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A new Swedish textbook on Product Development and Design

Jan-Gunnar Persson	Hans Johannesson	Dennis Pettersson
Department of Machine Design Royal Institute of Technology KTH, Stockholm jgp@md.kth.se	Department of Product and Production Development Chalmers University of Technology, Gothenburg hansj@chalmers.se	Department of Human Work Sciences/Industrial Design Luleå Technical University LTU, Luleå Dennis.Pettersson@ltu.se

Abstract

Several textbooks on systematic product development and design methodology have been published during the nineties. This literature, in English, is to a large extent based on recent international design research. However, these textbooks are primarily of more abstract character, treating only the product development process and design methodology.
In Scandinavia, there has been a lack of a modern textbook on Product Development and Design in a Scandinavian language, particularly for the shorter educational programs (bachelor level) in Mechanical Engineering and Engineering Design. Besides the product development process and design support methods, also industrial design and engineering design should be treated; materials selection and dimensioning, production methods, quality, robust design and tolerances, design of experiments, computer modelling and simulation, optimisation, visualisation and communication, creativity support, cost calculations, project planning/handling, intellectual property and patents.

A new modern textbook in Swedish covering most topics related to product development and product realisation as listed above, written by the authors of this paper, was introduced in Sweden in 2005. This book was originally intended as a basic text for educational programs in Mechanical Engineering and Industrial Design Engineering on bachelor level, but it is now also used for educational programs on master level (civilingenjör). The focus has been on synthesis, but some chapters also cover analysis e.g. by means of computer modelling and simulation for concept evaluation. The intention has been to give a broad overview of the various topics in Engineering Design and Industrial Design. A comprehensive chapter on Design theory and methodology, based on recent design research in Sweden (in particular at Chalmers University of Technology) and in the Nordic countries has also been included. This chapter, covering fundamental issues like functional decomposition, function means tree, coupling analysis by DSM-matrices, requirements handling etc. will be of specific interest for master programs in Engineering design. So far, this book has been well accepted in Sweden. 769 books have been delivered, by April 2006. This paper presents a brief overview of the contents, as well as some feedback from its use in different types of engineering programs in Sweden.

Keywords: Engineering Design, Industrial Design, Product Development, Education, Textbook

Background and scope

Considering the lack of a modern textbook on Product Development and Design in a Scandinavian language, one major Swedish publisher initiated a contact with professor Hans Johannesson at Chalmers University of Technology, concerning the possibility for writing a new textbook. This first contact was taken early in 2003. Such a book should primarily meet the needs for the shorter educational programs in mechanical engineering and engineering design, on bachelor level ("Högskoleingenjör"). However, the proposed textbook should also be feasible as introductory literature on masters level ("Civilingenjör" programs). It became obvious that a broad scope of Product Development would be preferable, covering both the PD process and design theory, as well as engineering design basics, industrial design basics, computer modelling/IT-support and other PD related topics. It was then decided to realize this book project proposal, as a joint effort between three Swedish professors, for a broad coverage of the field of PD. After finalisation during 2004, the new book entitled "Produktutveckling – effektiva metoder för konstruktion och design" [1] was introduced on the Swedish market in January 2005.

Professors Johannesson and Persson have the chairs in Machine Design at Chalmers University of Technology (Gothenburg) and the Royal Institute of Technology – KTH (Stockholm), respectively. Professor Johannesson has a forefront position within Product Development and Design theory, and Product Models. His research team has presented a number of theses on the industrial application of the Theory of Technical Systems [2], Theory of Domains [3], requirements handling, function-means modelling and analysis of couplings. Professor Persson´s research has been more directed to model driven design and computer simulation of mechanical systems and energy transforming systems, as well as EcoDesign. He has also a firm background from industry, in solid mechanics, dimensioning and optimisation of load carrying structures. Professor Pettersson, with a background as industrial designer, has the chair in Industrial Design at Luleå Technical University. Besides basics in Industrial Design and ergonomics, he also covers several fields within PD, as function analysis and creativity methods. All three authors carry out industrial PD projects within their courses in applied design, and they have long experience from industrial product development and co-operation with industry.

