15. SYMPOSIUM „DESIGN FOR X“
NEUKIRCHEN, 14. UND 15. OKTOBER 2004

DESIGN FOR FLEXIBILITY

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Abstract

Designers of today have to execute different types of generally complex tasks. Hence a new deal has been developed, which looks for design activities from aspects of specialisations. This is design according to an aspect, so called DfX (Design for X). It has several departments, which have expanded for today really serious scientific areas.

Modularity makes high level of flexibility in the area of design and producing. Hence I have nominated the method supporting these kinds of machines to Design for Flexibility (DFF). The basic of DFF that one can use the advantages of modular system during design and producing phases - which are depends on the product and other kind of demands and requirements - of a production line, which is able to produce complex products.

Modular system based on principles of DFF can be applied in all phases of design process. During specification, case-based searching, identification of earlier cases, adoption of those and design, modular technology has several advantages. In addition, special kinds of steps (such as bidding, estimation of costs and time demand, or definition of measuring procedures) became much more simply, qualitative and exact with DFF. During the article I am introducing the main principles of DFF, so the develop steps of a modular build-up machine, and finally the appliance and the advantages of those.

1 Introduction

Due to demands of mass-product, which nowadays owns a huge slice of product activities, modular products have appeared in the market. In other words, producer companies build up their products in higher rate from standard and modular elements (e.g. automotive or mobile-phone industry). Producing of modular products leaded very quickly to the modularly connectable technological steps (think e.g. for SMD /Surface Module Device/ technology, which has these properties in electric industry), and also to the modular machines. In other hand these mentioned machines are also products (e.g. company Bodine), so these kinds of machines have been forced from both sides towards modular structure.

A very important criterion of flexible appliance is the suitable construction of standard connections of all modules. Just it can ensure the ampleness of variations, what increases the number of available cases [1]. Flexibility is also very important, because market demands (and therefore the products) changing very often, hence a really quick and easy conversion of product line components is required. In addition today is also a real demand to accomplish quick changeover between similar product-versions.

2 Advantages of DFF-principle

Element-set established according to DFF-principle ensures high level of flexibility in case of every design and production steps. Replicated appliance of developed modules is a guarantee of quality by continuous solving of occurrent problems and issues. By this process, elements of modular system will be more and more perfect. In addition, this kind of modular system supports so much the appliance of design based on earlier cases. Storage of earlier solutions in an electronic database makes this procedure more effective.

3 Practical steps of DFF

First step of DFF-based design is modular elaboration of units, which are required to design special (product-specific) machines [2]. Primary purpose is not the substitution of special machines, but developing of a modular machine-family. By using of this machine-family, designers can up-build approximately the ninety percent of a production line, what is able to manufacture the given product-family (in quicker and much more cost-effective way). Later, after choosing suitable modular elements, and by design specific (individual) parts follows the fitting all of modular and non-modular parts and subassemblies. And finally, as a result of this method the required special machine is completed.

Design-system based on DFF can be divided into two main parts. First is the *process of development steps*, what means the determination and design of modular elements. Second is the *tool-system*, which supports DFF-principle. It contains the definition, the creation of design-tools and the theoretical background what supports the evaluation of modular system. Figure 1 helps to overview all of these steps and tools, where one can see the tools supporting DFF-principle inside of the ellipse, and steps according to DFF-principle are situated outside.

