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METHOD FOR ALIGNMENT OF PRODUCT AND PRODUCTION CONCEPTS

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1 Introduction

The right use of modular product architectures can help companies provide a great variety of customized products at a competitive price level, by reuse of knowledge, components, processes and utilization of economies of scale in many of the activities that are necessary to provide products for customers.

Modular product architectures often serve as a basis for several products often referred to as product families. One or more product families may constitute a substantial amount of the total product portfolio of a company, and it is, therefore, of the greatest importance that concepts and solutions are evaluated thoroughly throughout the design phases because any design fault is likely to propagate to a large part of the business.

Developing modular product architectures is therefore also the task of ensuring a fit between the products that can be made on the basis of the architecture and the production system upon which manufacturing will take place. This fit is referred to as *alignment.*

The aim of this paper is to present a new design method that can help design aligned modular product and production architectures. The method has been applied and evaluated at the Danish company Danfoss Industrial Controls. The method consists of two tools and a guideline on how to use these tools.

2 Research method

The work presented in this paper is based on the theoretical foundation presented in the Theory of Technical Systems [1], The Theory of Domains [2] and the Theory of Dispositions [3]. We have made use of two important approaches that has formed the basis of the work:

- A study of state of the art literature within relevant design methodologies and tools and logical reasoning upon those references
- Development of new methods/tools and a study of a third party applying the methods

On the basis of a literature study and on the basis of practical experiences gathered from the case company, Danfoss Industrial Controls, we have developed a method consisting of a set of design tools and a guideline and then tested these in the following way;

First we observed engineers using the tools to develop product concepts. Second we observed management using the tools. Management used the tools to decide on how to produce the different developed product concepts, and to evaluate the overall organisational implications of different product concepts.

We have worked as facilitators of a process while the reasoning and decision-making regarding the actual products and processes has been made by the employees at Danfoss. Thereby we have tried to base the conclusions on what we can see from a practical application of the tools and not only from our own perception of the implications of the tools.

We have had two iterations where the tools has been refined before presentation in this paper. After an initial test we changed the layout of the tools to accommodate comments from the people involved in the project.

3 Modular product architectures

In fact, any product has an architecture, yet the term becomes useful once we manipulate the architecture to obtain one or more specific effects. The *modular* architecture is characterized by standardized interfaces among physical subsystems. A product architecture contains design rules and a specification of how the physical structure of the products fits into the functional structure. Once the architecture becomes modular, there is a good fit between the functional and the physical structure of products. This is due to the separation of functions into the subsystems in a way that ensures that changes of the characteristics of one part of the product will propagate only in a minimal degree to the remaining physical components and subassemblies of the product. It will also ensure that a large proportion of the product can be interchanged and used in other products, due to the way functions are supported by the product and the way the interfaces are made. This way of designing products can improve engineering variety and manufacturing flexibility and reduce the resources needed to engineer a customized product. This is largely due to the reuse of knowledge, components, processes and manufacturing equipment and the reduction of the effects of complexity in the total product assortment.

A documented modular product architecture often serves as a basis for a whole range of products and not just a single product. This range is often referred to as a product family. The architecture sets up possibilities and limits of the design of those products that can be *derived* from the architecture. This is to keep focus on solutions that will fit well into the product assortment and the key competences of the company, thus keeping the company from sub-optimising single products at the expense on the portfolio in general.

The documentation of the architecture needs to serve as a design template for those product families that can be derived from the architecture. Designing the architecture then becomes the task of preparing the design activity, while engineering of customized products becomes the execution of the actual design activity. Thus the main difference, when designing product architectures for a family of products rather than single products, is the split between preparation and execution efforts.

The architecture becomes the media in which the possible designs are documented. Target product specifications, specifications of interface and characteristics of subsystems and other such aspects from the architecture document the range of products that *can* be derived, but are not necessarily derived. The architecture is a kind of solution space that has to be maintained and planned in accordance with the portfolio management of the company [4].

