8 DESIGN WITH ASSEMBLY — A NEW APPROACH

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This paper describes a design method in which assembly activities are integrated in the conceptual phase of the design process. Most products designs need to be redesigned before they can be assembled. In the current market, companies have to introduce new products at the right moment and against the market price. The goal of this method is to create new products first time right designs. Three assembly aspects are important to know during the design process: product architecture, joining and part design.
Design with Assembly is a new approach which consists of seven successive steps. The assembly aspects are taken in account from the beginning to the end of the design process. The method is based on creating of logical product architecture with suitable joints in the conceptual phase of the design process. The type and amounts of joints are determined in the beginning of the design.

Keywords: Design with x, Assembly, Method, Design for Assembly.

1. INTRODUCTION

The history of the assembly tells us that the first assembly plan is described in the Noah's Ark which includes material, design and dimensions in 2500 BC.[1] This type of assembly was known as craft assembly. But all assembly was done manually until Henry Ford introduced the assembly line. In 1970 the flexible assembly was introduced by means of assembly robots, robots cells, and programmable controllers.

The goal of the assembly is the ability to manufacture products at optimised volume against the lowest price. According to the pioneers of mass production, price and volume are the main drivers of a product design. Ford, Taylor and Whitney, and later Boothroyd, Nof, Warnecke and Rampersad are influential assembly professionals, who introduce an assembly method for manufacturing or design. Design for Assembly (DfA) is a method to come to a product design, that can fulfill the function and what is easy to assembly against the lowest cost.[1,2] Whitney gives insights with his mechanical assembly thoughts that the sequence method of assembly is also useful.[3] The sequence method is combining the three methods of Design for Assembly which are mentioned by the others.

Three types of Design for Assembly (DfA) methods are distinguished:

- the ruled-based methods of assembly
- procedural methods of assembly
- artificial intelligence based methods of assembly

The product design may now be focused to bring assembly to the conceptual design phase. Design with Assembly (DwA) will be the method to effectuate the integration in the conceptual phase. DwA has to overcome the barrier of detailing by using assembly information at concept level. The objective is to create a new method that inspires designers and supports them in creating products. But the product design should be assembled at the demanded quality, within the required assembly time and against the lowest assembly cost, but right for the first time.

Before explaining the design with assembly method, the assembly fundamentals must be cleared about the operations or tasks, the added value, functions joints, manual vs. automated, assembly systems and interchange ability. Design with assembly involves the influences of the assembly task already in the conceptual phase.

2. ASSEMBLY FUNDAMENTALS

Assembly is part of the production system.[1] But assembly is also a knowledge domain which is developed for manufacturing non-monolithic products.[4]

An assembly is a compounded product of individual's parts, components and sub-assemblies.[5] Still the best assembly is no assembly; such products are called monolithic products such as a washbasin, watering can, laundry basket, spoon, etc. The core task of assembly is joining of parts, components and sub-assemblies to products.

Before joining, the parts must be made, transported and handled through inserting. After joining the joints must be checked. In Figure 1 the production process is structured with the manufacturing process, the internal and external transport, the assembly process, and the economical result. The production structure is based on the assembly structure[4] which is extended to production with manufacturing parts and transport. The economical results are added for further development of the production systems.

Joining and manufacturing are added value activities, thus the gaining activities; all the others cost only money. If the added value is more than the total costs, then you should make profit. You can suffer losses if the added value is lower then the costs. In this case the advice must be stopping the assembly of these products, before running out of business.

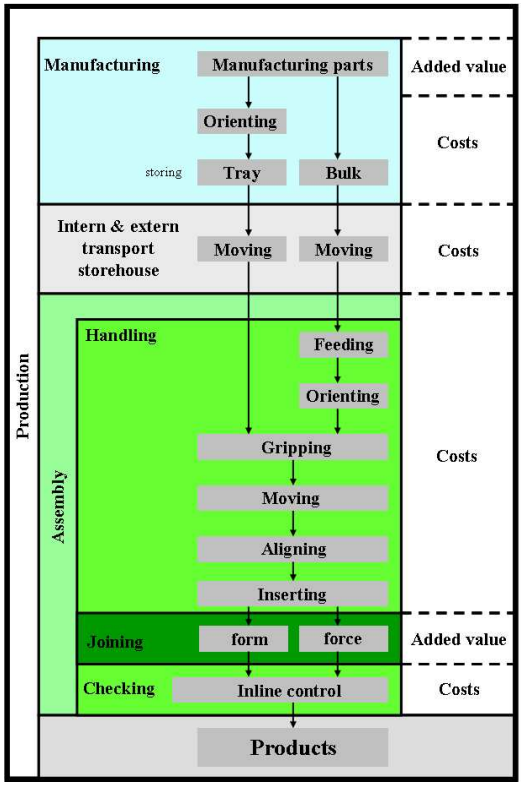

Figure 1. The structured production process with its economical results.

