Production Management I

- Lecture 3 -

Product Planning & Engineering

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Lecture Overview

Innovative products are a major aspect of success in producing companies. The task of the development of innovative products is no longer a singular task of the development department, it has become more of a department overlapping process in which intern divisions like e. g. marketing, manufacturing and assembly as well as suppliers –caused by increasing amounts of advance performances- are involved.
It is important to use the information of other divisions in an appropriate way and to implement it into the product design because a major part of the future product costs are ascertained by the engineering and the decisions in the product development.
A systematic procedure at the product development ensures that all important activities are fulfilled and that the results are passed on in time to the correct place in the company.

Product developments are usually being performed in form of projects. Basis of the planning of these projects is the engineering systematic. A variety of different engineering methods exists in literature and in practice. The guideline VDI 2221 which was presented in the lecture has the greatest circulation in practice and demonstrates with it‘s 7 main tasks in the 4 phases planning, drafting, designing and elaborating one of the most detailed procedures. Based on the development of a wind power plant this lecture presents the specific tasks in the guideline VDI 2221.

The activities in the product development contain on the one hand creative activities at which innovation stands in the center of attention and on the other hand research activities with the intention of integrating already engineered components and modules or vendor parts efficiently into the new product and the ambition of finally realizing scale effects.
There are different formalized methods like brainstorming, the morphological box or the formation of analogies available to fulfill creative activities which takes especially place in the early phases of product development. The formalized proceeding ensures in this case that the „mental abilities“ of the members are concentrated onto the problem or the creative task and not the proceeding. Particularly the brainstorming is very popular in today‘s industry.

Caused by the increasing costs pressure the product development and engineering have to work efficiently and especially give their contribution to the efficiency of the company concerning the potential of influencing costs.
An appropriate IT-application is very important for the efficiency of the product development. 3D-CAD-systems and product-data-management are the current state of technology.
Components are directly transferred from the catalogues of the suppliers into the CAD-model. The usage of already existing components and modules plays a major role in the increase of the company efficiency.

Glossary

Requirement specification sheet:

Collectivity of receivables from goods and services from the customer to the producer. The requirement specification sheet has to contain all requirements from the customer‘s point of view including all restrictions. These should be qualifyable and provable. The requirement specification defines the fundament and the reason of a task. (DIN 69905-VDI/VDE 3694 – VDA 6.1)

Feature specification sheet:

By the producer compiled realization demands based on the requirement specification. The feature specification contains the requirement specification.
The customer demands and in addition the realization demands considering certain solution attempts are described in detail in the feature specification.
The feature specification defines how and where demands have to be realized. (DIN 69905-VDI/VDE 3694 - VDA 6.1)

VDI 2221:

Guideline about the method of developing and engineering technical systems and products which is edited by the society of German engineers (VDI)

Brainstorming:

Brainstorming is a creativity and idea finding technique. It consists of a heterogeneous group of 5 to 7 persons who are supposed to develop ideas, solutions and comprehension considering a given problem by using certain regulations with extraordinary creativity. During the brainstorming there is no criticism on other contributions allowed; the ideas of the participants can only be reflected or complemented.

Morphological box:

The morphological box is systematic structure analysis with the goal of finding new combinations. In the morphological box the partial functions of a problem, which can have different solution principles, are combined to an overall solution.
This method is going to bring out several solution possibilities by using different combinations.

CAD (Computer Aided Design):

Computer aided designing, drawing, engineering and planning with specific software.

Classification systems:

A classification system, also called „full communicating number system“ makes it possible to name and identify an object by it‘s classification number. (Betriebshütte, Produktion und Management, 7-49)

Combined number system:

In a combined number system, also called „partly communicating number system“, the object is assigned to a class by it‘s classification number and identified by it‘s counting number. A system like this highly qualified if certain characteristics of an object can be easily identified and if there are only a few objects in one class. (Betriebshütte, Produktion und Management, 7-49)

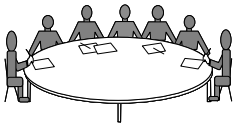
Parallel number system:

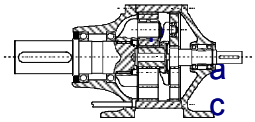
The parallel number system is an advancement of the combined number system. It consists of a classification and an identification number which can be addressed in combination or apart from each other. The classification is only done by the classification number and the identification number makes a quick bordering of the searching field possible. (Betriebshütte, Produktion und Management, 7-49)

Lines of subject characteristics:

Lines of subject characteristics provides the possibility to summarize, mark out and choose standardized and not standardized, material and immaterial objects which are similar to each other. (Betriebshütte, Produktion und Management, 7-49)

Lecture highlights





- Relevance of costs in engineering
- Engineering referring to VDI 2221
- Utilities for engineering
- Methods for concept detection and evaluation
- Classification systems
- Exercise: Creating a feature specification and using the morphological box

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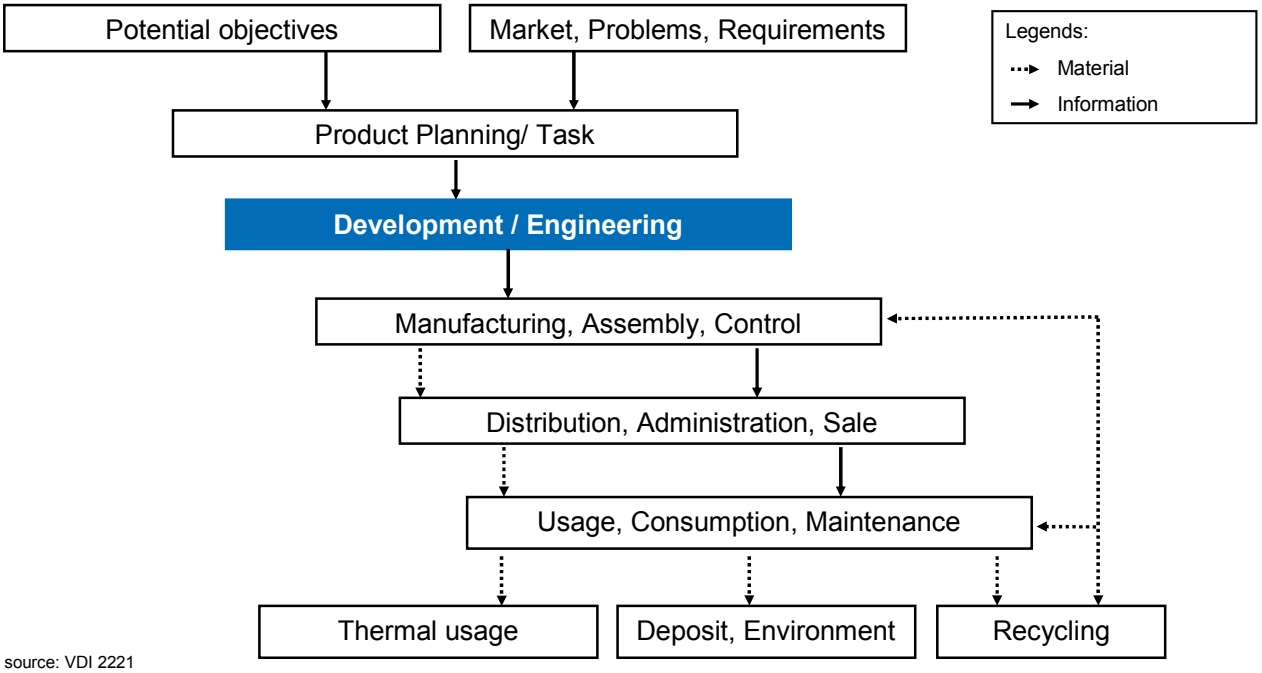
Product development and life cycle