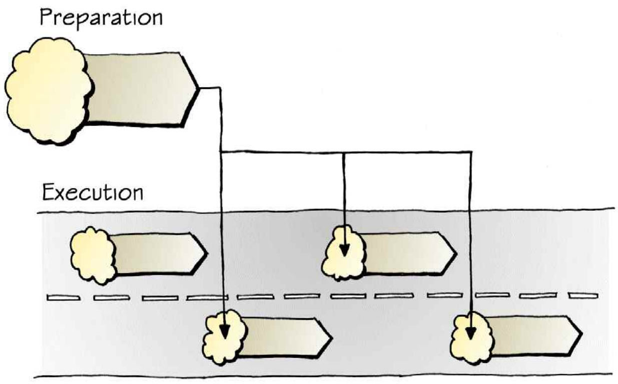

Figure 1. When designing modular product architectures, companies can split preparation and execution of engineering tasks. The architecture serves as a design template consisting of standardized solutions, designs and of knowledge, from which single products can be derived. A highway is used in the figure as a metaphor to represent the increase in time-to-market.

Fig. 1 represents the notion of having an architecture that sets up the possibilities of the products encompassed by the architecture. Standardized and reusable design and knowledge help speeding up the engineering/customizing process due to the high degree of preparation. Thus, a stream of derived products can be developed with short time-to-market and great speed, hence the metaphor of a highway upon which engineering and customisation can occur fast and efficiently.

This idea of a split can support the mindset behind the *knowledge space* used by Toyota and explained as *set-based concurrent engineering* [5][6]. Set-based concurrent engineering is referred to as a tool to reach a more lean development process, and often mentioned in relation to lean manufacturing, yet the only similarity between these two concepts is probably the Japanese origin and the fact that they are derived from the same kind of organization.

Whether the overall corporate objective of companies is to become lean, to utilize mass customisation or to gain from the benefits of a modular product architecture, the main constituent necessary to reach such goals is to distinguish the development of single products for a unique purpose from the development of knowledge and standardized solutions. These standardized solutions can be physical, conceptual or product related knowledge as for example well-known trade-offs between design parameters and product characteristics documented as trade-off curves or other such documentations of test results.

The distinguishing between preparation and execution in both cases (that of product architectures and set-based concurrent engineering) is an important paradigm shift in many modern companies of today, and a shift that many companies have yet to accomplish.

3.1 Aligned product and production architectures

In the previous discussion of modular product architectures focus was kept on products. It seems though that there is a need for encompassing more than just the engineering view of the architecture. A given product architecture design has to have some sort of fit with e.g. the manufacturing set-up in order to have mutual alignment between the structure of derived products and the production equipment upon which the manufacturing takes place. The internal interfaces among components/sub-systems in the product are not the only demarcations that should be addressed during design of the architecture. Product external fits between components/sub-systems and the production system are also important. If all components handled by e.g. the same pick'n'place unit have the same gripping surface to the unit regardless of the product variant in which they are used, then several different products can make use of this one production unit without difficulties in change-over.

Aspects like outsourcing, assembly and even the whole supply chain management in general are also highly affected by the structure of the derived products. If the product architecture fits well with production on both a corporate, family, product, structure and component level, we say that the product architecture is *aligned* with the production system architecture (fig. 2) [7].

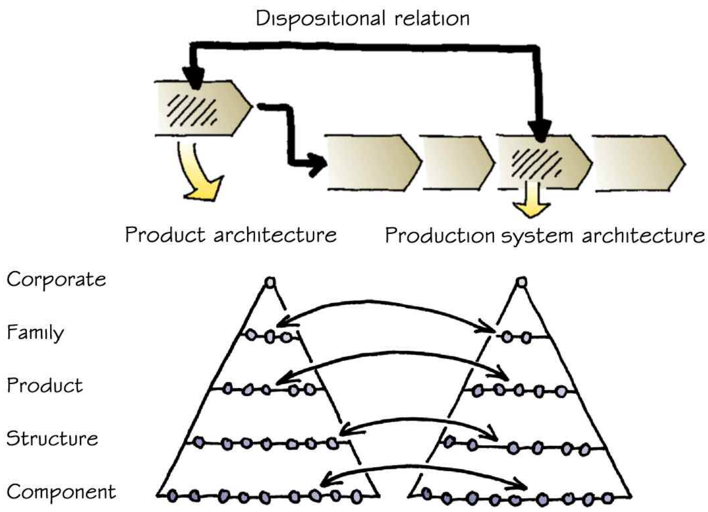

Figure 2. Alignment between the product and production architecture. Aligned architectures will create a fit between e.g. production lines and product families, processes needed and components used, or tooling and detailed geometries [7].