Table 1. Division of joints into appearance categories.

Category	Kind of joint	Type
	Welding	Spot welding
Material	Soldering	Laser welding
	Glue	Ultrasonic welding
	Snap-fit	
Shape	Lip	
	Clinching	
Object (extra fasteners)	Screw	Self cutting screw
	Bolt	Self drilling screw

Source: Design with Assembly, graduation report.[11]

Joints are also the connections of parts, components and subassemblies in such a way that they together represent a functional product. Joints can be categorised by:

- process used to create the connection
- appearance of the joint
- chemical bond

In Table 1, the most recognizable and visual aspects of joining are given. These are the chosen joints in this paper and they cover the largest part of the market. The categories of joints are given in the Industrial Designer.[6] But the kind of joint is extracted from the categories and the types are example joints.

Companies can survive and compete in the current market only by time, efficiency, high quality, flexibility and innovation. The main assembly aspects should be developed and designed.[6] Efficiency should be reached with the desired quality as fast as possible against the lowest cost. High quality is the quality the consumers expect at a certain price level. A shorter product life cycle requires choices between investments in machinery or outsourcing an assembly to the low cost countries.

Just in Time is one of the main issues in the supply chain, parts and components play an important rule: which parts are at the right time and on the right place. Complex parts are such parts which high integrated level of functions

The designs of product families increase the number of modular units, which lead to larger manufacturing volume of parts.

3. DESIGN FOR ASSEMBLY

Three types of Design for Assembly (DfA) methods are distinguished in according to Nof:[1]

- Rule-based methods, following a list of guidelines to design assembly friendly products
- Procedural methods that are evaluation methods of products, sometimes computer-assisted.
- Artificial intelligence based methods. Artificial intelligence methods include for example knowledge based design.

The most popular Design for Assembly method is the Boothroyd method. The Boothroyd method is a procedural method which is focused on redesign of the product and to optimise it from the assembly point of view. The characteristic of this method is the scoring system that is used to evaluate part design. The scores given per part can be translated to assembly time and cost. By use of software, an advice can be obtained for the redesigning of parts with major handling and moving problems is provided.

An interesting fact is that the DfA methods such as Boothroyd, were initially introduced for the conceptual design phase and not for redesign. The main goals of these methods were to eliminate the number of parts and to achieve savings in cost and lead time. In the course of time these goals were achieved at a later design phase. This was possible because more details of the parts are known. Therefore the focus changed to the optimisation phase.[1]

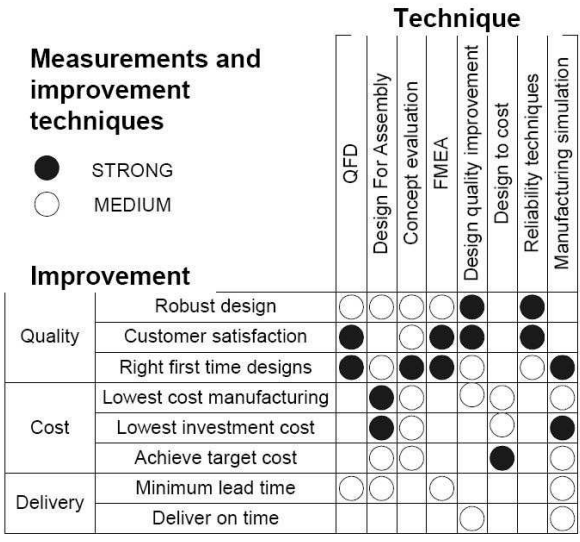

Figure 2. Techniques versus performance improvements according to miles.[9]

'The DfA house' is one of the DfA methods that focus on the optimisation of products.[7] The difference between this method and other DfA methods are that it takes into account the relations between the assembly aspects. Rampersad and Boothroyd both give some guidelines for assembly friendly product design. A new Design for Assembly method that is focused on the integration of assembly in the conceptual design phase is developed.[8]

The ideal situation should be that the designer can consider the assembly issues during conceptual phase of the design process. In this stage of the design process the need of a prediction tool or method is desired. The functioning of a product with a certain number of parts and joints should be established. The main goal of the DfA methods and the prediction tool is to do right while designing the first time. The main disadvantages of the existing Design for Assembly methods are:

- The high amount of detailed data needed
- The evaluative character of the existing method
- The existing methods are focused on the reduction of parts and handling operations

Designers have limited time available and many other aspects of a design also require attention. So designers give low priority to the assembly. Product design optimisation can be done by other tools such as FMEA. The core of the assembly is handling and joining while joints are combination of parts. In the new tool there should be made choices made on the type of joints and how they work.