Introductory chapters

The introductory part of the book starts in chapter 1 with a historical overview of product development and design, as well as a discussion of the somewhat fuzzy concept "Design" and its different interpretations. Also, the concepts of synthesis and analysis are being defined. Chapter 2 continues with an overview of the industrial PD and design process and current trends in industrial PD. Driving forces, "hard" and "soft" product properties and requirements stressing the importance of industrial design, and complex multi-technology system products are discussed. Chapter 3 gives a brief overview of the PD process, characterised by integration (technical and organisational), iteration (the synthesis-analysis loop, figure 1), and innovation. The product life cycle, for an individual product unit considering production, use and disassembly-recycling, and for a product generation on the market ("S-curve", figure 2) are discussed. The PD process is further treated more in detail in chapter 5, that presents new research results on design theory and its adaptation for computer representation, as opposed to the rest of the book that merely has the form of a compilation of established knowledge from different fields, related to PD.

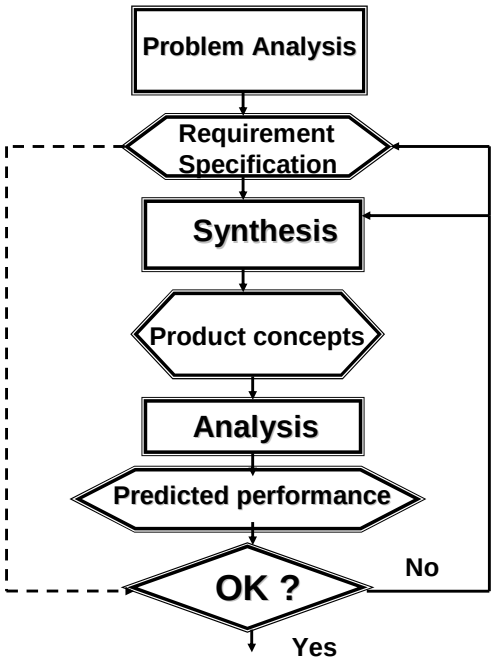


Figure 1. The iterative synthesis - analysis loop

In chapter 4 the industrial PD process is further elaborated, including product strategy, and market analysis. The design phases feasibility study, product specification, concept generation, concept evaluation/selection, detailed design, prototyping, adaptation for production, market introduction – market support/maintenance and finally product retirement and recycling, are discussed.

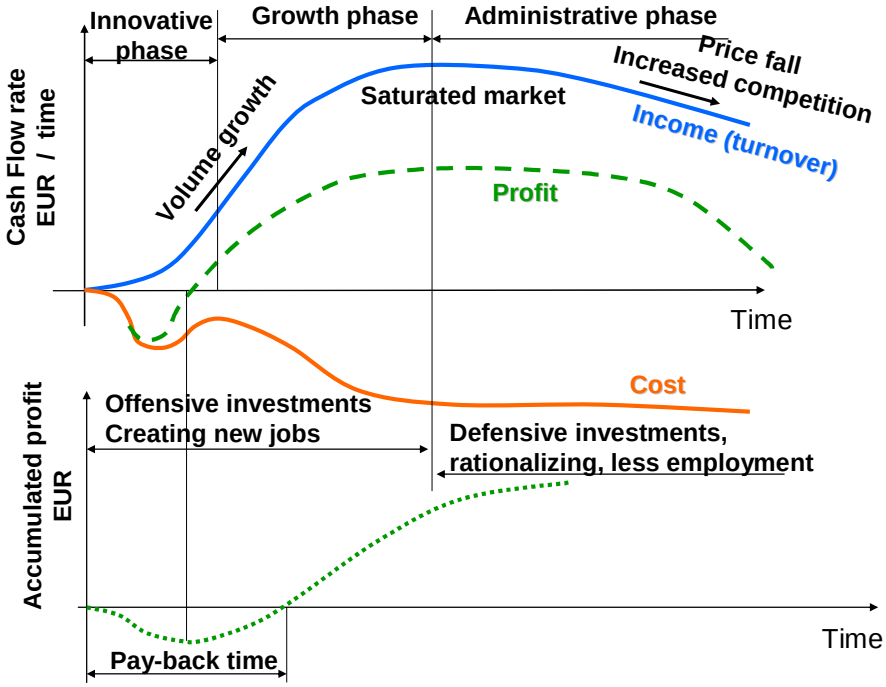


Figure 2. Product life cycle – for a product generation on the market (S-curve)

PD theory and support methods
Two topics that initially motivated the writing of the book are design theory and methodology and design support methods. Besides presenting well-known theories and methods from the literature, the book also presents new Swedish research results from this area.