source: VDI 2221

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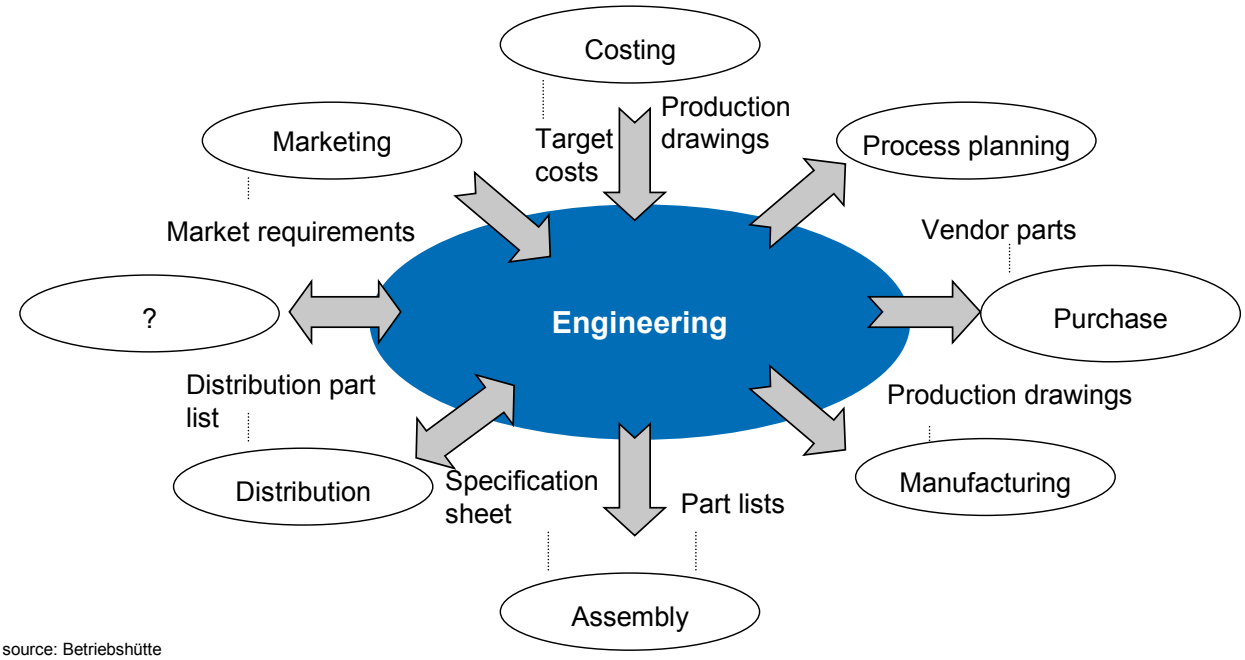
Engineering – central meaning as information source



source: Betriebshütte

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Notes on Figure:

Attributes like favorable price, high quality, adequate functionality, pleasing design and similar attributes decide the market profit of a product and conductive the protection of company existence. Predefinition of design attributes and consequently the features of a product takes place in engineering department. The results of the design process, the geometrical and technological product attributes, document as technical drawings, part lists, geometrical models, etc. and make available for consecutively departments as procedure documentation. Engineering gets a central meaning as source of information.

Product Planning: Requirement/ feature specification

Requirements	Transformation	Measure	Sensor	Product attributes
hierarchical structured	to measurable dimensions	physical	physical	Which attribute correlates with which measures?
completely (incl. legal obligations)		evaluation table	experts	

Requirement specification ⟷ Feature specification

relevant customer requirements, assessed ⟷ Measure + tolerances assessed: necessity, wish, etc.

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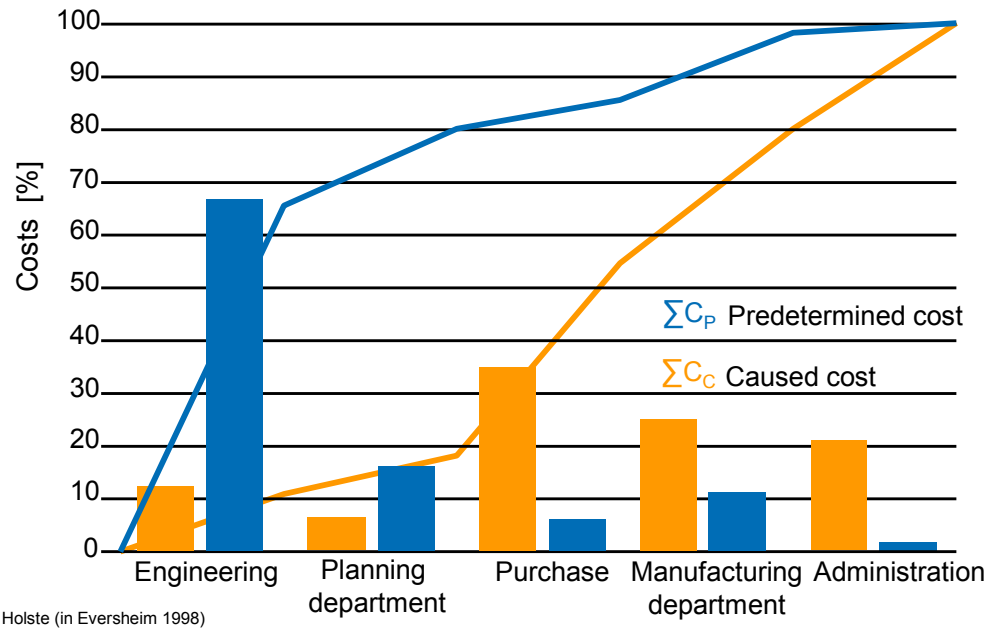
Notes on Figure:

The customer requirements can be ascertained on three ways:

- to be a customer
- talk to customer
- to simulate customer requirements

The comparison to competitors is important. The biggest problem is the difference between the languages. The customer forms his requirements in feelings, functionality or does not form the requirements for new products. A new effective transformation is the „House of Quality“. Customer requirements are confronted with technical characteristics and are discussed in a team of concerned persons. This warrants a simple documentation, but the problem with the quantification is still there. It is difficult to quantify aspects like user friendliness, elegance, flavour, etc.. In this case only an expert can help. Quantitative parameters have to be conform to the principles relevance, acceptance, transparency and economy.

Determination and causing of cost



source: Bronner, Holste (in Eversheim 1998)

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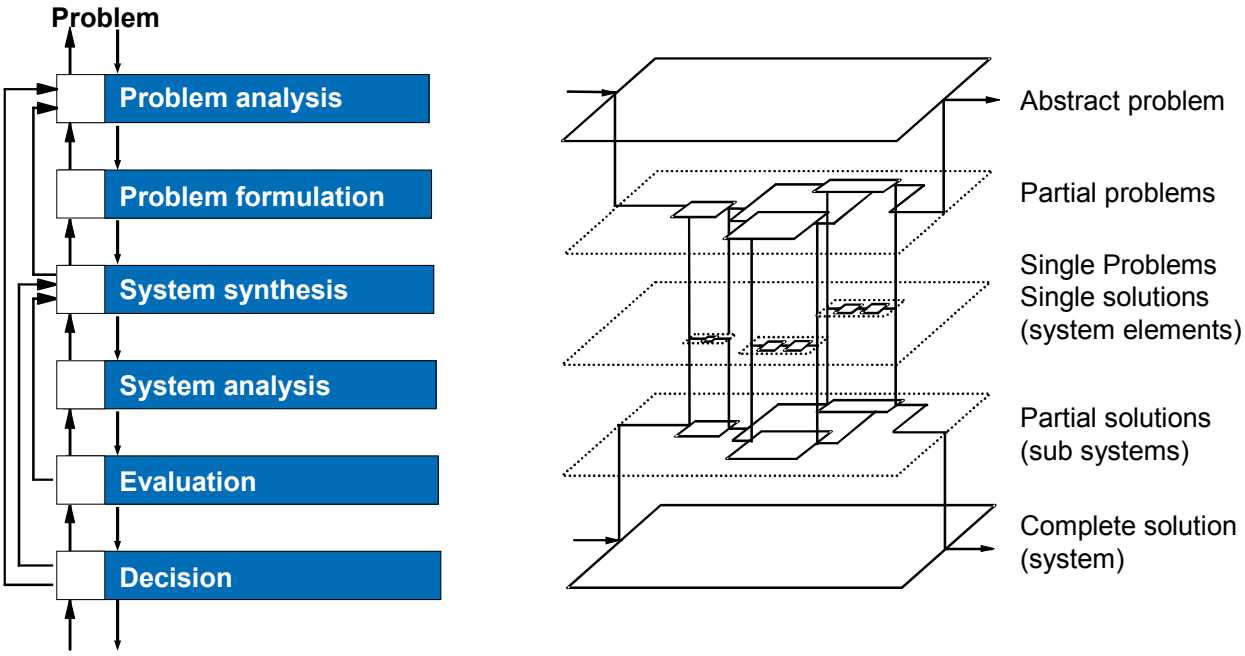
Notes on Figure:

The engineering procedure can be characterised by the corresponding predefined costs and caused costs. On the one hand, only a comparatively small part of the entire life cycle costs (approx. 12%) is caused within the engineering department. On the other hand, at the end of the engineering phase approximately 70% of the life cycle costs are already determined.