The goal of this paper is to create a method for Design with Assembly that inspires designers and supports them in creating products without the need for redesign. The products can be assembled at the supposed quality, within the assembly time and against the supposed assembly cost.

Several techniques or supporting methods are already available for designers to improve their work with among other things DfA. An overview is given for the relationship between the techniques, the supporting methods and the improvements of quality, cost and delivery,[9] see Figure 2. But Robust design is a real technique and Design quality is an improvement. Design with assembly may be considered as a technique which gives quality improvement as right first time designs and cost improvements as lowest investment cost.

When the focus is on the DfAA method, Design for Automatic Assembly[10] (Figure 3), but it is the same approach as DfA only with a clear focus on automatic assembly. The problems are alike if the

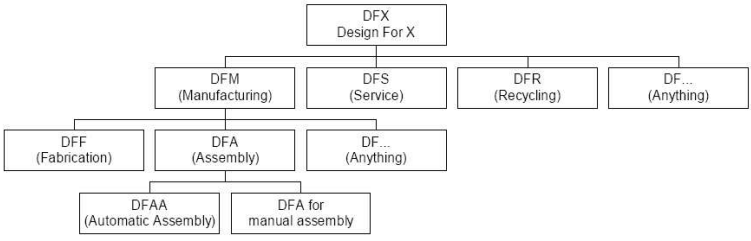

Figure 3. Design for X is the base the life cycle, with DfAA as part of DfA.

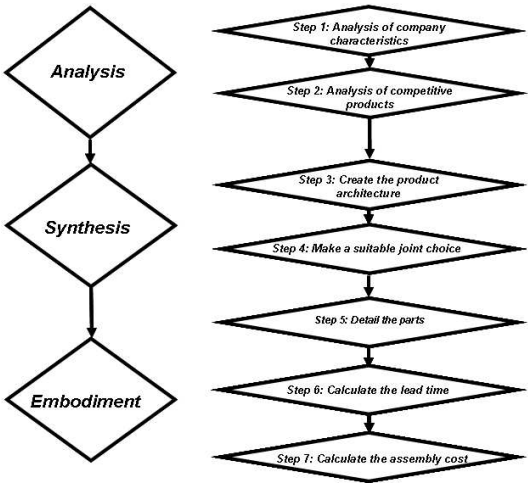

Figure 4. The design process is linked with the new design with assembly method[11].

assembly process is hard or flexibly automated. It is just an evaluation method again like Boothroyd, Ramperstad etc.

4. DESIGN WITH ASSEMBLY

In this section, the background of design with assembly method will be explained. The link between assembly and the design process is the base for the new method. The method consists of seven steps, see Figure 4. All steps are divided into sub-steps to make the method accessible and prevent the input of too much information at the same time.

The starting point of the method was to support designers who take assembly aspects into account from the start of the design process, without hindering the creative process. This way of thinking is turned to the development of a method that supports the design process by showing the fields of tension between assembly and other design aspects. The vision develops to inspire the designer by showing of the advantages that method creates against competitive products.

It has more advantages than that it does not hinder the creativity of the designer. The idea of the method is that designers collect information that can be used during the following steps, Figure 5. The advantage of this method in relation to other 'design for assembly' methods is that it contains a step structure that gives designers a hold on how assembly aspects can be integrated. The designers are stimulated to create the possibilities instead of following fixed rules. Another advantage is that less detailed information is needed than in existing 'design for assembly' methods to get insight in

Step 1: Analysis of company characteristics (internal)
- 1.1 Fill out company characteristics
- 1.2 Extract main guidelines for design

Step 2: Analysis of competitive products (external)
- 2.1 Draw a precedence diagram
- 2.2 Analyse competitive products
- 2.3 Extract main guidelines for design
- 2.4 Check the system characteristics

Step 3: From principle solution to product architecture
- 3.1 Create a minimum amount of parts and distances
- 3.2 Create a main part
- 3.3 Use the main guidelines to find optimum amount of parts
- 3.4 Draw a precedence diagram
- 3.5 Compare the concepts and check guidelines

Step 4: Make a suitable joint choice
- 4.1 Check joints to main guidelines
- 4.2 Compare the joints on economic aspects
- 4.3 Look for alternative possibilities
- 4.4 Make a joint choice
- 4.5 Check the guidelines

Step 5: Detail the parts
- 5.1 The main part from system point of view
- 5.2 Storing and supplying
- 5.3 Gripping and positioning
- 5.4 Orientating and aligning
- 5.5 Inserting
- 5.6 Joining
- 5.7 Checking

