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ASSEMBLABILITY AND SERVICEABILITY IN A CONCEPT DEVELOPMENT CASE

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Abstract

Applying DFA is often considered to improve serviceability, or at least increase the potential for improved serviceability. However, it is not self-evident that if a product is easy to assemble it is also easily serviced. In this paper assemblability and serviceability aspects in the conceptual design stage are considered. The product in the case study is a stand alone energy producing unit, size of which is approximately 1000x1500x2000 millimetres. Altogether five variations were evaluated by giving ratings on realisation of assemblability and serviceability guidelines to the concepts subjectively. The results show correlation between the assemblability and serviceability, but also exceptions occur. The exceptions are related to component accessibility in assembly or service operations, and the difference in the nature of factory assembly and field service operations.

1 Introduction

In today's market products have to be more optimised than ever before. With no doubt design determines a majority of life-cycle costs of a product, although the often-presented figure of 70 % is debatable [Barton et al.01]. Design for X (DFX) methods have obtained wide acceptance in product design. DFX stands for focusing on a few issues (assembly, manufacturing, recyclability, serviceability, etc...) at a time in designing products or associated processes and systems in a concurrent engineering context [Huang96]. The overall aim is to reduce total life-cycle costs for a product through design innovation [Kuo01].

Applying design for assembly (DFA) is considered to improve serviceability, or at least increase the potential for improved serviceability of a product through simplification of the product structure [Dewhurst&Abbatiello96]. However, it is not self-evident that if a product is easy to assemble it is also easily serviced. The objective of this case study is to observe correlation of assemblability and serviceability in conceptual design stage. In this paper service is defined as pre-scheduled or on need basis occurring tasks carried out aiming at maintaing the product's ability to perform its original function. A service operation usually consists of three stages: disassembly, service task and reassembly.

The costs of design changes increase rapidly in product development. It is often stated that DFA should be applied early in the design process so that late changes can be avoided and the design is performed "right first time". Huang states that applying DFX methods is expected to cause more design changes in the early stages of design, but reduce the amount of changes in later design stages significantly [Huang96]. When optimizing life-cycle costs of a product several DFX aspects have to be considered. Huang suggests that DFA (and Design for Variety) should be used first in order to rationalize the product structure, and use the other DFX tools after that. The tools should be used as early as feasible; the earlier the more potential there is left [Huang96]. The risk is that after DFA there are less degrees of freedom left, especially because assembly and manufacturing as more visible in-house problems have often left serviceability as a secondary issue at the design stage [Gardener&Sheldon95]. Dewhurst and Abbaticllo suggest that important service operations should be analysed at the early concept-layout stage concurrently with the earliest assemblability studies [Dewhurst&Abbaticllo96].

In the concept stage the amount of information available is limited. The quantitative DFA methods have been criticized about the information that is not yet available [Egan97]. In this study, assemblability and serviceability and their correlation are evaluated in the conceptual design stage. The evaluation is performed by a concept development tool [Salonen04]. In this case, due to the size and complexity of the product, the concepts were at a level were they had only approximately 25 % of the estimated final part count so quantitative analysing at this stage was not considered feasible.

2 Research approach

The case study object is a new product development product, a stand alone energy producing unit. The authors participated in the design process as design team members. The dimensions of the unit are of magnitude 1000x1500x2000 millimetres depending on the layout. In the design process, the generated concepts had components dealing with the physical energy producing process, an outline of the frame and covers, approximately 50% of the piping and space reservations for other items. Five different concepts were generated and 3D modelled. The five concepts had different layouts resulting in a different appearance (table 1). In design of each concept, assemblability and serviceability among other requirements were drivers of design.

In the design process, the ease of assemblability and serviceability were taken into account as guidelines respective to requirements set for the concept development. In serviceability operations, identification of a defect is excluded; it is assumed that the service personnel perform pre-defined operations. In the concept selection tool, the following requirements considering assemblability and serviceability were set:

1. Assemblability – minimizing of the assembly time. Key guidelines: ease of access, minimising of part count, easy lifting of heavy components by crane
2. Parallel assemblability – the concept allows the desired entities to be sub assembled, possibly by a subcontractor. Key guidelines: realisation of desired groupings, independence of the subassemblies

3. Assembly sequence – the concept allows a desired assembly order so that components having the longest delay from order can be assembled last and/or the invested capital on a non-finished product is minimized. Key guideline: realisation of a desired assembly order.
4.-11. Serviceability of components A-H - minimising of service operation times. Key guidelines: ease of access, minimum need to manipulate components that are not targets of the service operation considered.