All of the life phases of the derived products should ideally be encompassed by the architecture, yet in this work we have focused on the alignment of products and production systems. In integrated product development [8], are market aspects are included to form an approach consisting of three parallel yet integrated chains of activities, namely those related to market, product and production aspects.

In relation to the implications of modular product architectures, we clearly see a need for design methods that support engineer's ability to design for product families (and not single products) and the aligned co-related production systems based on an architecture. Not only do this method need to support the development of several products. It also needs to ensure a concurrent development of production technologies and process concepts.

Alignment of products and production architectures, therefore, becomes a key issue in such a method.

3.2 Design method objectives

Visualization and communication of design ideas is often a crucial part of the convergence towards specific design solutions. However, the ability of an engineer to create good technical concepts does not always go hand in hand with his or her gifts as a sketcher. Moreover, design team members with a non-technical background do not always have the training to draw technical concepts. If somehow the alternative solutions and a graphical representation of those can be prepared before the actual generation of concepts, then a great variety of people can get involved in the creation of concepts. People from marketing, management, production, engineering and research all have specific backgrounds and agendas, and they almost certainly have different opinions as to what constitutes a good solution.

The modularity of products also demands another property of the method, which is the ease of modelling alternative placements of interfaces in the product. Graphical representations of sub-solutions, which can be easily interchanged and used to build up alternative concepts, will provide an interactive tool to synthesis. Another benefit would be that alternative solutions are presented in a uniform style ensuring an equal evaluation of concepts and an equal perception of solutions in the minds of the members of the development team [9].

The background of the work presented in this paper is a belief that such a tool can make development of modular product architecture based products more efficient and effective and help a variety of people converge towards an optimum solution. The tool should;

- constitute an interactive tool for modelling and visualizing *alignment* between product and production architectures.
- visualize effects on possible production layouts arising from the manipulation of *modules* and *interfaces* in the products.

First, we will discuss to what extent present methods and tools fulfil these two demands.

4 Existing design methods

The generic idea behind the use of modular product architectures has many similarities with those of lean product development and in particular set-based concurrent engineering. Therefore approaches to modular product architecture design and set-based concurrent engineering will be discussed briefly in the following.

4.1 Set-based concurrent engineering

Toyota’s system of set-based concurrent engineering is different from ’traditional’ US and European product development in the way decisions are sequenced and made.

Traditionally a few concepts are developed and detailed to a certain level of concretisation, the strongest concept then chosen and refined even further until a final product occurs. A large proportion of testing and verification is done after the organisation is committed to the chosen concept, which makes this approach sensitive to unforeseen technical problems, a sudden change in market demand or other changes in project prerequisites.

Set-based concurrent engineering on the other hand is an approach encouraging that several concepts be kept ’alive’ simultaneously throughout the development phases, and that as much prototyping and testing on alternatives is done as early as possible, even though many of the things tested might never end up in the final product. One of the cornerstones is that these tests and any other knowledge developed during the project will be documented in a standardized media and transferred to a ’library of knowledge’, a knowledge space containing the entire competence of the company. This makes the knowledge reusable. Thus, the engineers have a responsibility to ensure high quality of products (from a relatively short-term project perspective) and to ensure that the knowledge of the company is strengthened and maintained (from a long-term corporate perspective). A way to support this dual development of knowledge is Toyotas matrix organisation with the responsibility of core technologies (represented by so-called functional managers) split from the responsibility of projects (represented by so-called chief engineers i.e. product/project managers).

This resembles our notion of a product architecture that contains the design rules and the product projects in which the derived products are developed. Thus, the split of preparation and execution is also found at Toyota.

It is not possible to find references that elaborate on the alignment of products and production systems in the context of set-based concurrent engineering, and there are no concrete methods as to visualize concepts interactively, which are the two constituents of the method presented in this paper (as discussed in the previous section).

We, therefore, claim that the tools presented in this paper can be very supportive to a set-based concurrent engineering approach because of the ability to visualise and model concepts more freely and creatively - even on the basis of the strictly standardized knowledge contained by the knowledge space.