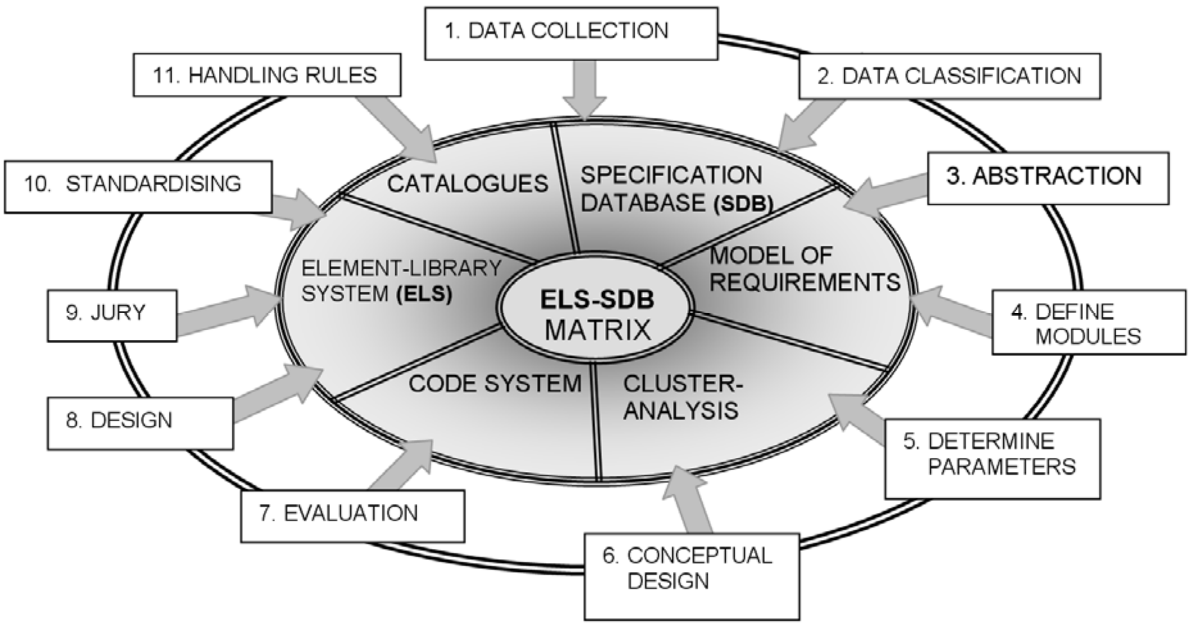

Figure 1: Most important elements of DFF-principle

To put you in the picture about the practical steps of DFF and the auxiliary tools of this method, I would like to introduce you all of these in next pages.

3.1 Develop steps of tools supporting flexible design

As one can see it on figure 1, first step is *data collection*, what is collecting of several earlier tenders, specifications and surveying of machines and units to standardise. Data collection should be a bit extended than it is demanded, because later a data can easily be more important, which one was inconsiderable at the beginning of data collection. Surveying and later data processing can be supported in high level by standardised and expediently made electronic surveying sheets. An example for these kinds of sheets is illustrated on table 1, in which one can register the part-movement combinations of manipulators what executes the technological required movements on a production machine. With these sheets we can register data in standardised form, and by classification of data we can get for example the most important manipulators, which can fulfil the ninety percent of earlier cases.

Table 1: An example for surveying sheet

Name of machine: Exhaust machine				**Production line:** GLS 2600	
Drawing number: NM12				**Type of machine:** conventional	
ps.	**manipulation**	**handled part**	**movements (mm)**	**pmc.***	**drawing no.**
1	loading	lamp	X30 X-30	1	NM12-1520
2	loading	tube	↑Y-90+X100 ↑Y90X-100	2	NM12-1780
3	bending	wire	X30↑Y-90 Z30 X-30↑Y90 -Z30	3	NM12-1580
1	checking	wire	X20 X-20	1	NM12-1420
1	measuring	wire	Z10 Z-10	1	NM12-1430
1	unloading	lamp	Z20 Z-20	1	NM12-1790
…	…	…	…	…	…
Notes, description: The task of this machine is to exhaust the sealed lamps, and to fill with inert gas and finally to close the exhaust tube.					
Surveyer person: John Smith				**Date:** 17/09/2004	

* part-movement combinations

Second step is *data classification*, which is analysing and processing of collected data to help later easier and quicker appliance. Third step is generalisation of specific data, so called *abstraction*. It is needed because development of modular units and the hierarchical system of those happens based on only the main properties of earlier cases, but the abstraction is originally required to create new and independent solutions. Fourth step is *definition of modular elements*. These elements generate the flexible system. During this step, element-library system (ELS) is developed, what one can realise by choosing of units which are cover up the ninety percent of the whole range [3]. Bigger and complex elements can be divided forward according to functional parts to get the modules, but smaller units can be the modules themselves. Next tables you can see an example for classification of surveyed units. On table 2 you can see the main modules of a production line, and the properties of those.

Table 2: A possible classification for production lines (the main modules of that)

Group	**Code**	**Modular element**	**Element type**	**Parameters**
Production line	**MBP**	Production line	*Assortable element group*	Velocity, product properties
	MBB	Base-machine	*Assortable element group*	Velocity, no. of heads, execution
	MBPC	Conveyor	Fitting element, auxiliary element	Velocity, up-build
	MBPF	Feeder	Fitting element	Process, product properties
	MBPP	Puffer	Special element	Capacity, up-build
	MBPM	Measuring, checking unit	Special element	Accuracy, velocity
	MBPC	Controller unit	Base-element, special element	Handling of data
	MBPX	Accessories	non-building element	Specific

And by forwarding classification of modules we can get a level lower (and so on). On table 3 you can see it as an example, actually in case of the base-machine.

