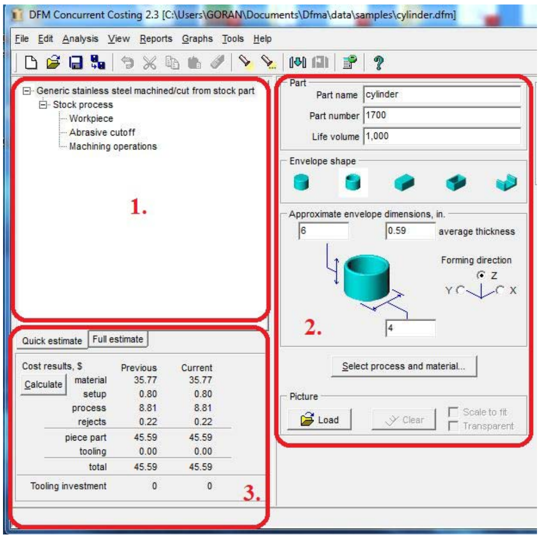

Fig. 6. Cost estimate in the example of cylinder (DfM)

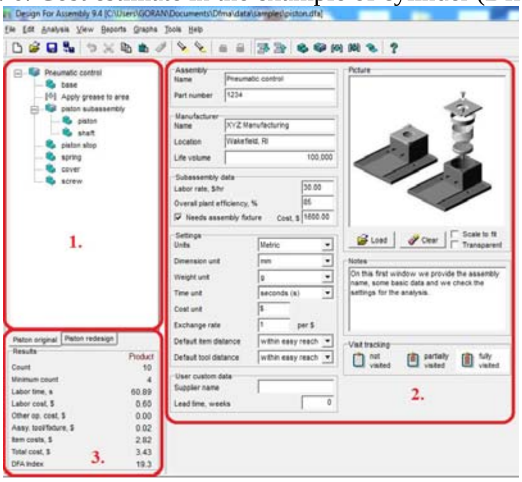

Fig. 7. Cost estimate in the example of piston assembly (DfA) [1]

In DfA aplications Design for Assembly 9.4, presents overall structure of the product or assembly, and can serve as an alternative selection for selection technical elements in the implementation of the correction on the product or assembly. In field to define certain data next to the assembly name, part number, manufacturer and life volume performed and data entry such as subassembly data and various settings that include units, dimension unit, weight unit, time unit, cost unit, etc. Field with results shows certain elements for the calculation of cost, DfA index and total cost.

After evaluation of the machining and assembly costs there is the possibility of generating reports in the form of tables or graphs with output results.

5. CONCLUSION

Costs of product design and their manufacturing process planning, participate in a small part of the total price of the product, but decisions made during this process significantly affect the overall cost of developing a new product an is essential for the market success of the product. Therefore, necessary to consider the problem of production as early as possible, even at the stage of the product design, namely, development of it's concept, because the costs of modifications of the product higher if you make changes in the later stages of product development.

In order satisfy these requirements has been developed appropriate DfX methods, whereas in the present study shown the most common methods of DfMA.

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