System oriented solution of problems



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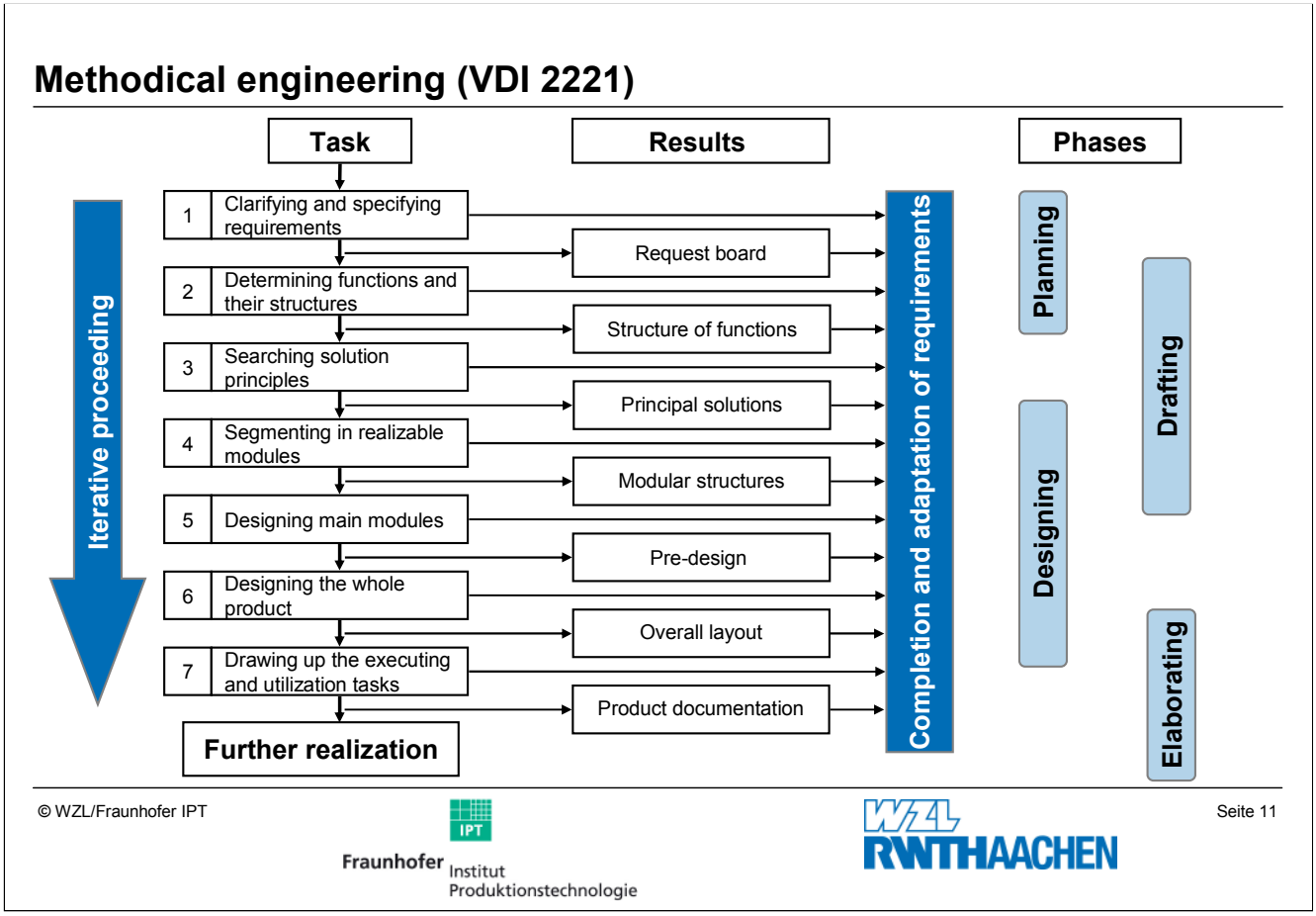
Notes on Figure:

Many different problems have to be solved within the engineering and design process. In this context, it is reasonable to apply the general problem solution procedure to the engineering and design process.

By structuring an abstract and comprehensive problem into sub systems and system elements a methodical basis for the effective and economic solution process can be generated.



Notes on Figure:

The methodical engineering process according to VDI 2221 is structured into seven work steps. The results of each work step represent the necessary input information for the following work step. Depending on the task the different work steps have to be fulfilled completely, partly or iteratively. These work steps can be summarised in groups to development and engineering phases, which represent a basis for the coordination of milestones and corresponding processes.

Clarifying and specifying the task

Customers' requirements (Performance specification)

- Economic efficiency
- Performance, Design
- Little annoyance
- High safety
- Ecological compatibility
- ….

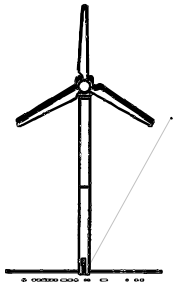
Constrains Company internal

- Technical possibilities
- …

Constrains Company external

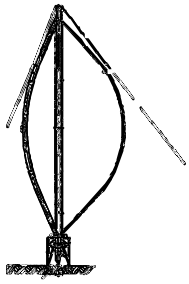
- Legitimate regulations
- …

Result



Specification sheet wind power plant

Type	Specification	Weight	Target value
F	Power [kW]		50
M	Price [€]		<130.000
M	Noise in 100m distance [dB(A)]		<50
F	Starting up wind speed [m/s]		2,5
M	Maximum wind speed [m/s]		<60
M	max. height [m]		<50



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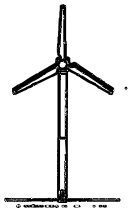
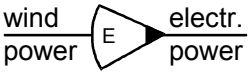
Notes on Figure:

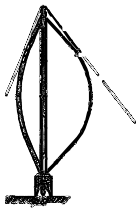
To define the technical specification of the new product it is necessary to clarify and specify the task which has been defined by the customer or by the product planning department. The result of this step is the specification sheet which represents the information basis for the following work steps and have to be updated continuously.

Determination of functions and their structures

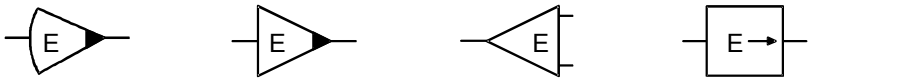


Determination of general functions





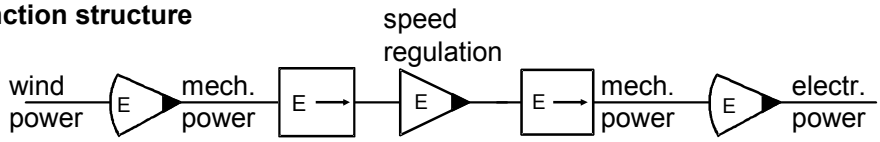
Determination of subfunctions



Conversion Transformation Combination conduction (one way)

