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DESIGN FOR VARIETY – EFFICIENT SUPPORT FOR DESIGN ENGINEERS

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1. Introduction

The intention to fulfil more and more sophisticated customer requirement has led in recent years to a continuous increase in the number of product variants. Therefore companies have to deal with two important tasks.
One task is to constantly adjust their range of products to reduce costs of complexity, which are induced by unnecessary product variants. The product development has to perform a different task. The challenge here is to minimize the internal complexity and its resulting costs without reducing the range of products. This activity is here referred to Design for Variety (figure 1).

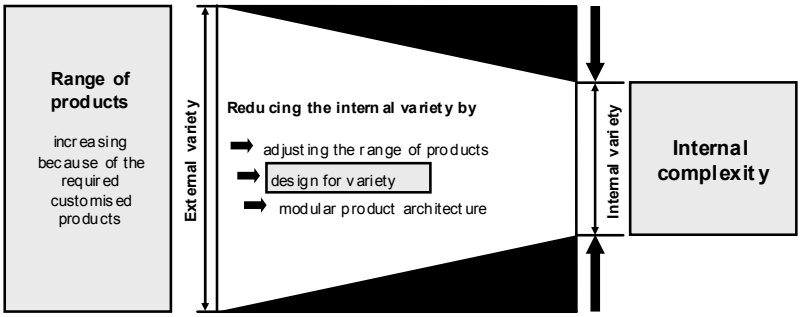


Figure 1. Intention of the Design for Variety

The intention of this paper is to supply an efficient support for design engineers developing products with a huge amount of variants. Therefore a compilation of Design for Variety guidelines is developed based on a literature research and the analysis of existing products.
Subsequently the guidelines are categorised and similar to the well known design for assembly guidelines [Pahl2007] illustrated. Thereupon the benefit of these guidelines is discussed on a product example.

2. Related literature

Below important studies in the field of the Design for Variety are presented, the main focus of each study is described and especially contained assumptions of good Design for variety are presented. Because a well-defined differentiation between the development of product architectures and the

Design for variety is hardly possible, every assumption which affects directly the product design is mentioned.
The term “Design for Variety” was established by Martin and Ishii [Martin2001]. They described in „Design for Variety: developing standardized and modularized product platform architectures” a methodology for the development of architectures of products with a huge amount of variants. This methodology is based on indices. The determination of these indices is not only useful for the evaluation of product architectures; it also creates a deeper understanding for the coupling between functional elements and for the estimated changes between current and future generations of the product. One presented possibility for the implementation of Design for Variety is the “increase of headroom of the specification”, which generally can be referred to as “overdesign”. The second mentioned approach is to add elements, in this case extension elements, to adapt the specific requirements of each variant.
Caesar [Caesar1991] presents an integrated approach for the development of mass products with a huge amount of variants. This approach is created as a synthesis of the VDI guideline 2222 and FMEA method. Once more the main focus was the development of product architectures for variety, which means in this case product modularisation with regard to the variety of the product. Within in this study assumptions on good design for variety were established and verified.
Based on the observation that costs for every new variant of a subassembly are declining with the number of already existing variants, a clear differentiation between standardised subassemblies and subassemblies with a huge amount of variants is mentioned as a basic instrument of the Design for Variety.
The creation of the variety at the end of the assembly process is mentioned as another main aspect of Design for Variety. To illustrate and evaluate this criteria the well known “tree of variants” which was established and further developed by Schuh [Schuh2001] is used.
In “Standardisierung der Produktstruktur zur Verbesserung der Ablauforganisation in einem Unternehmen des Spezialmaschinenbaus“ [Franke1993] presents Franke a special approach for the development of products with many variants. In addition to this approach techniques to list the variant specification characteristics and to differentiate between standardised and variant components are described.
Main point of this paper is to identify a clear differentiation between variant and standardised components as an essential task of the Design for Variety. Although it is revealed, that these variant components should take a minor part of the whole product value.
In addition to this approach three general principles of the Design for Variety are shown in “Variantenmanagement in der Einzel- und Kleinserienfertigung“[Franke2002]. Especially the character of principles like overdesign or the use of higher symmetry is very similar to common design guidelines. Therefore they are almost unchanged transferred to the following compilation of Design for Variety guidelines.

3. Developing of guidelines for the design of variant products

3.1 Definition of Design for Variety

The term design is to be understood as the activities of the construction process, which determine the shape and dimensions of the components, their arrangement and their connections, as well as their material [Franke2002]. The term Design for Variety is to be determined as possibilities of design and product architecture, which minimise the costs of the development and production of variant products. A clear distinction between Design for Variety and product architecture for variety is hardly possible. Therefore the following design guidelines include all aspects, which have a significant impact on product design.