4.2 Modular architecture design methods

We now discuss a few modular product architecture design methods. A few of the most interesting methods are;

- Function-based / Heuristics
- Modular Function Deployment
- Design Structure Matrix

The term function-based modular design methods actually covers many somewhat different methods that build on the common strategy of identifying possible modules by modelling the product functional structure and striving to create a modular architecture following the functional structure [10]. One of the most acknowledged methods for clustering elements in the functional structure into modules is a heuristic function-based reasoning [11]. This method set up functional definition rules for the generation of a functional structure. Having the functional structure strictly based upon these rules, the heuristic defines three principles to identify three different types of modules: *dominant flow, branching flow,* and *conversion-transmission* modules.

Generally, these function-based design methods focus on structuring the combination of modules and interfaces to optimise functional commonality within the modules seen from a product point of view and not regarding interaction between the product and e.g. the manufacturing equipment.

Modular Function Deployment (MFD) [12] on the other hand identifies modules using a 12 so-called *module drivers*. Instead of only focusing on the manufacturer’s ability to derive a variety of functional different products, Erixon introduces these drivers to point out some elements of the product into a module. The MFD considers relationships between the components or sub-systems of a product and the 12 modules drivers and create in this way alignment between the modular structure and the functional areas related to the drivers. If a number of components have a strong relationship with one of the drivers and no particular relation to other drivers, this could be a reason to cluster these components into a module.

Unlike MFD, the Design Structure Matrix (DSM) method base the identification of modules on relationships between the physical components or systems in the product [13]. DSM basically decomposes the product into components/systems and identifies the interfaces/relations between these. Algorithms are then used to cluster components closely related into modules.

As mentioned earlier the real effects of modularising a product are not visible seen only from a product point of view. Only when the modular product architecture is aligned with e.g. the production set-up it is possible to benefit from the strength of modularisation. One potential weakness of the methods mentioned above is the lack of focus on aligning the modular product concepts with other aspect in the product life cycle. Only MFD has elements towards alignment by introducing e.g. *separate testability, service/maintenance,* and *supplier availability* as module drivers.

The methods discussed above are developed to the use of mainly design engineers or people with a technical background, which more or less prevent the participation of other stakeholders in the conceptual design process. These methods are heavy in use and not very stimulating for the dynamic process of evaluating alternative concepts.

Based on what we can see in literature on modular product architectures, we also (as in the case of set-based concurrent engineering) see a need for a tool that can help design aligned product and production architectures and serve as an interactive and creative tool to visualize the effects on e.g. the production set up from different ways of making interfaces in the products.

4.3 Discussion of set-based in relation to modular product architecture design

Literature within product development reports great results to be achieved by companies using modular product architectures, yet focus is often on single products rather than product families. Literature on modular product architecture does, however, bring forward the notion of the architecture as containing the knowledge and standardized designs prepared so that they fit into the totality of the product portfolio. In other words, the architecture sets up design rules for physical building blocks, and these physical building blocks will often be manufactured and used over several generations.

Those parts of literature inspired by the lean philosophy see the preparation as more abstract and knowledge-oriented, consisting of documentation of excepted product characteristics, i.e. design rules on a higher level. Reuse of components and subsystems is also reported in such references, yet there is a lack of concrete methods as to how this reuse should be documented.

No references in literature elaborate on a combination of tools related to lean product development (and what we might call the studies of Toyota best practice), such as set-based concurrent engineering, lean development [5][6], multi-project management [14] and a modular product architecture approach.

The overall objective in both strategies is the same, i.e. to split preparation and execution, and thereby to make the most efficient use of the knowledge in the company and to provide the most effective engineering activity with the shortest possible time-to-market.

We claim that the method presented in this paper is beneficial in both a lean development/set-based context and a modular product architecture context or a combination of both.

5 Method/tool development

The idea behind the method is to modularise the concept process similar to the way products are modularised, meaning that the process will be divided into two phases: a preparation phase and an execution phase. This split is not to be confused with the split of the whole engineering phase. Here it is only the concept phase that is to be split.

Modularisation of products is often visualized using a jigsaw puzzle as a metaphor where the individual pieces represent a module (or a sub-system). The pieces are then combined to form the larger picture or in this case the complete product.