Definition of a function structure

Result: function structure



source: Roth

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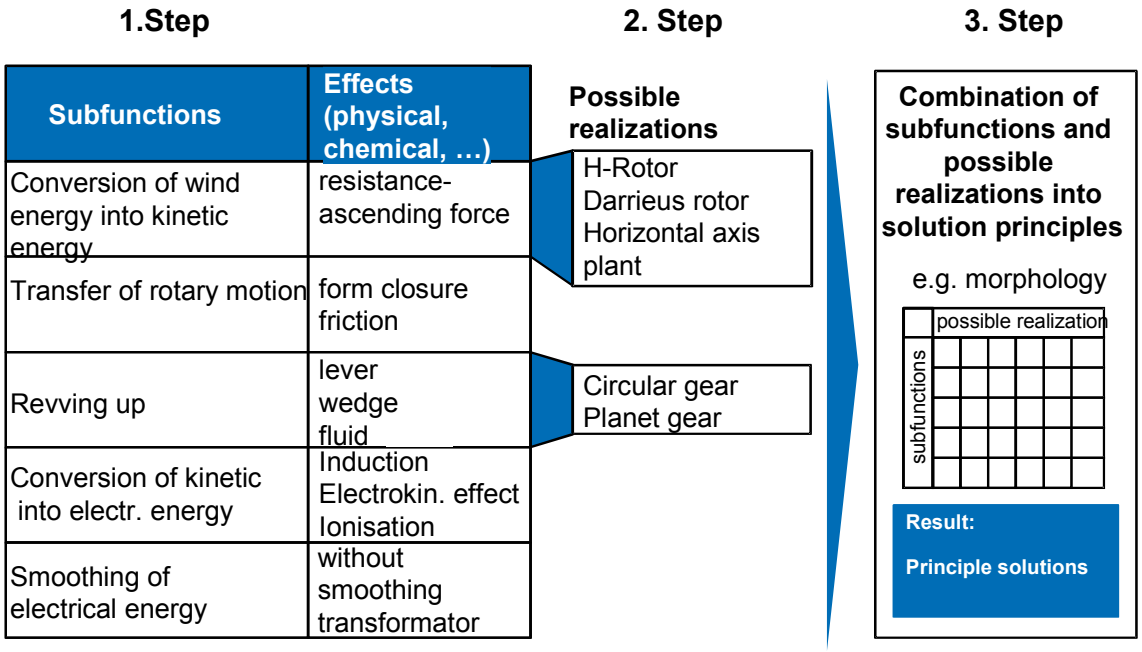
Notes on Figure:

At first, the main sub functions can be derived from the overall function of the product. Thereafter, these sub functions have to be structured and combined to a functional structure which represents the starting point for finding a product solution. The result is a functional structure which can for example be documented in a circuit diagram.

Search for solution principles



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Notes on Figure:

Solution principles have to be found for all functions or main sub functions. In the first step, physical, chemical or other effects have to be identified and related to the relevant sub functions. In the next step, these effects are realised by using function carriers. By combining different alternatives (possible realisations) for each sub function one or more product solutions can be developed.

Segmenting into realizable modules

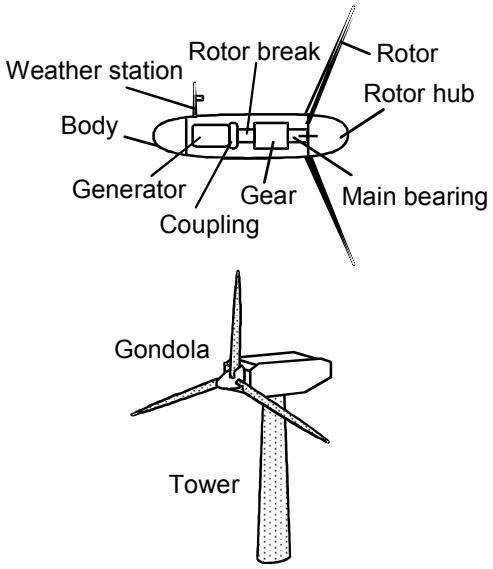
Approach

- Segmenting the solution into essential groups and elements
- Definition of interfaces
  - Efficient partition of engineering tasks
  - Identification of development priorities

Construction modules

- Modules from work-related and pragmatic points of view
- Maintenance modules for service friendly products
- Recycling modules
- Basis and variation modules
- …

Result: modular product structure



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Notes on Figure:

In this work step, the principal product solutions will be decomposed into realisable modules which are worked out more detailed later on. By identifying and specifying all relevant interfaces a modular product structure can be developed. In this context, single modules can be differentiated according to relevant criteria.

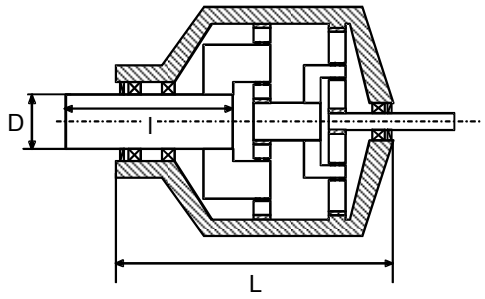
Designing essential modules

Designing modules which are significant for product and system optimization

- Ways of presentation
  - Rough drawings (to scale)
  - Circuit flow plans
  - …
- Degree of concretion must be adapted to an optimal designing
- Considering all essential restrictions

Result: Pre-layout for essential modules

- Example: Planet gear



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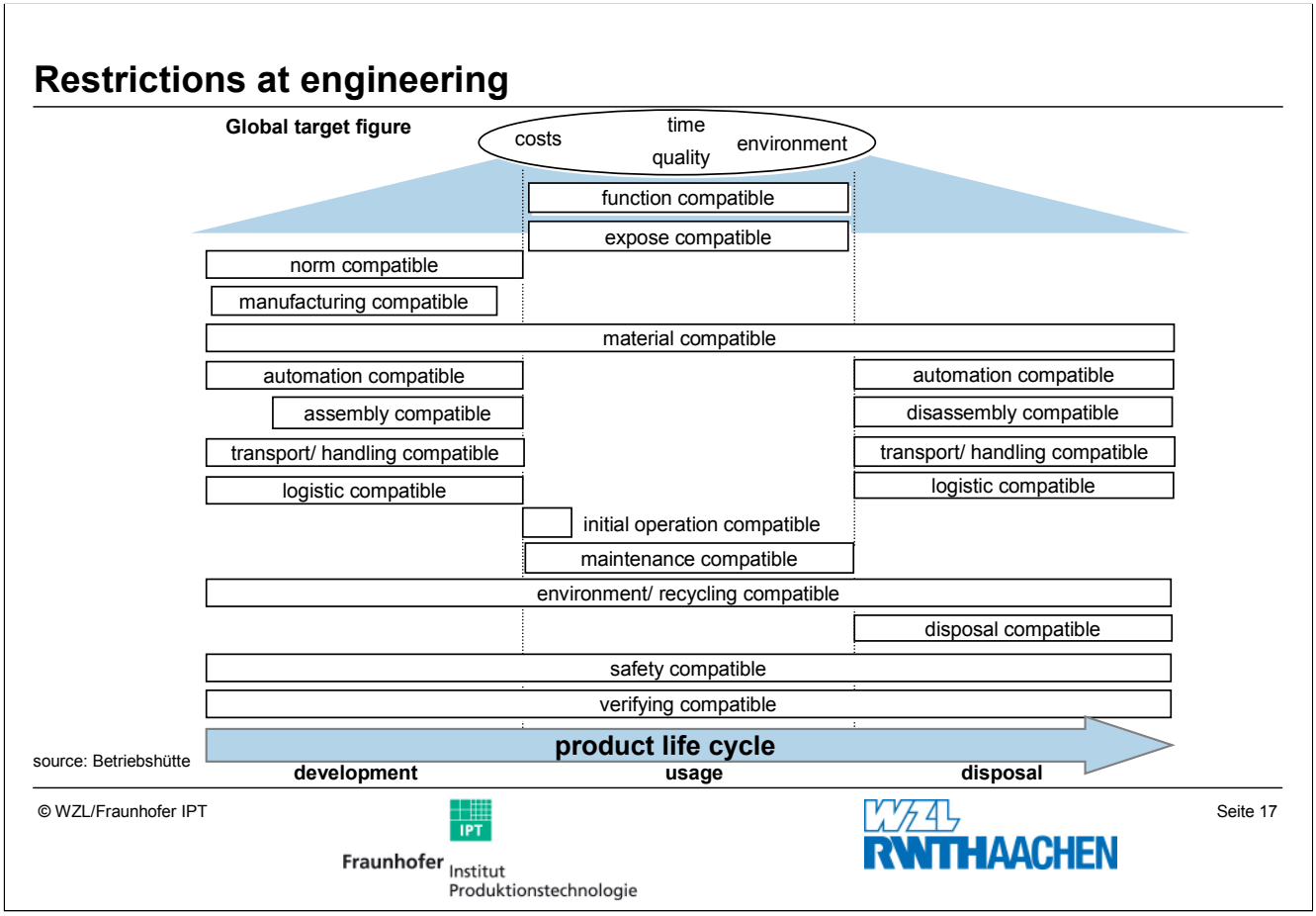
Notes on Figure:

The product is being concretised by designing main modules for product respectively system optimisation. The level of detail has to be adapted to an optimal design process. It could be called pre-detailing at this design state. The results are pre-layouts of main modules documented as raw full-scaled drawings or stream flowchart.