Table 3: A possible classification for base-machine (the main modules of that)

Group	Code	Modular element	Element type	Parameters
Base-machine	**MBB**	Base-machine	*Assortable element group*	Velocity, no. of heads, execution
	MBBS	Structure of machine	Base-, auxiliary or specific element	Up-build type, geometry
	MBBD	Driving system	Base-, auxiliary or specific element	Velocity, performance, indexing
	MBBP	Part handling	Base-element, fitting element	Product properties
	MBBA	Actuator	Base-element, auxiliary element	Demand of movement, velocity
	MBBM	Manipulator	Special element	Sub-movements, intervals
	MBBX	Accessories	Non-building element	Specific

Fifth step is *clarifying of parameters*. During this step we have to determine the main parameters of the modules, and the range of those. In addition we have to divide units to fixed and alternate parameter-value types to create module-versions. Sixth step is *conceptual design* of modules, hence it is needed to elaborate some preliminary-design versions for all modular units. Seventh step is *evaluation*, what is choosing of most suitable of elaborated versions. This step is executed by a DFF develop-team. I suggest this team has to be defined at the beginning of development process, and have to contain one competent expert from all specialities. Eighth step is *design*, what is final elaboration of chosen module-versions. During this step all of elements have to be redesigned according to modular demands (e.g. variability, standardised connections etc.).

Ninth step is *accomplishment of juries* (by DFF-team), what means the realisation of required smaller modifications and finings, and finally the acceptation of designs. It leads us to the tenth step, which is *fasting of accepted modules*, so called standardisation. In the future alternation of fixed modules can happen only in very reasoned case. It is a base-condition of building from standardised elements (so called principle of building-blocks []). And last but not least, eleventh step is *determination of handling rules*. These rules contain the access rights and the appliance conditions of flexible tools and modular elements.

3.2 Flexible design supporting tools

In this chapter I will introduce the flexible design supporting tools (in randomise order). *Model of requirements* (MR) is collection and systematisation of demands and requirements of flexible system, which are precedent during developing of flexible tools. It is very important, because modular properties often conflicts other important requirements, so during develop process DFF-team has to decide that in given product-surround which properties are more important.

Specification database (SDB) is a result of surveyed specifications, and (give) high level of help in forwarding time, for example in specification phase of newer machines. The structure of SDB is illustrated on figure 2.

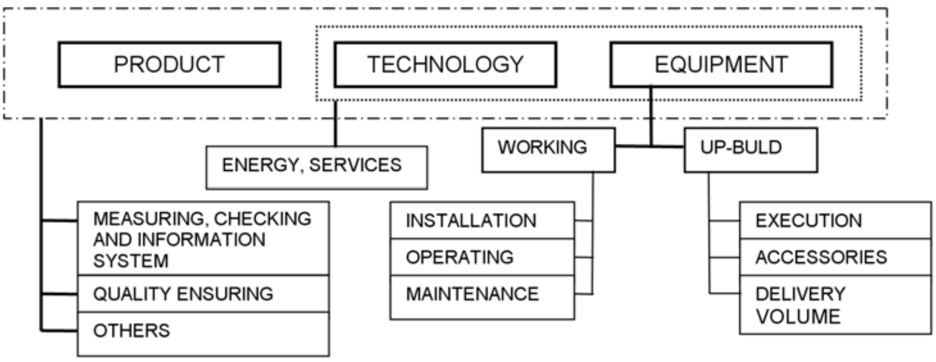

Figure 2: Structure of specification database

To establish SDB, studying of several earlier specifications is suggested to create a database, which considers (almost) all parameters. By using of SDB designers always are able to create a suitable specification, which is the base of whole design process [4].

Element-library system (ELS) contains the modules of flexible system in hierarchical layout. And the code-system helps to handle all elements in easier and more definite way. The result of module-classification is illustrated on figure 3.