In the concept evaluation, the design team consisting of five designers discussed and considered how well the key guidelines had been realised. In the evaluation, the team had 3D models and visual form representations of all the concepts available. The design team consisted of a mechanical designer, a mechanical designer with extensive expertise in the key technology in question, an industrial designer, a designer with expertise in conceptual design and designer with expertise in DFA. All the designers gave a rating for each requirement; a number between 1 (poor) and 5 (excellent). The final rating for the respective requirement is an average of these five individual ratings. In comparison of overall assemblability and overall serviceability, averages of the three assemblability ratings and eight serviceability ratings are used.

3 Results and analysis

Results of the evaluation regarding to assemblability and serviceability of the individual concepts are presented in figures 1-5. Pictures of the concepts are presented in table 1. Because of confidentiality reasons, only visual form presentations of the concepts are presented.

In figure 1, ratings of the concept "Compact" are presented. This concept has weaknesses in assemblability, but is good in five out of eight serviceability requirements. In this concept, the volume of the device is minimized, leading to access difficulties and difficult lifting operations in assembly. Some components are easily serviced, some require disassembly of other components.

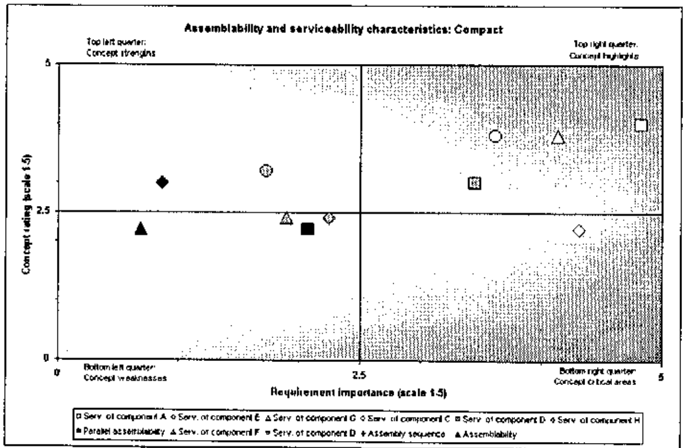

Figure 1. Assemblability and serviceability ratings of the concept "Compact"

Figure 2 presents the ratings of the concept "Core" that has a process-oriented layout of the components. In this concept, three of the serviceability requirements are in the critical area (high requirement but weak fulfilment)

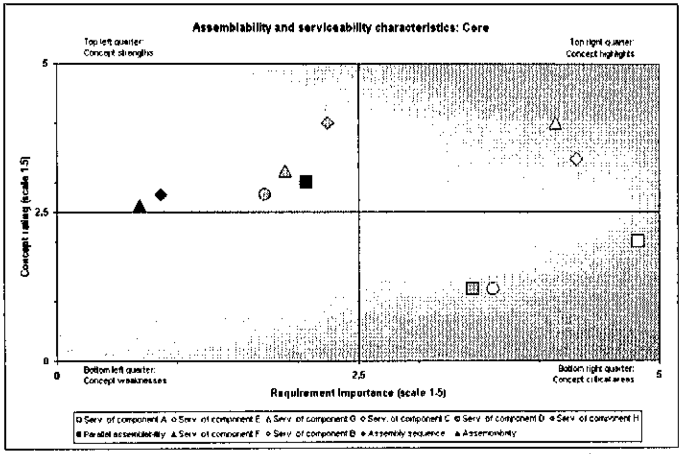

Figure 2. Assemblability and serviceability ratings of the concept "Core"

The concept "Floor" also has three important serviceability requirements in the critical area, and also parallel assemblability is considered a weakness, see figure 3. However, all the requirements are relatively evenly distributed around the 2,5 –rating line.