Step 6: Calculate the lead time
- 6.1 Define the operation time per part
- 6.2 Calculate the minimum cycle time
- 6.3 Divide the tasks over the stations
- 6.4 Calculate the total lead time

Step 7: Calculate the costs
- 7.1 Calculate the part / component cost
- 7.2 Calculate the cost
- 7.3 Check the guidelines

Figure 5. The seven steps of design with assembly with the sub-steps.

the assembly aspects during the design process of the product. The method is focused on the main assembly aspects which are important for designers instead of many general aspects. The method contains a database that the designers can use to enlarge their knowledge about the assembly process. The designers draw a conclusion and evaluate at the end of each step. The collected information should be processed by the designer. So the assembly problems can be located as early as possible. This prevents for example product architecture problems and too high costs at the end of the design process.

This chapter DwA is the main outcome of the graduation project and the next chapter new approach is a verification of only step 2. This analysis of competitive products is only a part of one step out the seven steps method. The results of the analysis is given in assembly data such as: total amount of parts, amount of separate parts, total amount of parts final assembly, amount of layers, etc.

5. NEW APPROACH

On the basis of step 2, competitive products are taken to show the differences with the other methods. By following of the sub-steps is a method to come to the first time right design, the sub-steps are: 2.1 Draw a precedence diagram, 2.2 Analyse competitive products, 2.3 Extract main guidelines for design, 2.4 Check the system characteristics.

Generating a precedence diagram requires special attention on how parts are joined (Figure 6), sub-step 2-1. Competitive products have to be analysed and conclusion drawn for getting the product structure for the new design, sub-step 2-2. The main guidelines should be extracted from the analysis of the competitive products, sub-step 2.3. Without checking of the system characteristics, the right first time design is almost impossible, sub-step 2.4.

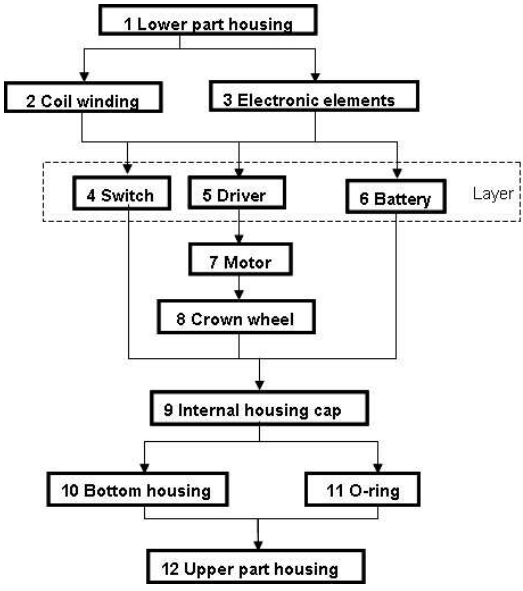

Figure 6. Final product architecture assembly of an electric toothbrush.

Assembly data from precedence diagram:	Total amount of parts	43
	Amount of separate parts	8
	Total amount of parts final assembly	14
	Amount of layers	9
Additional data:	Principle solution basic function	Electronic, mechanical
	Kind of joints	Glue, solder, melted pin, snap fit, press, pin hole, screw (self-cutting)
	Amount of different type of joints	8 (2 kinds of glue)
	Disassembly time	7200 s
	Selling price	€ 19.99

Figure 7. Assembly data and additional data in conceptual phase (step 2).

In the conceptual phase of the design, the assembly data from precedence diagram and additional data are generated and specified, Figure 7. The design process can be finished in the rest of the steps with this data. So, all the steps can be done inclusive the product design that leads to the proto-type.[10]

6. CONCLUSION

The fundamentals of a[10]ssembly are essential for understanding the creation of an assembly system and New Product Development. But this is valuable to the product design from the assembly perspective.

Joining and manufacturing parts are the added values in the making process; all the other aspects cost money during assembling.

The choices of joints give certain direction to the product design, which are captured by category, kind of joint and type.

Design for Assembly has not given the first time right design because DfA is based on evaluation if the details are known. The focus of the existing DfA methods is reduction of parts and handling operations.

DwA is a method that the designer inspires in well-organised steps that come to right first time design. The differences between DfA and DwA are: DfA is something you do at the end of the process. When the design is finished, the designer evaluates the product design. DwA, you define the assembly requirement at the beginning of the process. That can inspirit the designer and the product design can be first time right.

The design of the Design with Assembly method (DwA) has resulted in the seven steps method. The DwA method must now be researched for a number of product concepts and new product designs. The research must give answers to inspiration of the right first time design for both product stages. The need of a tool that can predict the quality of functionality of products should also be researched for supporting the first time right design.

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