Notes on Figure:

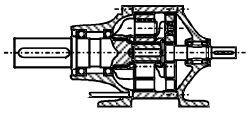
Constraints compatible engineering is engineering with consideration of conditions. These conditions result from customer requirements of a product or from back flowed requirements of following departments. Considering the requirements time and costs, which arise in phases of product life cycle after engineering, should be reduced fundamentally or the quality of a product should raise. Reduction of possible negative environmental pollution of a product is an other example, which is important during the developing process.

In the approaches to constraints compatible engineering concerns special enlargements of methodical engineering. These are mostly called manufacturing, assembly and recycling compatible constructional requirements.

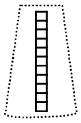
A complete registration of all possible requirements is not useful, because it is possible to derive them from every process out of product life cycle. Specifications can be defined in the whole life cycle, e.g. environment compatible or in very short phase, e.g. initial operations compatible. This picture shows well-known requirements and assigns with the relevant product life phases. More requirements are existing, but these are partial aspects of the in the picture described requirements. An example is, that forge compatible design is an partial aspect of manufacturing design.

Designing the whole product

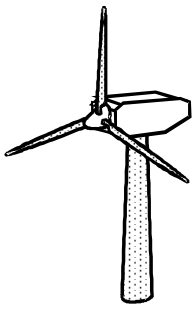
1. **Final or detailed design of pre-designed modules**
   - e.g. planet gear



2. **Designing and completion of modules which have not yet been considered**
   - e. g. ladder on tower



3. **Combination of all modules and elements**



Result:
Global layout containing all essential design information for product realization

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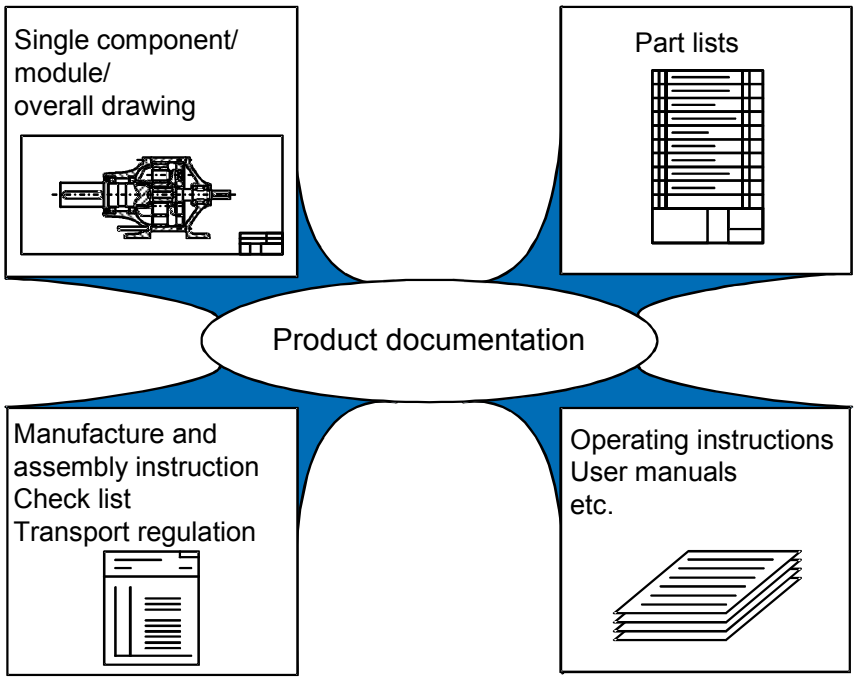
Notes on Figure:

The pre-designed modules have to be detailed further. This includes the final design of the main modules and the design of other remaining modules and components. The entire product design can be developed by combining all modules and components. In this documentation all design decision concerning the product realisation are documented. This work step can also be described as final design, in this context.

Documentation of working and using tasks



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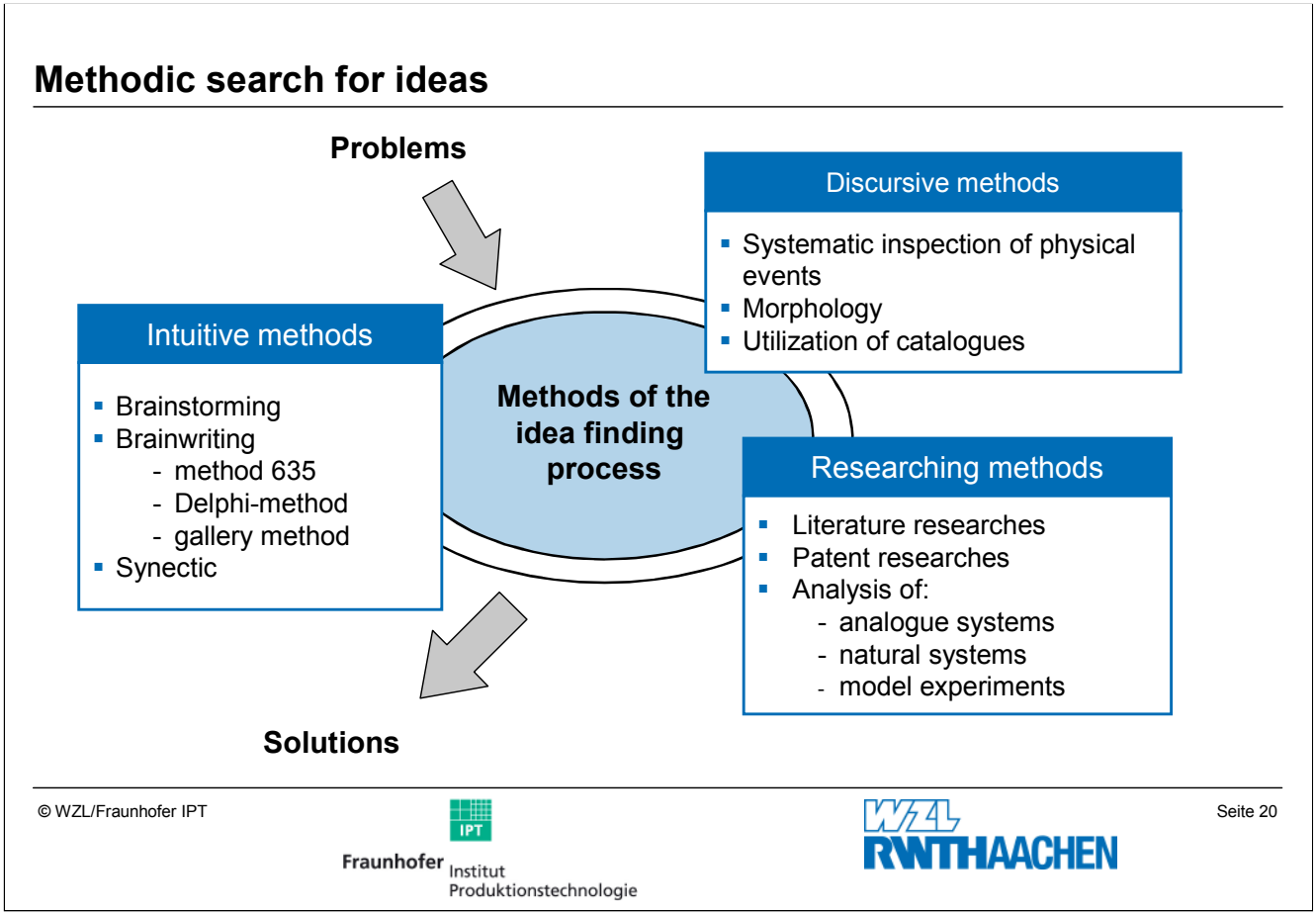
Notes on Figure:

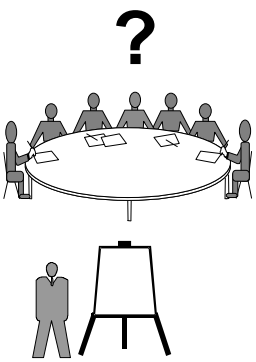
The last work steps include the elaboration of all instructions in regard of a product realisation and usage. The engineering department is responsible for all these instructions. The result of this step is the product documentation which comprehends drawings of single components, assemblies and the entire product as well as part list and instructions etc.