3.2 Development of products with regard to variety

An integrated approach (figure 2) to the development of products with a huge amount of variety is pictured below to disclose the essential contribution of design guidelines.

Since the approach was already presented on the DfX Symposium 2007 [Kipp2007] only a basic overview will be given.

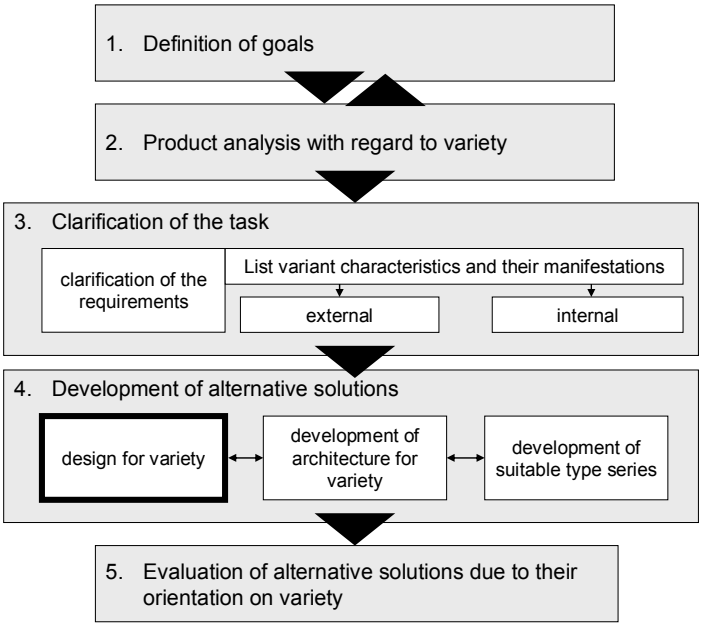


Figure 2. Design for Variety approach

The presented approach is based on proceedings by Ehrlenspiel [Ehrlenspiel2007] supplemented with the phases "definition of goals" and "Product analysis with regard to variety", which are necessary in the development of variant products. In addition to these new phases, significant changes occur especially during the "clarification of the requirements" and the "development of alternative solutions".

In the first stage concrete, realistic and quantified goals are defined, which reduction of negative effects of variety is aspired. In the second stage the influence of variety of the main assemblies on the previous defined goals is examined. In the following exclusively main assemblies with a huge amount of variants and a strong influence on the defined goals are observed.

In the stage "clarification of the requirements" all variant characteristics of the existing product are listed and differentiated between internally or externally caused variance. Due to this distinction, different alternatives of action are specified in the following stage: On the one hand internally caused variety should be eliminated if possible. On the other hand externally induced variety has to be provided exactly as far as the customer requires it.

In the stage "development of alternative solutions" the developer is not only confronted with the task to find a corresponding design considering the special needs of products with an high variety, but also has to develop a suitable product structure and adequate type series. Each of these activities requires special knowledge and the support of appropriate methods.

The development of convenient product architectures and suitable type series is discussed many times unlike the activities of design for variety. This could be an explanation, why in the researched literature no systematic, comprehensive and appropriate visualized compilation of guidelines for the design for variety is to be found.

According to Pahl and Beitz design guidelines help to adapt the particular conditions and especially support the basic rules “clearly”, “simple” and “secure” [Pahl2007]. In the field of Design for Assembly (DfA) for example, design guidelines are established for years. To provide such an efficient support in the field of Design for Variety, this paper will generate a systematic compilation of Design for Variety guidelines and will afterwards try to validate the benefit of their use.
These guidelines furthermore summarise all major design goals of the Design for Variety and therefore establish an important basis for the further development of an integrated methodology for the development of product families.

3.3 Representation of the design guidelines

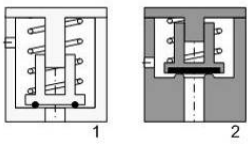
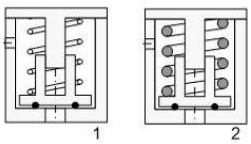
In order to develop the complete benefit for learning appropriate design forms and to be used as a reference work, design guidelines should use an adequate wording and suitable illustrations. Thus the text should be easy to understand and the illustrations should be descriptive.
Based on these assumptions, the formulation of all design guidelines is revised with the goal of simplicity and clarity. A symbolic black and white representation is used for each illustration. To minimize the number of elements in these illustrations, the benefit of the Design for Variety is displayed by at most two variants.