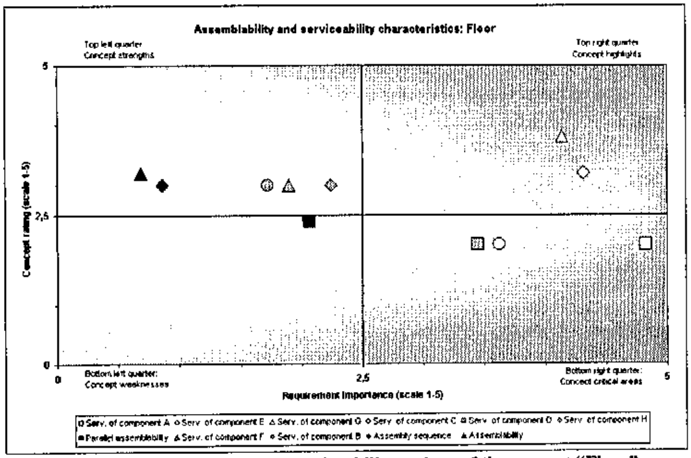

Figure 3. Assemblability and serviceability ratings of the concept "Floor"

The concept "Tower" seems to be an exception in the assemblability / serviceability correlation (figure 4). Assemblability is a strength of this concept, all the three requirements are above the 2,5 line and average of the three is 3,6. However, the concept is weak in five out of eight serviceability requirements. In this concept, a difference between factory assembly and disassembly – service task – reassembly is brought forward. In the assembly stage, the assembly sequence allows good access to components being assembled, but in the field service operation, other components must be manipulated in order to reach the target component. Also, the correlation is decreased by a conscious compromise of making the most important service operation easy on cost of making the less important more difficult.

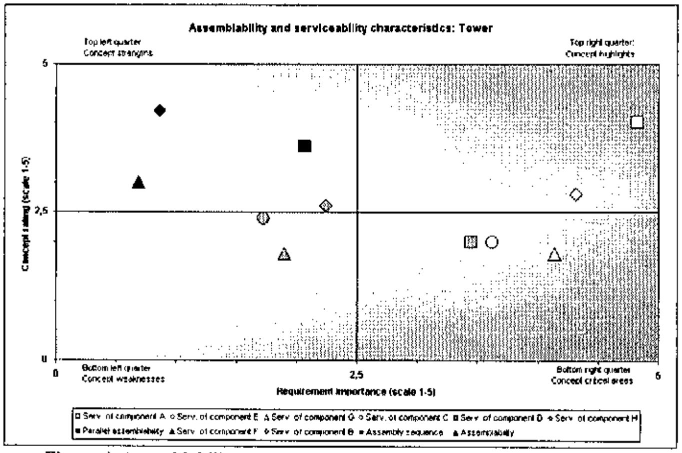

Figure 4. Assemblability and serviceability ratings of the concept "Tower"

The concept presented in figure 5, "Wall", is an example of systematic correlation between assemblability and serviceability. This concept has a shape and structure that allows independent assembling and service of the components with easy access.

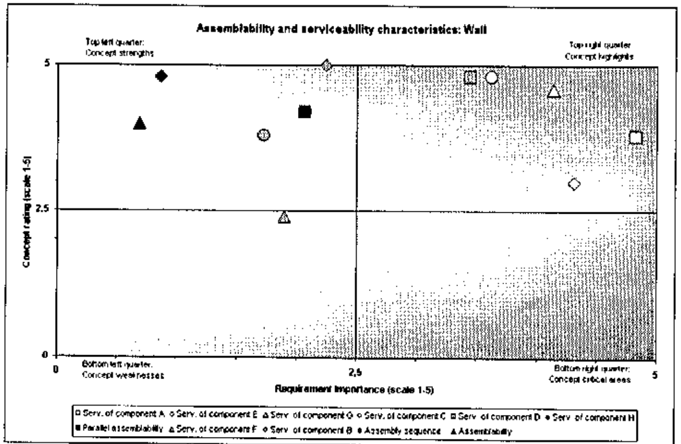

Figure 5. Assemblability and serviceability ratings of the concept "Wall"

In table 1 the averages and deviations of all the assemblability and serviceability ratings are presented. "Compact" concept has the worst overall assemblability average as a result of a compact and most integrated structure. Assemblability of "Core" is better but its serviceability is worse than that of "Compact", due to that some of the service requiring components are in the middle causing access difficulties. This is also shown as a high deviation between the serviceability ratings. "Tower" has the lowest serviceability average although the assemblability average is the second best. "Wall" has the best averages in both. Deviation of serviceability ratings is also high, but the scale of the ratings is from 2,5 to 5, as seen in figure 5.