One such example is a function-means based product platform description model developed at Chalmers University of Technology. The model concept introduced is a *system structure* composed of *a hierarchical function-means tree* in order to capture the design intent, rationale and history of platform based products, and a *configurable component structure* that has the capability to define the generation of a *representation of ´physical´ hardware and software part structures*.

These representations are objects in an object-relation model. Product requirements defining the functionality desired and constraining factors are modeled as *functional requirements* (FR:s) and *constraints* (C:s) respectively. A design solution fulfilling a functional requirement is modeled as a *generic design solution* (DS). A DS is the generic carrier of the wanted function or the generic means of realizing it. To implement generic design solutions into configurable realizable product items, *configurable components* (CCs) are used. A CC is a parametric representation of a family of realizable product items (hardware or software) that can be configured into an instance variant, given the current instantiation parameters. Instantiation means that the CC configures and defines an instance representation referring to ´real physical articles´.

To more fully describe and explain the product representations, documents, attribute lists and models can be linked to the DS, FR and C objects. ´Olsson matrices' can also be linked to these objects, as aids for sorting descriptive information into different life cycle phases and aspect domains. The ´Olsson matrix´, which was proposed by the late Freddy Olsson, former professor at Lund University, in his doctoral thesis [4] from 1976, is a matrix based checklist with product life cycle phases as rows and product related aspects as matrix columns. The modeled objects and their linked items are shown in figure 3.

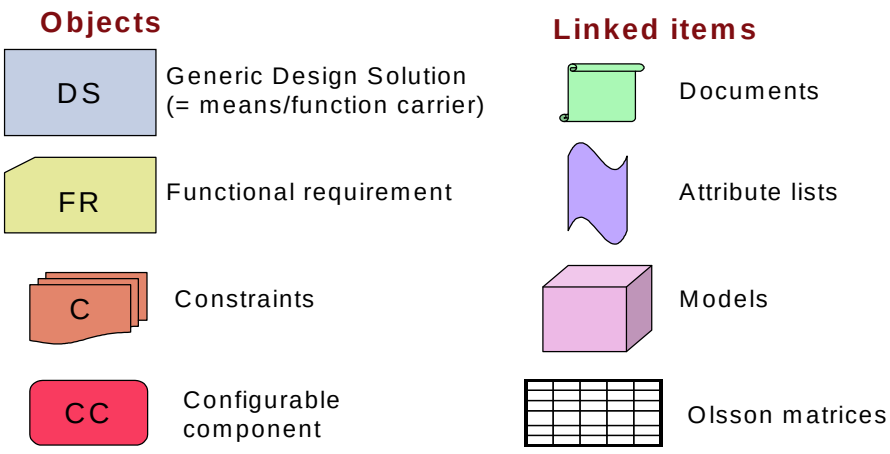


Figure 3. Modeled objects and linked items

The relations (1/1=one to one, 1/n=one to many, n/1=many to one) between the different objects and the linked items are as follows:

- DS to FR (1/n): *rf = requires_function*
- FR to target DS (1/1): *isb = is_solved _by*
- FR to non-target DS (1/n): *iib = is_influenced_by*
- DS to C (1/n): *icb = is_constrained_by*
- C to DS (1/n): *ipmb = is_partly_met_by*
- DS to DS (1/n): *iw = interacts_with*
- CC to DS (1/n): *iaio = is_an_implementation_of*
- CC to Parts (1/n): *iprb = is_physically_realised_by*
- CC to lower level CC (1/n): *icu = is_composed_using*
- Objects to attribute lists (1/n): *ha = have_attributes*
- Objects to documents (1/n): *hd = have_documents*
- Objects to models (1/n): *hm = have_models*
- Objects to matrices (n/1): *hom = have_Olsson _matrix*