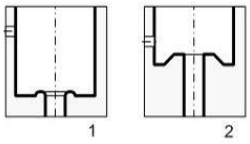
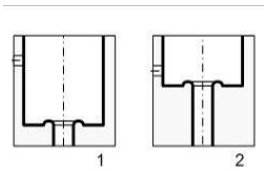
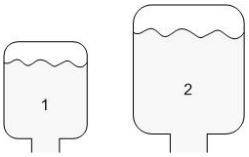
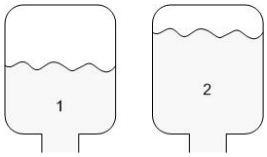
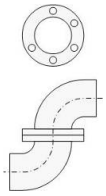
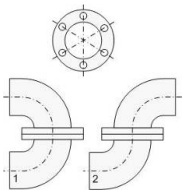
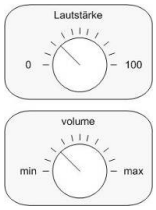
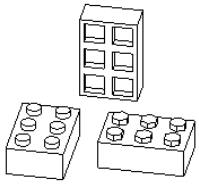
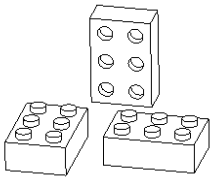
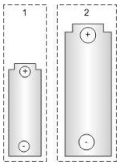
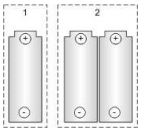
3.4 Guidelines for the design of variant products

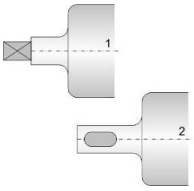
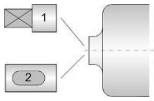
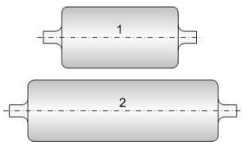
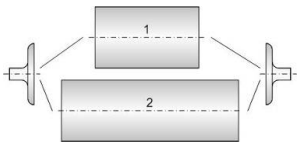
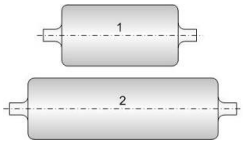
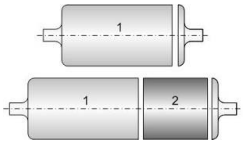
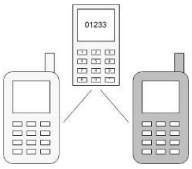
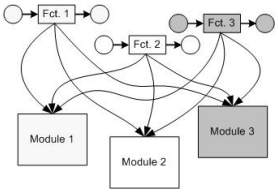
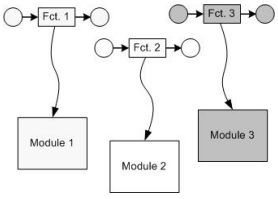
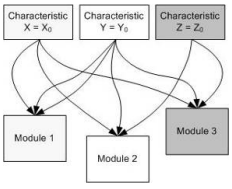
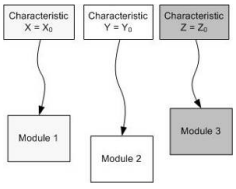
The following Design for Variety guidelines are either based on principles found by analysing existing products or principles implicit mentioned in the presented sources. In order to provide a clear illustration of the developed design guidelines (table 1), they were classified in the following categories, which are aligned to the three different tasks in fourth stage of the previous shown approach.

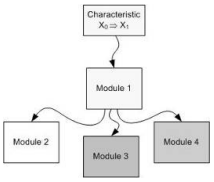
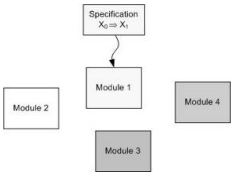
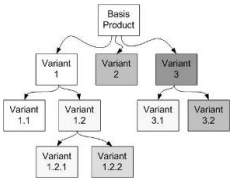
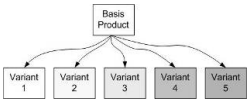
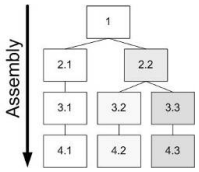
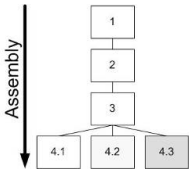
- Category A describes design approaches, which support an easy creation of product variants without affecting the product architecture.
- Category B contains design approaches, which affect directly the product design as well as the product architecture. As common basic principle all these guidelines show possibilities how to divide components into standard and variant parts.
- Category C includes basic principles, which should be considered in the development of product families’ architectures. Idealised the common intention of these guidelines is the design products consisting of totally independent modules, which together provide the overall function.
- Category D describes basic rules for the development and production of variant products. These rules do not affect the product design, none the less they should be considered while designing a product. Therefore they are mentioned in this paper.

Table 1. Guidelines for the development of variant products

Nr.:	Guideline	unfavourable	favourable
A	**Guidelines only affecting the design of the product**		
A1	Use as many common parts as possible to create product variants (e.g. check valves with different spring force).		