Table 1. Averages and average deviations of the assemblability and serviceability ratings

	Compact	Core	Floor	Tower	Wall
					
Overall assemblability, average	2,47	2,80	2,87	3,60	4,33
Overall Assemblability, average deviation	0,36	0,13	0,31	0,40	0,31
Overall Serviceability, average	3,10	2,73	2,71	2,43	4,03
Overall Serviceability, average deviation	0,57	0,94	0,56	0,53	0,78

In figure 6 the overall assemblability and overall serviceability is presented in a graphical form. It can be seen, that considering the concepts "Compact" and "Tower", the averages are far from each other. In the other three the overall assemblability and overall serviceability are in practice the same. In figure 6, the concepts are from left to right in order of increasing overall assemblability rating.

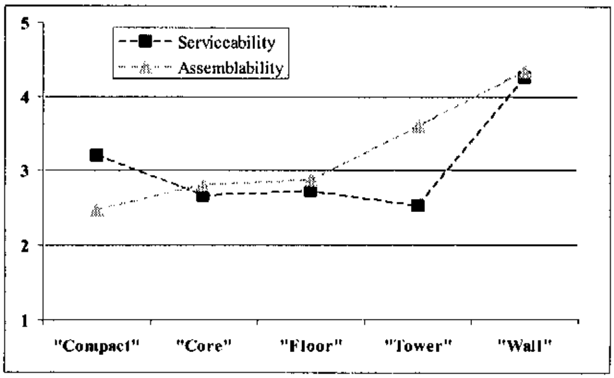

Figure 6. Overall assemblability and overall serviceability of the concepts

4 Discussion

In this case study quantitative analysing of assemblability and serviceability was not considered feasible. At the concept development stage for this particular product, about 75 % of the parts are not yet present in the model. The concepts could have been analyzed with for example the Boothroyd DFA method, but the resulting assembly time in seconds would have been far less than it will be in the finished product. Scaling of the results by some probable factor of parts or operations in the finished product is doubtful because of the differences in degree of completeness in different subsystems. This would have depreciated the value of the result of a quantitative analysis: The analysis results would have been numbers that can be compared to others, but they would not have had meaning in calculating real labour costs. However, estimation of concept's potential also in assemblability and serviceability in the very early stage is fruitful. Because of these reasons, we found it feasible to do the evaluation on a subjective basis together with 17 other requirements evaluated by the same method at the same time.

In the evaluation, the same people that designed the concepts evaluated them. The given ratings are thus subjective, leaving also the possibility of "ugly baby syndrome" [Boothroyd et al.02]. In the evaluation situation every requirement was however discussed and decisive facts were found, that then were weighted subjectively to form an individual rating. Considering the early stage of design process and available information, we believe that the method used gives reasonably valid results.

In the results two of the five concepts cause exceptions in the correlation of assemblability and serviceability. In the "Compact" concept, assemblability and possibilities of parallel assembly are weaknesses due to tight packaging, but many of the service-requiring components are accessible. In the "Tower" concept, it is the opposite: overall assemblability is good but service operations require manipulating of components that are not targets of the service operation in question. Dewhurst and Abbatiello state that with poor access or inappropriate securing methods a good DFA redesign can be more difficult to service [Dewhurst&Abbatiello96]. This seems to work also the other way around. If components are more easily accessed for service, assembly can be more difficult due to limited possibilities in realising a rational assembly sequence. Also, the difference in nature of initial assembly in the factory and service operations in the field is notable and dependent on the assembly sequence. Naturally, labour costs in the assembly and labour together with down time costs in field service are very different. Final optimising between these two can be calculated with reasonable accuracy only after much more design hours are used.

5 Conclusions

Although DFA is considered to be a mature field in design science, the other DFX methods are younger. There is relatively little data on simultaneous use of multiple DFX methods, and their influence in the product. In addition, the use of quantitative analysis methods in the concept stages of product consisting of hundreds of parts is complicated due to the lack of information.

According to the results in this case study, there seems to be a correlation of assemblability and serviceability, but that correlation can also have discontinuities. After selecting the concept having a good potential in both and obtaining more information further in the design process, a quantitative analysis is feasible in optimising the more detailed design alternatives. At the later stage also new guidelines become an issue. For example the number of tools needed to carry out a service operation that could not be determined at the stage considered.

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