Notes on Figure:

Objective of a systematic search for ideas is to increase the efficiency by accelerating engineering processes and by increasing the process productivity. This means, more good ideas in less time. There are three different categories of methods which are primarily used for the determination of functions and the functional structure as well as for the search for solution principles. Intuitive Methods are mainly based on team work and should activate the knowledge potentials of entire groups to develop high quality solutions.

Brainstorming



Purpose:

- Search for ideas/ solution in interdisciplinary teams

Organization:

- 5-12 team members (meeting time max. 30 min.)
- No significant hierarchical differences

Work steps:

- Express all ideas free and spontaneously (no criticism)
- Formulate results as solution proposals
- Order all proposals
- Constructive criticism
- Evaluation and choice of solution proposals

Result:

- Chosen solution proposals for specified problems
- All members identify with these solution proposals

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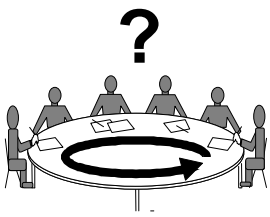
Brainwriting (method 635)



- **6 persons**
- **3 ideas**
- **5 minutes**

Purpose:

- Find and formulate (in written form) solutions in interdisciplinary teams

Organization:

- Team consisting of 6 persons from different disciplines
- Announcement of the problem at the beginning of the session

Work steps:

- 3 solution ideas are described (in written form) within 5 minutes
- Pass the document to the neighbor
- Neighbor adds 3 ideas
- Team evaluation of solution ideas
- Selection of solution ideas

Result:

- max. 6 x 3 x 6 = 108 solution ideas
- Documented solution ideas

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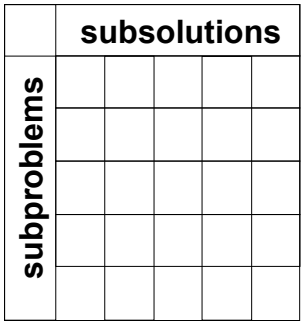
Morphological box



Purpose:

- Systematic presentation of all problem solutions
- Collection of all sub-solutions

Organization:

- Appropriate for subsequent processing of results of intuitive
- and researching methods

Work steps:

- Segmenting the problem into sub-problems
- Collection of sub-solutions
- Reasonable combination of sub-solutions to a general solution
- Assessment of general solutions

Results:

- Set of all possible solutions
- Selection of meaningful solutions

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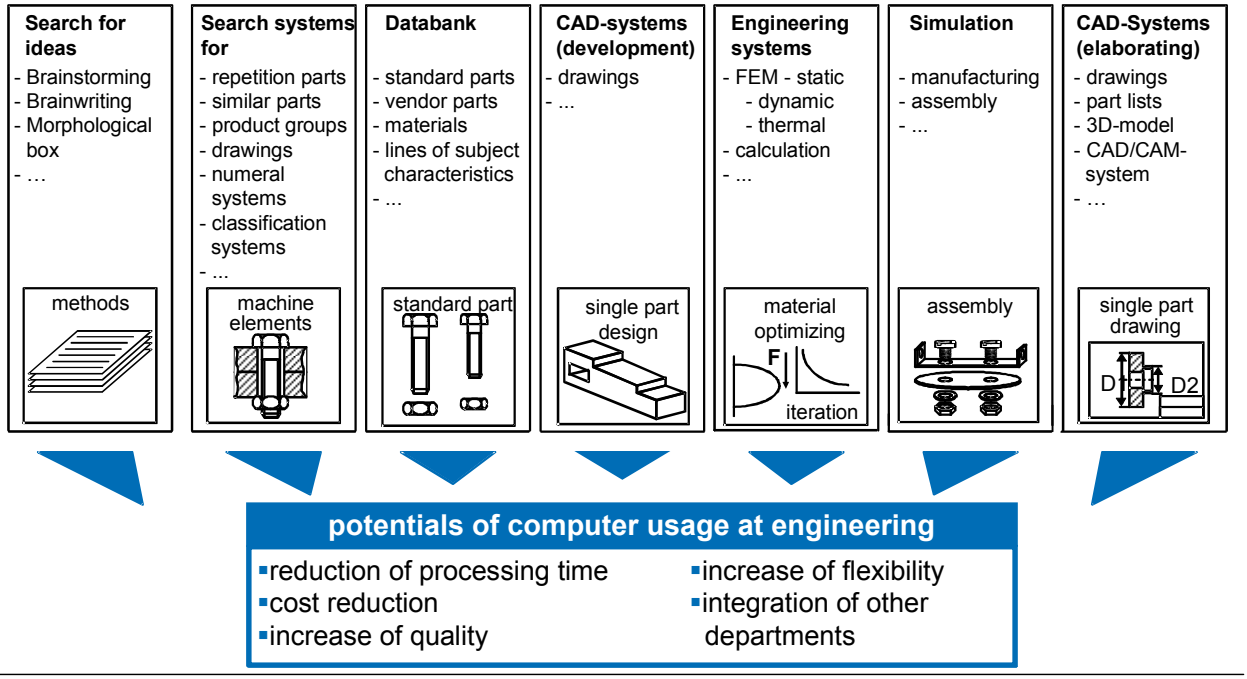
Engineering tools



potentials of computer usage at engineering

- reduction of processing time
- cost reduction
- increase of quality
- increase of flexibility
- integration of other departments

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Notes on Figure:

Besides CAD-systems for the generation of the part geometry, drawings and part lists additional software tools can be implemented in the engineering processes. A continuous use of these tools is one auspicious approach to increase efficiency and productivity within the engineering department and moreover to increase the competitiveness of the company.

CAD-working place

source: Parametric Technology

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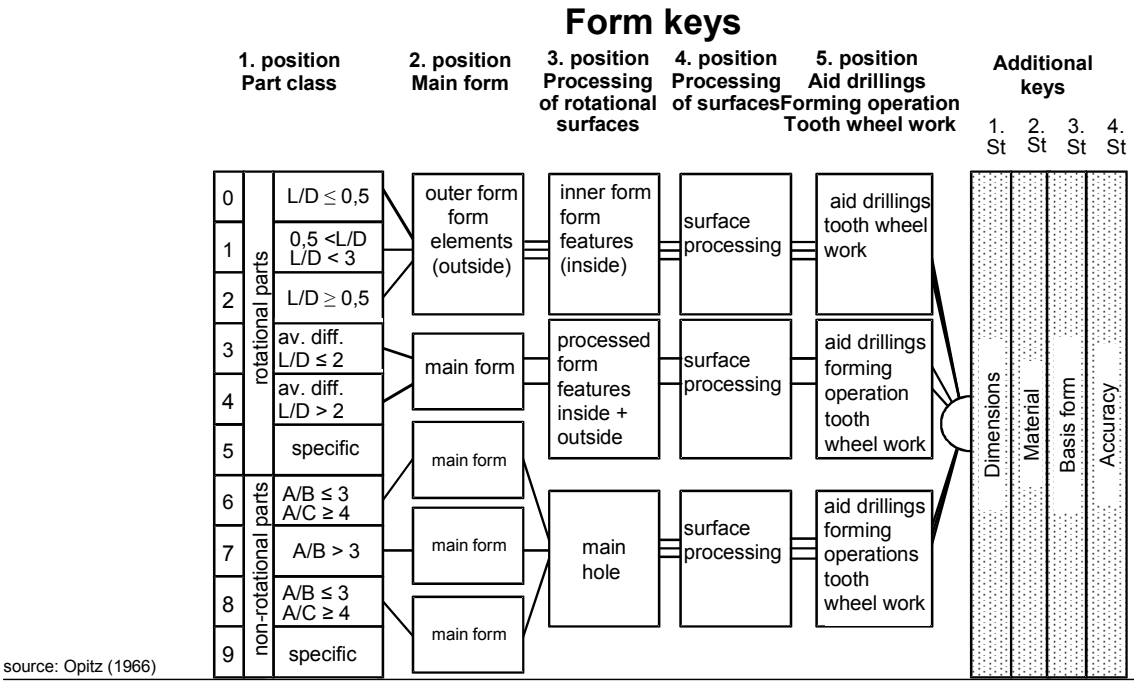
Notes on Figure:

The performance of available software tools increases continuously because of permanent innovation and optimisation of hardware components and software functionality. Consequently, even most complex tasks can be supported by these tools.