As mentioned earlier the real effects of modularisation are only visible in context with e.g. the production set-up - that is when the product architecture is aligned with the production architecture. Thus we need a similar tool to develop the production simultaneously with the product.

The method presented in the following is a realization of this modularisation metaphor. We use the word *method* to denote the whole step-wise procedure and the word *tool* to denote the tool iteself (the two puzzles respectively that will be discussed later).

5.1 The puzzle

Using the puzzle metaphor as a tool for modularising the process of developing products and the coherent production set-up clearly divides the process into two phases (fig. 3):

- Preparation: Identifying and modelling the puzzle pieces
- Execution: Assembling the puzzle and reading the created picture

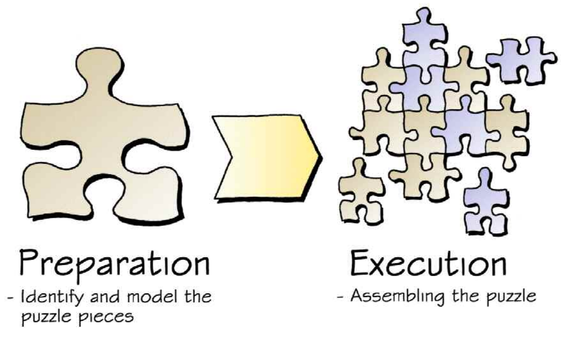

Figure 3. The puzzle divides the concept developing process into two phases: a. the preparation phase where the puzzle pieces are identified and modelled, and b. the execution phase where the puzzle pieces are assembled to form a bigger picture.

In the preparation phase, the puzzle pieces are fabricated. This includes identifying possible modules and interfaces (i.e. the product architecture), identifying possible solutions to the realisation of each module/interface, and identifying supporting manufacturing processes.

The execution phase is simply the assembling of the puzzle pieces. The pieces are prepared in a way to allow different combinations of puzzle pieces (or sub-solutions and processes) unlike a traditional puzzle. From the combination of sub-solutions, it is possible to form a broad variety of products and production set-ups very efficiently, as all the pieces are prepared beforehand.

The developing process leads to five steps using the puzzle as inspiration for modularising:

1. Identify a generic product structure including possible modules and interfaces
2. Identify possible sub-solutions to the design of modules and interfaces
3. Identify possible manufacturing processes supporting the sub-solutions from step 2
4. Prepare the puzzle pieces, visualising solutions from step 2 and 3 in an abstract and simplified way
5. Combine sub-solutions
6. Create aligned product and production concepts

These steps are further described in the following.

1. Identify a generic product structure including possible modules and interfaces

The first step in creating the puzzle is to identify the structure of the puzzle, i.e. describing the positioning of the interfaces and the functionality of the different modules. Thus, it is necessary to identify all functional elements of the products, and afterwards structure these elements into modules and interfaces.

In the case of reengineering, making a *function - means tree* [15] (fig. 4) can be a powerful tool to support establishing an overview of the functional structure of a product. It is important not to detail the function-means tree to the lowest level of abstraction. Doing this will only reduce the creativity and increase the complexity when searching for solutions.

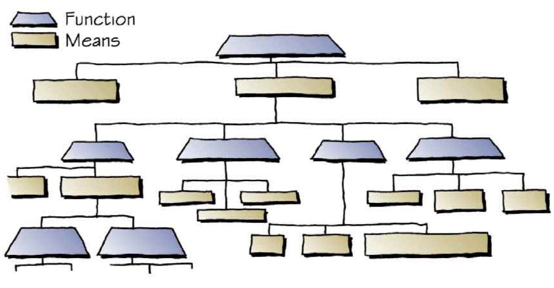

Figure 4. The function - means tree is a tool that can support the identification of the functional elements of the products and the means to realize these functions.

Having established an overview of the functional elements, the task is now to position these elements into a generic physical structure. This generic structure is the foundation of the product puzzle. If we avoid integration or strong dependencies between the elements, the result will be a function-based architecture.