Consider as an example a functional requirement FR = ´Carry load´, with a linked attribute list with the attributes ´static load = X kN´ and ´dynamic load = Y kN´, a linked document containing requirement related product planning background information and another that contains building construction safety regulations. This FR ´is solved by´ the generic design solution DS = ´Console´ which has a link to a CAD file with a model of the console geometry and another link to a document containing motives for the taken design decisions related to this chosen DS. The DS is also ´constrained by´ the constraining requirement C = ´use approved standard profiles´, and this C is further connected to a standard profile catalogue via the concerned life cycle cell in a linked ´Olsson matrix´. The final implementation of the DS, i.e. the description of the console family and the rules for creating console family members, will be found in the linked object CC = ´Configurable console´. This CC contains a parameterized solid CAD model, rules for input parameter variation, an implemented method for retrieval of standard profile data from the standard profile catalogue as well as for generating the output information needed to manufacture a console instance.

Using this set of objects with linked information it is possible to describe both WHAT to design (FRs and Cs with attributes and linked documents containing regulations, standards and other referenced background information), and HOW (DSs with attributes, linked describing models and reference documents containing motives, decisions, and other relevant information) a design solution has come to be what it is. I.e. major parts of the design history can be handled in a structured manner with this approach. By combining this description with the CC concept it will then also be possible to generate the information needed to produce product instances.

The creation capturing part of the proposed product platform model is based on the enhanced function-mean tree with its linked items, figure 4. The complete product platform model is established by linking the bottom level DSs to design solution implementing CCs, which are then aggregated bottom-up to form the hierarchical configurable product platform structure.

Another example of a research result from Chalmers is the “Robust design and tolerancing (RD&T) method”. RD&T is a method and a software tool for handling geometrical variation throughout the product development process. It considers geometrical variation due to disturbance sensitivity of the chosen geometrical concept, part variation and manufacturing process variation. RD&T provides procedures to find geometrically robust design concepts, to allocate optimal tolerances to geometrical dimensions and to identify critical dimensions by

means of stability analysis (= predict the effect of a each parts variation on other parts or critical dimensions in the system), variation analysis (= determine variation distributions of critical dimensions) and contribution analysis (= predict the contribution of each part tolerance to the distribution of the critical dimension).

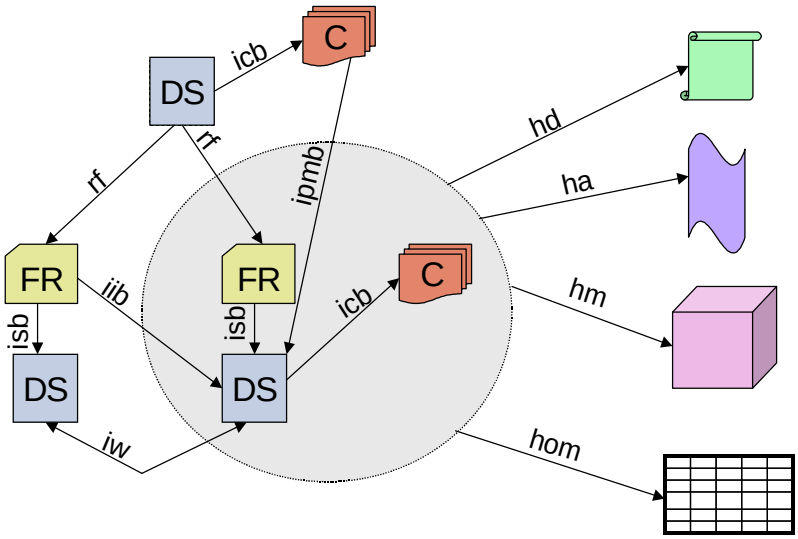


Figure 4. Function-means tree with linked items

In chapter 6, dimensional analysis, as well as nomenclature used in the book is discussed, followed by a description of PD support tools – DFX. This section is introduced by some historical background, from Operations Research and Value Analysis during the 50-ies, to methods for Quality Assurance and current DFX-tools to support integrated product development. Here commonly used tools as VA, QFD, MFD, FMEA, FTA, DFA, Robust Design / RD&T and DOE-factorial testing are presented, as well as EcoDesign tools and methods as DFD and LCA for environmental and product life cycle consideration.