CAD-systems on PC-platforms gain more and more importance especially for small and medium enterprises, because these systems offer high performance potentials and don’t need high investments.

Classification systems for work pieces



source: Opitz (1966)

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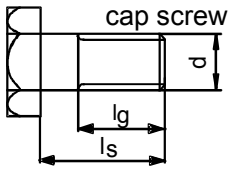
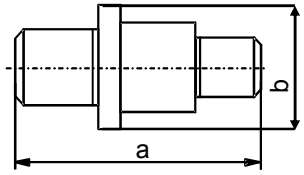
Notes on Figure:

The targeted access to knowledge or documents is one precondition for the efficient reuse of existing solutions. But this knowledge has to be gathered, structured and registered. Established organisational means are classification systems and numeral systems.

Survey of different numeration systems

Classification system (full communicating number system)	Combined number system (partly communicating number system)	Parallel number system
E.g.: hexagon head cap screw 	E.g.: shaft 	
Nr. 10 30 40 diameter of thread d = M 10 thread length l_g = 30 mm shank length l_s = 40 mm	Nr. 100 50 07 a ≤ 100 mm ident- b ≤ 50 mm number	Nr. 4711 - 100 50 Identi-fication number a ≤ 100mm b ≤ 50mm
Identification = Classification	Full identification always depends on classification	Identification is independent of classification

source: REFA, DIN

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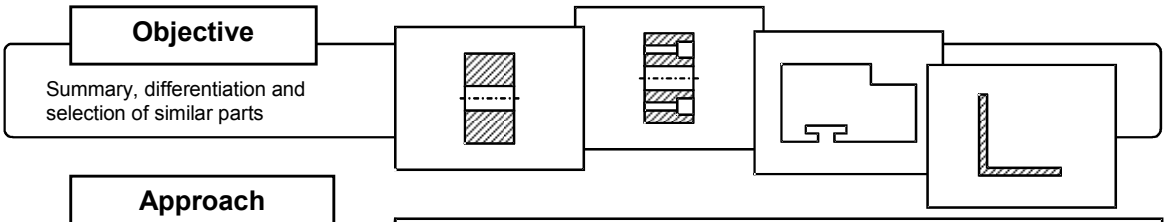
Notes on Figure:

There are different kinds of number systems. The appropriate number system can only be identified by considering the complexity and the comprehensiveness of the product spectrum. Concerning the conception of a number system it is indispensable to provide sufficient figures (numbers). Otherwise the number system can become invalid in case of an increasing amount of products.

Lines of subject characteristics (DIN 4000)

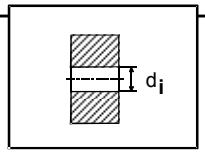


Objective

Summary, differentiation and selection of similar parts

Approach

1 Definition of subject characteristics



2 Development of lines of subject characteristics

3 Integration of lines of subject characteristics into standards, documents (e.g. repetition parts catalogue)

source: DIN 4000

fig. 1

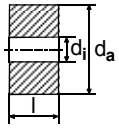
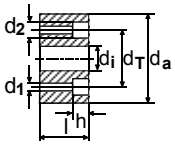


fig. 2



line of subject characteristics DIN 4OOO - ...

classific. letter	A	B	C	D	E	F	G	H	J
nomination	inside diameter d_i	outside diameter d_a	length l	height h	graduated circle diameter d_T	diameter d_2	diameter d_1	material	
reference									
unit	mm	mm	mm	mm	mm	mm	mm		

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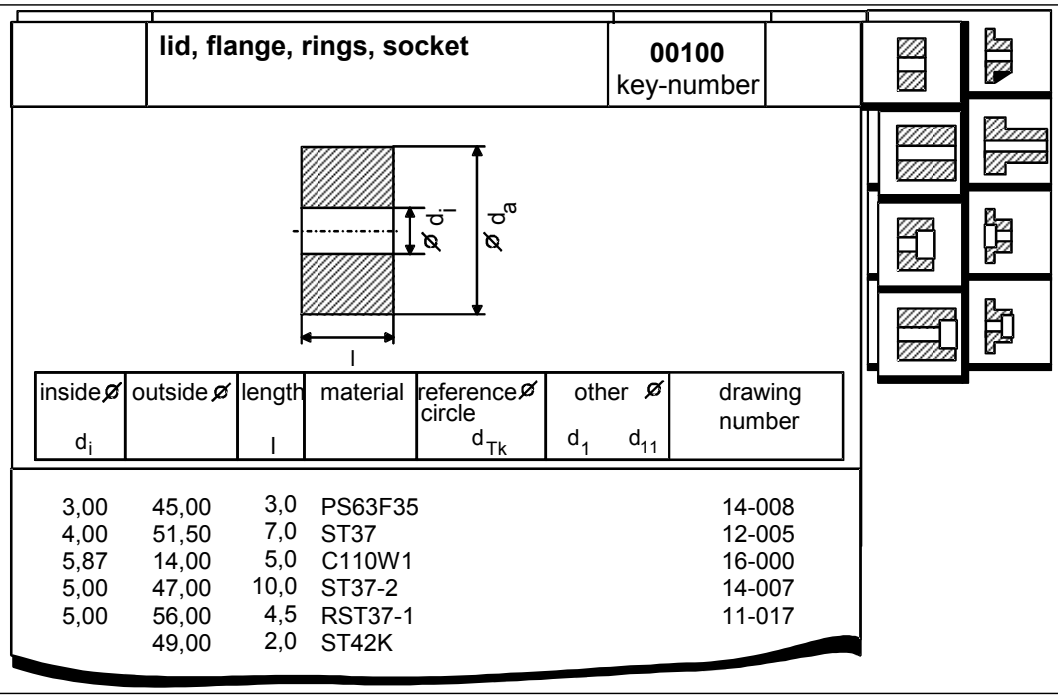
Notes on Figure:

To benefit from the high potentials of reuse within the engineering phase it is indispensable to use corresponding methods and tools. For example, components and modules can be described by lines of subject characteristics to ensure the fast identification of appropriate solutions.

A systematic development of these lines of subject characteristics is an essential precondition for the efficient use. Therefore components have to be reasonably structured and classified by non-ambiguous subject characteristics to ensure a high degree of reuse.

Repetition parts catalogue



inside Ø d_i	outside Ø	length l	material	reference Ø circle d_{Tk}	other Ø d_1 d_{11}	drawing number
3,00	45,00	3,0	PS63F35			14-008
4,00	51,50	7,0	ST37			12-005
5,87	14,00	5,0	C110W1			16-000
5,00	47,00	10,0	ST37-2			14-007
5,00	56,00	4,5	RST37-1			11-017
	49,00	2,0	ST42K			