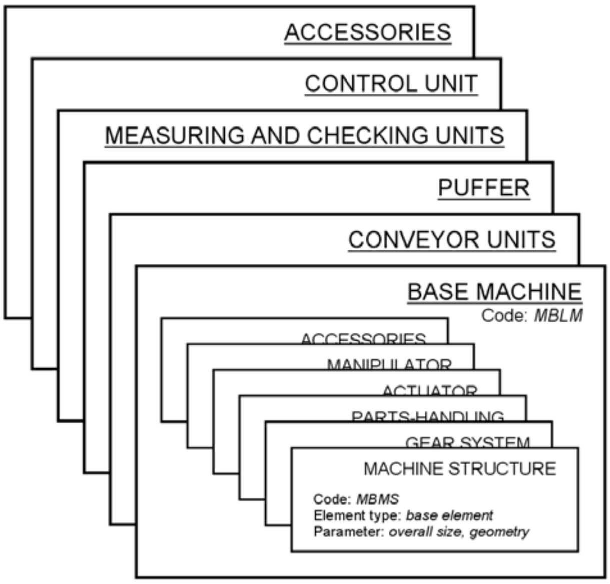

Figure 3: Structure of element-library system

By combining of these two systems (SDB and ELS) one can get the *ELS-SDB matrix* – which is illustrated on table 4. This matrix helps to define and connect parameters of modules and specification activities – in both of two directions. First direction, if we are searching for the parameters, which has to be specified to design a unit (reading along rows). Second direction, if we want to define which properties of which modules depend on a required (and specified) parameter-value (reading along columns). One can see that the *matrix* can be used in case of any direction and level [4].

Table 4: Structure of matrix ELS-SDB

		SDB																	
		PRODUCT				TECHNOLOGY					EQUIPMENT				…	SERVICES			
	Parameters / Units	size	type	material	…	principle	description	prescribe	property	…	no. of heads	capacity	up-build	…		electricity	gas	cooling	…
ELS – BASE MACHINE	actuator	■		■	■	■			■			■	■				■	■	■
ELS – BASE MACHINE	manipulator		■	■	■	■		■	■		■			■		■	■		■
ELS – BASE MACHINE	…	■	■	■		■	■	■	■	■		■	■	■			■	■	
ELS – PUFFER	anaconda	■										■							
ELS – PUFFER	gug			■					■					■			■	■	■
ELS – PUFFER	…			■										■					
ELS – …																			
ELS – CONVEYOR UNITS	chain		■						■				■						■
ELS – CONVEYOR UNITS	belt			■	■	■													
ELS – CONVEYOR UNITS	…			■	■							■					■	■	

Cluster-analysis is a well-known method [5], which can help us to define the overlaps of created specification and the accessible module-set by appliance of matrix. And finally, *catalogues* makes the handling of established system easier and quicker. To accomplish all of demands, three types of catalogues are needed. First type is *design catalogue* of modular machine family, which helps the work of DFF-team and contains the develop steps and phases in fully detailed form [6]. Second type is *catalogue of ELS*, which presents the modular elements of flexible system (with the properties and detailed descriptions of those) and introduces the whole system. It has been made for constructors who will use modules during their design activities. And the third type is a *commercial catalogue*, which shows the modules as standard products for that kind of machine-builder companies, who would like to order ready modular-units, and use those according to their own imaginations.

4 Is this modular system really flexible?

Yes, because

- Modules of element-set what contains modular units is *flexible changeable,* so several combinations of elements can be created.

- Parameter-values (e.g. number of head-positions, velocity) of a flexible machine can be *alternated flexible* during test run. It can happen even by setting of units or even by changing of modules.

- When the equipment is already works, often repetitive demand the type-changeover, what (opposite earlier conventional solutions) also *can be solved flexible* with the help of element-set - *short term modification*

- The whole modular element-set and the parameter-values of those stored in electronic form by a database and handled by an auxiliary program. Hence the parameter-values and the modules can be *flexible changed* according to the alternate market-demands - *long term modification*

- *Flexibility of system* appears also after disassemble of the equipment, by repeated usage of several modules. It ensures a very high level of *recycling-rate*.

5 Summarising, conclusion

Most important is to highlight, that the key of flexibility of the whole system is the *determination of the most suitable modular elements, and the perfect design of those*. The well elaborated modular element-system, and a computerised background, which handle the elements in high level together able to present so level of flexibility, which can watertight well in the surround of technical requirements and alternate market demands of nowadays.

6 Literature

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