Basics in Mechanical Engineering Design

In chapter 7, materials selection is discussed and an overview is given of mechanical properties, physical properties, heat treatment etc. for different types of engineering materials used for mechanical design. Metals, polymer materials and ceramics, as well as composite materials (figure 5) are covered. Dimensioning of load carrying structures, applied strength of materials and structural mechanics is then discussed. This section covers dimensioning criteria – strength or stiffness - , types of mechanical loads and different failure mechanisms. Further, spectrum load and endurance life considering fatigue is discussed. In particular, simplified dimensioning methods considering fatigue in welded steel designs is covered. Finally, load carrying capability of basic structural elements as beams, torsion bars (figure 6), plates, and shells are being clarified. Principles for shear stabilization of a structure; trusses, frames and reinforced plate/shell structures; is discussed (figure 7), as well as reduced load capacity considering buckling of reinforced shell structures. Such understanding of basic structural mechanics will be essential not only for simplified analytical calculations, but also as a basis for the students ability to create numerical (FE) models.

In chapter 10, a brief overview of manufacturing methods for engineering materials, as well as joint technologies is given. Forming by cutting and machine tools are covered, as well as plastic forming. Properties and processes for welding, brazing/soldering, gluing and mechanical joints are described.

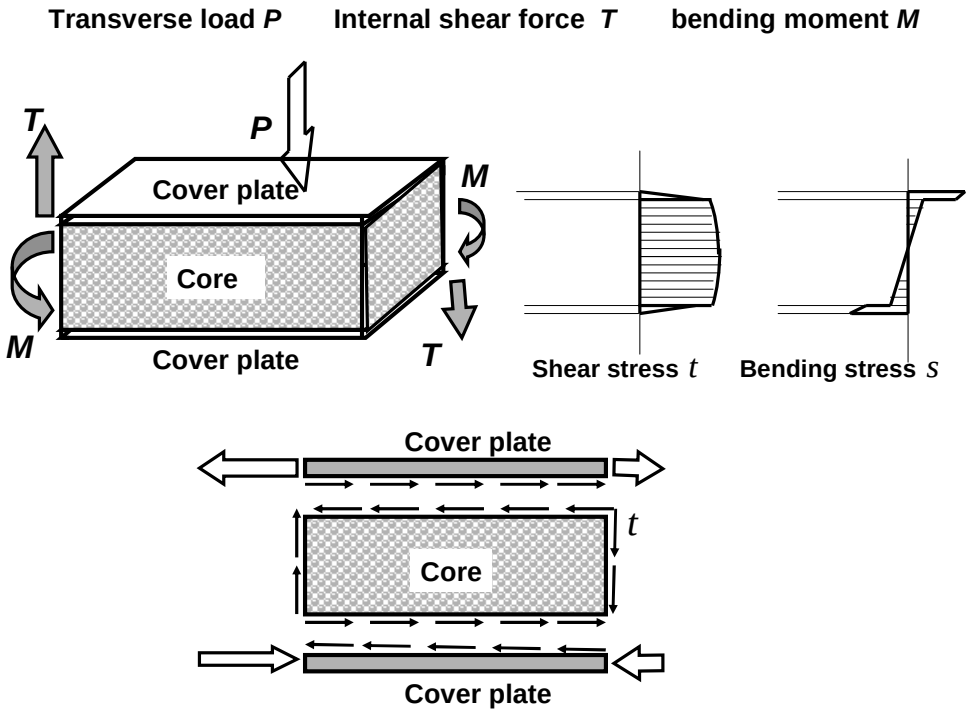


Figure 5. Sandwich material, load carrying function for transverse mechanical loading (bending stiffness)

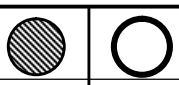
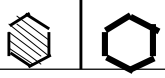
Profile type	Solid	Thin walled			
		Closed		Open	
		Single cell	Multi cell	Plane profile sections with common intersection	Others
Not rotational symmetry					
	Little warping of cross section				Considerable warping of cross section
Rotational symmetry					
Regular n-polygons					
	No warping				

Figure 6. Torsion, cross section warping for profiles of various cross section geometry