An important part of defining the generic product is to identify which elements should be generic and which elements could be subject to changes, i.e. which puzzle pieces should always be a part of the puzzle and which pieces can be substituted to allow different combinations (fig. 3). Identifying generic and variable elements is a task of understanding customer's needs. In the Danfoss case study, the main input to this task was research on the existing product portfolio, standard options as well as specials. In this case, this gave sufficient statistics to identify which features has been customized to meet a specific customers needs. This study of product history might not be sufficient in other cases, and must then be supported by a suitable market analysis.

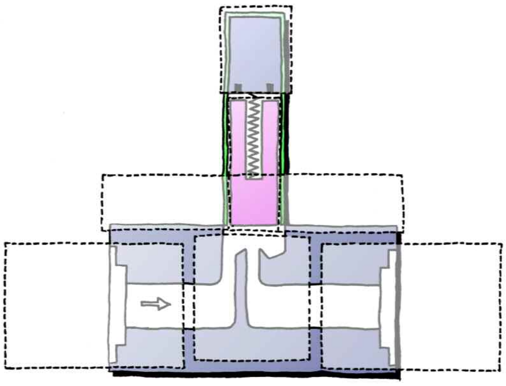

Figure 5. The identified generic structure of a solenoid valve from the Danfoss case study. The dashed rectangles are the elements which are subject to changes.

Once the generic structure is identified, it should be visualized to make up the foundation of the puzzle. The trick is to illustrate the entire product at a suiting level of abstraction where the illustration does not give away details of how the product is designed and yet describe the overall structure of the product (fig. 5).

To illustrate which elements of the structure are generic and variable respectively, the variable elements are marked with a dashed line enclosing the element (fig. 5). To describe the product in details, the dashed areas need to be filled in.

2. Identify possible sub-solutions to the design of modules and interfaces

In the generic product structure, we have defined a number of dashed areas that represent sub-problems to which solutions need to be identified, i.e. means to realize the sub-functions in the function-means tree.

The search for solutions to fill out the dashed areas calls for both systematic and creative problem-solving methods. In the Danfoss case, a long history of delivering customer specific products has meant the use of many different solution principles to realize the sub-functions. Thus, a large number of solutions could be identified simply by studying the existing product portfolio, although the need for more creative methods cannot be ignored.

3. Identify possible manufacturing processes supporting the sub-solutions from step 2

The product sub-solutions identified in step two call for manufacturing processes that support the product solutions. Some product solutions may be realized by several different manufacturing processes with coherent advantages and disadvantages. To see the real effects of the chosen processes, a production puzzle was prepared similar to the product puzzle used in step 1 and 2.

Like the generic product structure serves as a template in the product puzzle, a template was also identified for the production puzzle. This template (fig. 6) represents a single workstation in the production layout. The workstation should be described in three dimensions:

- Transformation of materials, input, output, etc.
- Processing like machining, welding, etc.
- Handling of components and products

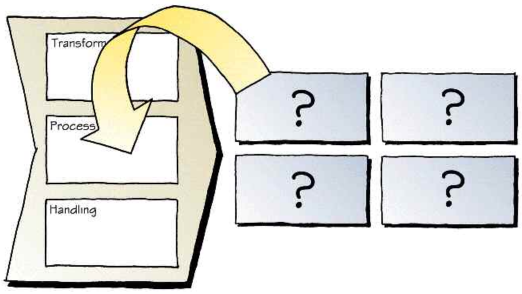

Figure 6. A single workstation in the production layout is symbolized by the transformation (what happens), the process used (how it happens), and the handling (level of automation).

The transformation block simply describes the purpose of the workstation, i.e. what happens at the workstation. The process block defines the manufacturing processes chosen to perform the transformation, i.e. how the transformation happens. Finally, the handling block is used to describe how the process is handled, i.e. is the process handled manually or fully automated?

From the sub-solutions found in step 2, a number of needed transformations are identified. Following a number of alternative manufacturing and handling processes can be found.

4. Prepare the puzzle pieces by visualising solutions from step 2 and 3 in an abstract and simplified way

Having searched and found a wide range of solution alternatives, both product and production wise, the sub-solutions should be converted into physical interchangeable puzzle pieces that fit into the respective templates.