Nr.:	Guideline	unfavourable	favourable
A	**Guidelines only affecting the design of the product**		
A2	Standardise design parameter (geometry, material …) of different variants (e.g. valve seat).		
A3	Use overdesign to avoid product variants (e.g. tank size).		
A4	Use higher symmetry to generate geometric product variants (e.g. flange design).		
A5	Use software instead of hardware solutions to create product variants (e.g. language variants).		
A6	Design module interfaces compatible.		
B	**Guidelines concerning both design and architecture of the product**		
B1	Use parallel and serial configurations to create performance variants. (e.g. battery)		

Nr.:	Guideline	unfavourable	favourable
B	**Guidelines concerning both design and architecture of the product**		
B2	Decompose cost-intensive components with a huge amount of variants to standard and variant components (e.g. roll flange).		
B3	Use cut to fit modularity to create geometric variants (e.g. size variant of a roll).		
B4	Use additional elements to create geometric variants (e.g. size variant of a roll).		
B5	Variant characteristics without any effect on the function should be isolated in new cost-efficient components (e.g. cell phone colour).		
C	**Guidelines concerning the product architecture**		
C1	Assign every function directly to one module of the product.		
C2	Assign every variant product characteristic directly to one module.		

Nr.:	Guideline	unfavourable	favourable
C	**Guidelines concerning the product architecture**		
C3	Changing one product characteristic should not effect more than one module.		
D	**Guidelines for the development and production of product variants**		
D1	Develop new product variants based on a non-order-related variant.		
D2	Product variety should be created in the end of the assembly process.		

4. Discussion of the design guidelines

In order to evaluate the use of the presented approach and the design principles in time, their first version was consequently used in the following case study on a corona station. These machines are used to prepare plastic film for following printing.

In the first stage a significant reduction of the delivery time was defined as the major goal of the Design for variety activities. In the second stage the roll subassembly of the corona station was identified as the main focus of the following activities. This roll subassembly includes the roll and the bearings. After listing all variant characteristics of the product and their manifestations, new alternative solutions were developed.

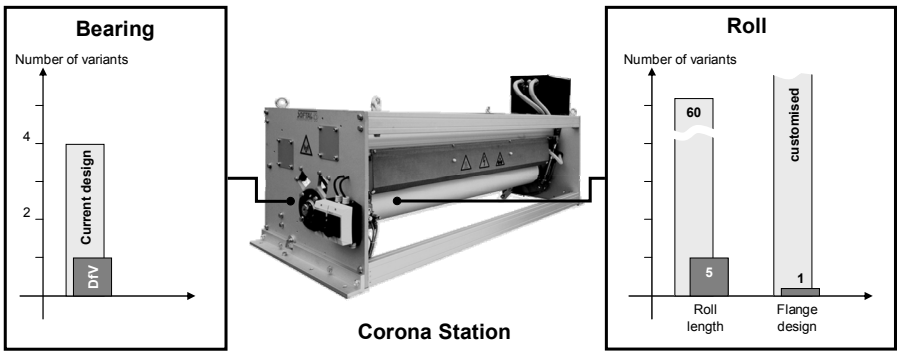


Figure 3. Reducing the internal variety of a "corona station"

Thereby among others guideline A3 “overdesign” was implemented on the bearing of the roll. By adding an adequate dimensioned opening for the flange of drive mechanism, the formerly four variants of the bearing were replaced by one standard bearing.
On the previous cost-intensive, customised and as one integral part produced roll the principles B2 “Decompose cost-intensive components with a huge amount of variants to standard and variant components” and B3 “Use cut to fit modularity to create geometric variants” were implemented.
The customised flange for the driving mechanism was separated in a new cost-efficient part. This new part is connected to the roll by a standardised interface. The roll itself was designed using the principle of “cut-to-fit modularity”. Thus it consists of to standardised end-modules and a tube in the middle. By the additional established preference type series the formerly customised length of the roll was replaced by five roll sizes (figure 3).
This example shows that at least in this case a significant reduction of the internal variety could be achieved by the use of the presented approach and the developed guidelines.

5. Summary

A set of sixteen Design for Variety guidelines were created based on a literature research and on the analysis of existing products in order to find good design for variety. The first use of an early version of these guidelines generated a significant reduction of the internal variety of the developed product. The current version of these guidelines will be further tested and afterwards the benefit of the use of these guidelines will be finally evaluated.
These guidelines not only support the design engineer in the development of products with high variety, they furthermore summarise all major design goals. Therefore the guidelines are a basic part of a new integrated Design for Variety approach.
In order to create this approach, methods supporting the development of architectures for variant products or supporting the optimisation of preference type series are currently in research.

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