source: Schuler

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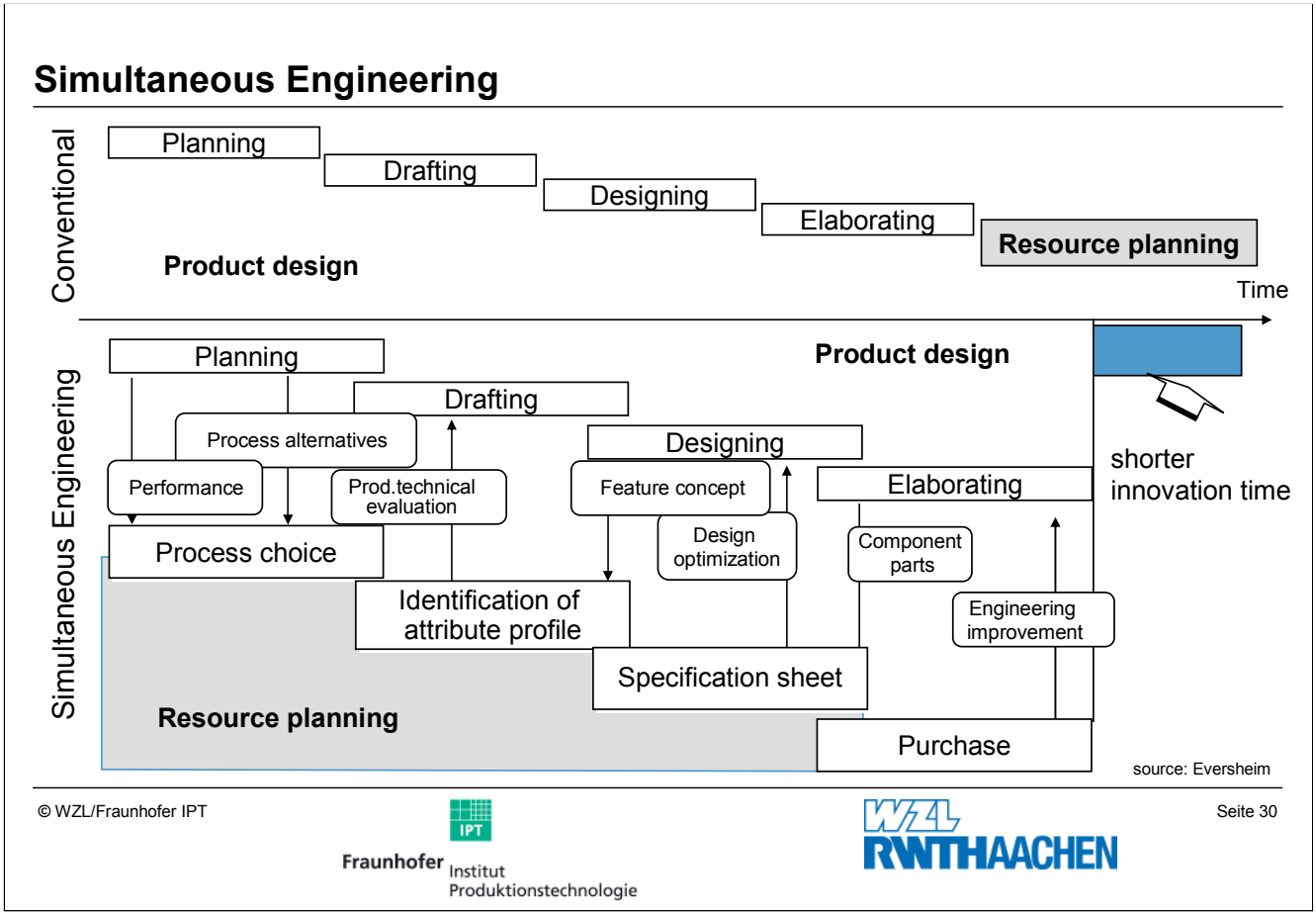
Notes on Figure:

One example for the reuse of existing solutions without software tools are repetition parts catalogues in which components are described by using principal drawings and variable geometric elements. The components are added to a catalogue.



Notes on Figure:

One approach for the acceleration of product development is Simultaneous Engineering (SE). SE is one part of the integrated product and process design. Focus of SE is the optimisation of organisational interfaces in companies by vertical and horizontal task integration in product development. Horizontal task integration is the early, process-oriented consolidation and coordination of tasks over the internal and external product development process chains. In the past the main focus was to adjust product development with product resource planning. Today, SE considers the whole product development, from the product idea to launch. The aim of a vertical function integration is to complete the planning knowledge of the indirect departments with the using knowledge of the direct departments. To achieve this skilled workers will be involved in product and process design for example. The parallel engineering process and the advanced coordination at workflow of the product development are therefore standing in the primary focus. The term Concurrent Engineering (CE) is used similar. Original meaning describes CE as the computer aided and simultaneous editing of objects from several design engineers in identical design rooms; a differentiation of contents of these both terms is not possible any more from today's point of view.

Literatur lectur 3:

Boutellier R, Gassmann O und Zedtwitz M v (2000). Managing global innovation - uncovering the secrets of future competitiveness, 2. Aufl, Springer, Berlin.
On the basis of empirical studies the authors have identified different types of global product development strategies. This book is foundational act for globally shared product development.

Cooper R G (2002). Top oder Flop in der Produktentwicklung - Erfolgsstrategien: von der Idee zum Launch, 1. Aufl, Wiley-VCH, Weinheim.
Cooper defined the State-Gate-Process. This process consists of phases (stages) in which the participants and organization units can assign their work content and procedure predominantly on their own.
On the other side are the gates. The results are synchronized referring to them. Especially the development process of the automotive industry are built upon them.

DIN (1992). Lines of subject characteristics : DIN 4000, Beuth, Berlin.
The DIN standard describes the buildup and the implementation of lines of subject characteristics.

Ehrlenspiel K (2003). Integrierte Produktentwicklung : Denkabläufe, Methodeneinsatz, Zusammenarbeit, 2. Aufl, Hanser, München.

Eversheim W (1998). Konstruktion, 3. Aufl, VDI-Verl., Düsseldorf.
Eversheim describes the designing options of engineers and gives a survey of different engineering methods. The author focuses especially on the rationalization of engineering processes by presenting simultaneous engineering on the one hand and IT-systems on the other hand.

Eversheim W, Bochtler W, Grassler R und Kolscheid W (1997). Simultaneous engineering approach to an integrated design and process planning. European Journal of Operational Research, 100(2), 327-337.

Eversheim W und Schuh G (1996). Betriebshütte - Produktion und Management, 7. Aufl, Springer, Berlin.
Standard reference book. Questions about product development are discussed in chapters 4, 6 and 7.

Koller R (1998). Konstruktionslehre für den Maschinenbau : Grundlagen zur Neu- und Weiterentwicklung technischer Produkte mit Beispielen, 4. Aufl, Springer, Berlin [u.a.].

Opitz H (1966). Werkstückbeschreibendes Klassifizierungssystem, Girardet, Essen.

Pahl G und Beitz W (1997). Konstruktionslehre - Methoden und Anwendung, 4. Aufl, Springer, Berlin.
Standardwerk der Konstruktionslehre.

Roth K (2000). Konstruktionslehre, 3. Aufl, Springer, Berlin.

Literatur Vorlesung 3:

Schuh G (2005). Produktkomplexität managen - Strategien, Methoden, Tools, 2. Aufl., Hanser, München.
The variety in the product program which is indicated by different customer requirements is a big problem for many producing companies. Scale effects can not be realized any more and the costs for products increase. In this book the consequences of complexity are pictured as well as methods and tools to avoid, control and reduce the variety of versions are presented.
Basis methods are the attribute-tree and the variant-tree.

Ulrich K T und Eppinger S D (2000). Product Design and Development, 2. Aufl, McGraw-Hill, Boston.
Standard reference book for product development in the American range. The authors present the product developing process by using 10 phases which are built upon each other.
An overview is given at www.ulrich-eppinger.net.

Utterback J M (1995). Mastering the dynamics of innovation - how companies can seize opportunities in the face of technological change, 3. Aufl, Harvard Business School Press, Boston, Mass.
Utterbacks shows longtime developments with regard to innovation and competition conditions in different industries.
Most important phenomenon in this context is the occurrence of a „Dominant design" which poses as a kind of industrial standard.
Until a „Dominant design" appears the number of competitors is high and the concepts are different. After a „Dominant design" has appeared the innovation activities focus more and more the manufacturing process to reduce the costs of the product.

VDI (1993). **VDI-2221** - Methodik zum Entwickeln und Konstruieren technischer Systeme und Produkte. Beuth, Berlin.
Standard for the development of technical products and machines which has been generated with the aid of the most important German engineering methodologists.

VDI (2003). Entwicklungsmethodik für mechatronische Systeme: VDI-Richtlinien; **VDI 2206**; Entwurf, VDI-Verlag, Düsseldorf.
Standard for the development of products with mechanical, electrical, electronically and software components.
This method focuses compared to VDI 2221 more on the designing and testing of provable single extents.

Wheelwright S C und Clark K B (1994). Revolution der Produktentwicklung - Spitzenleistungen in Schnelligkeit, Effizienz und Qualität durch dynamische Teams, Campus, Frankfurt am Main.
Wheelwright and Clark describe the development process in the automotive industry.
An essential aspect is the classification of innovations according to innovation extent and product or process relation.