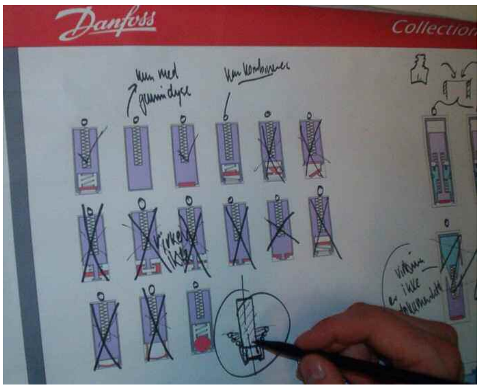

Figure 7. Collecting alternative sub-solutions on one board initiated a number of new solutions as well as an evaluation and deletion of other not promising alternatives.

It is important in this process to maintain the same level of details and styling on all puzzle pieces, like when choosing between different concepts. They need to be detailed to the same level to be able to perform an objective choice of the best promising concept, or elimination of the weakest ones.

All sub-solutions are then collected on one board representing the space of solutions. An early evaluation of the solutions on the board initiated deletion of some solutions and the creation of new alternatives (fig. 7).

5. Combine sub-solutions

With all product and production puzzle pieces prepared it is now time for execution. The extent of the preliminary work makes the execution phase very fast and interactive and the participants are able to combine sub-solutions into total product and production concepts at a fast rate (fig. 8).

In addition, the preparation of the puzzle pieces decreases the demands to the participants' skills to express themselves visually, why stakeholders, who are normally not able to contribute in the early concept phase, can participate when using this method. This of course increase demands on making the puzzle pieces understandable to the participating stakeholders.

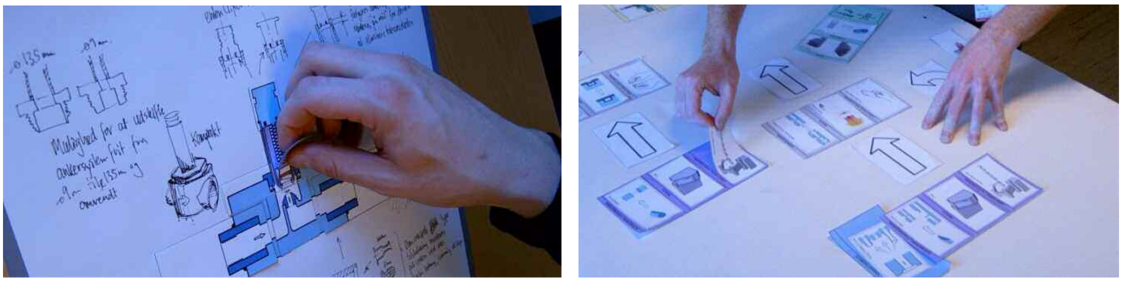

Figure 8. Combining different sub-solutions to visualize alternative product and production concepts. Note that there are added remarks to the concept beside the template of the generic product structure. This could e.g. be remarks on possibilities/constraints linked to the choice of a given sub-solution.

As fig. 8 illustrates, space is made available on the product template (on the left) to add details if necessary, e.g. small changes to one of the chosen sub-solutions or remarks on which possibilities/constraints are linked to a given sub-solution.

6. Create aligned product and production concepts

Using the product and production puzzle simultaneously clearly demonstrates which effects choice of a giving product sub-solution has on the production set-up and vice versa (fig. 9).

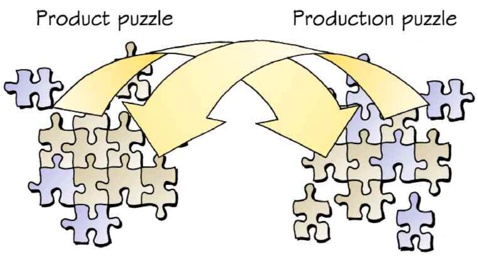

Figure 9. Using the product and production puzzles simultaneously enhances the process of aligning product and production concepts and hereby reach truly positive effects of modularising the product portfolio.

This ability to model product and production concepts simultaneously and interactively improves the chance of creating aligned product and production concepts significantly.

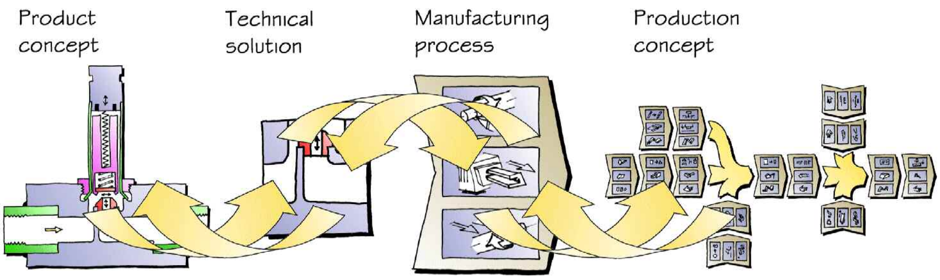

Figure 10. The principle of aligning architectures using the two puzzles. The product concept consists of several sub-solutions or technical solutions. Each of these solutions corresponds to a transformation that has to take place in the manufacturing set up. The process chosen corresponds to the overall set-up, hence the layout of the production depends on the product concept and this dependency is modelled and visualized instantly.

Fig. 10 shows the principle of aligning architectures using the two puzzles. The product concept consists of several sub-solutions or technical solutions. Each of these solutions corresponds to a transformation that has to take place in the manufacturing set-up. The process chosen corresponds to the overall set-up, hence the layout of the production depends on the product concept and this dependency is modelled and visualized instantly. Once the dependency is optimised in accordance with the best possible product concept and the best possible production set-up, we might say that the product and production architectures are aligned.

6 Case study: Danfoss Industrial Controls

The Danish manufacturing company, Danfoss Industrial Controls, has launched a pilot project covering the possibilities of introducing new modular product architecture as a basis for their solenoid valve product portfolio. The main objective of the architecture is to support the customisation of engineering-to-order products.

The method described in this paper has been used in the conceptual phases of this industrial project. In the preparation phase (steps 1-4), the participants using the method were primarily engineers from production and especially product development. In the execution phase (step 5), managers from different functions (e.g. marketing, logistics, purchasing, etc.) in the company was brought in to participate (and only a couple of engineers remained) to create a multi-competent discussion forum. The preliminary work with the fabrication of the puzzle pieces creates a common language in which the stakeholders could communicate their opinions on the future modular product architecture concept.

Results from the pilot project proved it probable to increase Danfoss' speed and responsiveness towards customers significantly when handling customer request using the new product platform concept and hereby reduce time-to-market, which was identified to be one of the most critical success factors in the customers' supplier selection.

7 Discussion

The use of this tool has its main application area in developing product families from modular product architectures, as alignment between product and production concepts is of the greatest importance here. Investing time and resources in ensuring that there is a proper fit between these two aspects pays off in any project (thus also in single product optimisation), but especially when several products are developed, as the risk is much more profound.

A limitation of the range of application is clearly the need for a generic product structure to serve as a template for the product puzzle. To identify such a structure, a common understanding of the structure in the future products is needed.

The method presented in this paper includes puzzles describing effects in the product and production concepts. Effects in other aspects of the concept (e.g. market aspect) could be interesting to visualize with a similar tool to support the alignment between market and product. This market puzzle should e.g. visualize the effects on performance of the product portfolio when choosing one sub-solution from another.

8 Conclusion

The method brings the rather abstract notion of product architecture to an operational and concrete level ready for the use of engineers in practice. Most methods for synthesis of product architectures are driven by either mathematical reasoning, methods of systematic clustering based on function analysis or drivers for improvement of products. These approaches do not constitute a concrete tool for engineers that are engaged in practical product development and do not visualize concepts or serve as a media with which a diversity of design team members can communicate. We claim that our method supports these aspects very well.

The method also supports development of aligned product and production architectures i.e. architectures that ensure a fit between products and production systems. The interactive nature of the method also encourages production to take a very proactive role in developing concepts to ensure real concurrent engineering. From our industrial application of the presented method and from the reactions we can see from the people involved in the use of this method, we can clearly state that the method has proven to be useful when developing concepts for aligned product and production architectures.

We have worked as facilitators of a process while the reasoning and decision-making regarding the actual products and processes has been made by the employees at Danfoss. Thus, this method is useful for structuring the knowledge that is present in a company and it supports the experts in the organisation to utilize their knowledge in a structured way in the creative process of making concepts.

We feel that this method is relevant to all companies interested in product architectures, lean product development, set-based concurrent engineering or other such improvements of the development efforts.

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