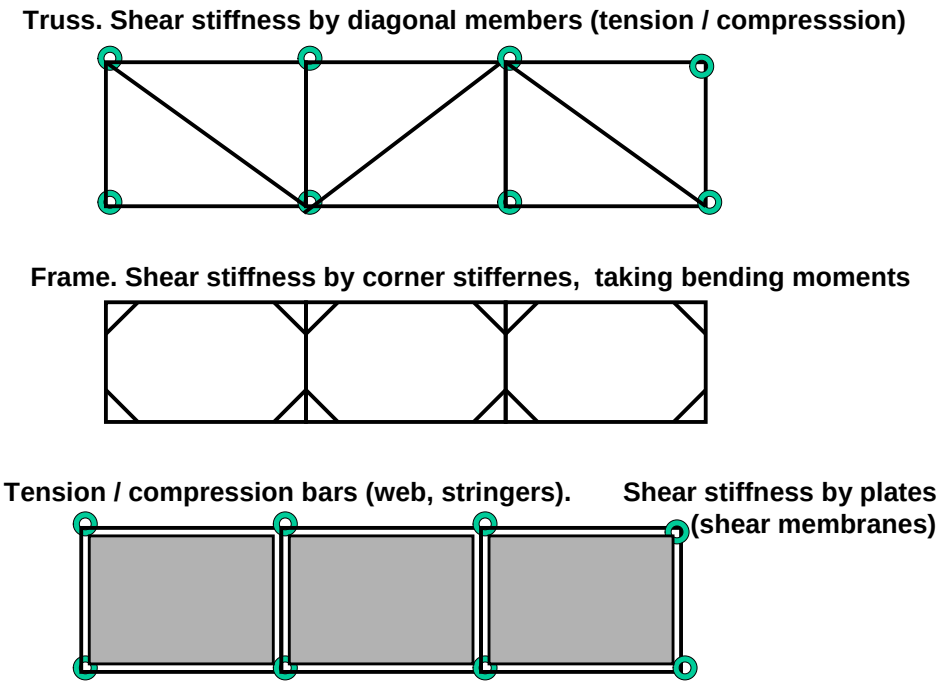


Figure 7. Different principles for shear stabilizing of a structure. Diagonal members (truss), stiff corners (frame), or shear membranes (plates)

Basics in Industrial Design

In chapter 8 Industrial design is introduced with a description of the history of the professions of industrial design. The context is the development of industry and the development of the profession is seen in the light of the shifting of focus in industry. From the beginning it was much about bringing in aesthetics for making the products appear more diverse than they actually were, but soon it was more of taking the user into consideration and make product design more holistic- design is not just the surface but the whole of the product. The development of the organizations for organizing of the professions in design is presented as an orientation.

Industrial design today is discussed and the different perspectives of design are shown from four viewpoints. One of those is the user perspective and how ergonomics is used for making good design for the users. We also discuss that the design of products always has been a way of communicating wealth, power or philosophies for the owner and user.

Another perspective is the company producing products and their use of professional designers for making products successful on the market. Here the aspects of design for marketing and selling are discussed as well as design and branding. The logics of the design for making the products and the functions of the products understood by the user, design for expressing the qualities of the product and in what ways design could be used for guiding the user in what way the products is meant to be used is discussed. A third perspective is design for bringing innovations to industry from a more structural viewpoint. This is not a new way of using design, after the Second World War the establishing of Design Council in England was a strategy for the development of British industry. The forth perspective is the society as a whole and the environmental load from all our products when in use and for recycling. It is discussed in what ways professional designers can contribute to sustainability in our society.

Figure 8. Car interior and welding with the protective helmet "Speed-glass" from Hörnells

Figure 9. The toaster "Dualit" as an illustration of Akio Moritos expression "Design is the visual evidence for quality". Akio Morito was one of two founders of Sony

Creativity in design is a big part of the chapter 8 and this is introduced by discussing in what ways design could be a driver for innovations in industry. The founding of the topic of creativity is presented by referring to J P Guilford and his thoughts from the early fifties. His ideas and definitions of creativity by discussing the creative product, the creative individual and the creative process is done before we present a range of methods for the creative processes in design. The base for this is a systematic way of solving design problems and value analysis and a battery of different methods for formulating the problem, the defining of the problem and the boundaries of the problem is presented. We also present methods for how to examine the design problem (again with value analysis, experiments, grading of functions and other activities). A wide range of methods for problem solving is presented with the original Brainstorming method as a starting point. Every method is presented in a way that

makes it possible for the reader to decide what method to use for different types of problems and advantages as well as some disadvantages for each method is discussed.

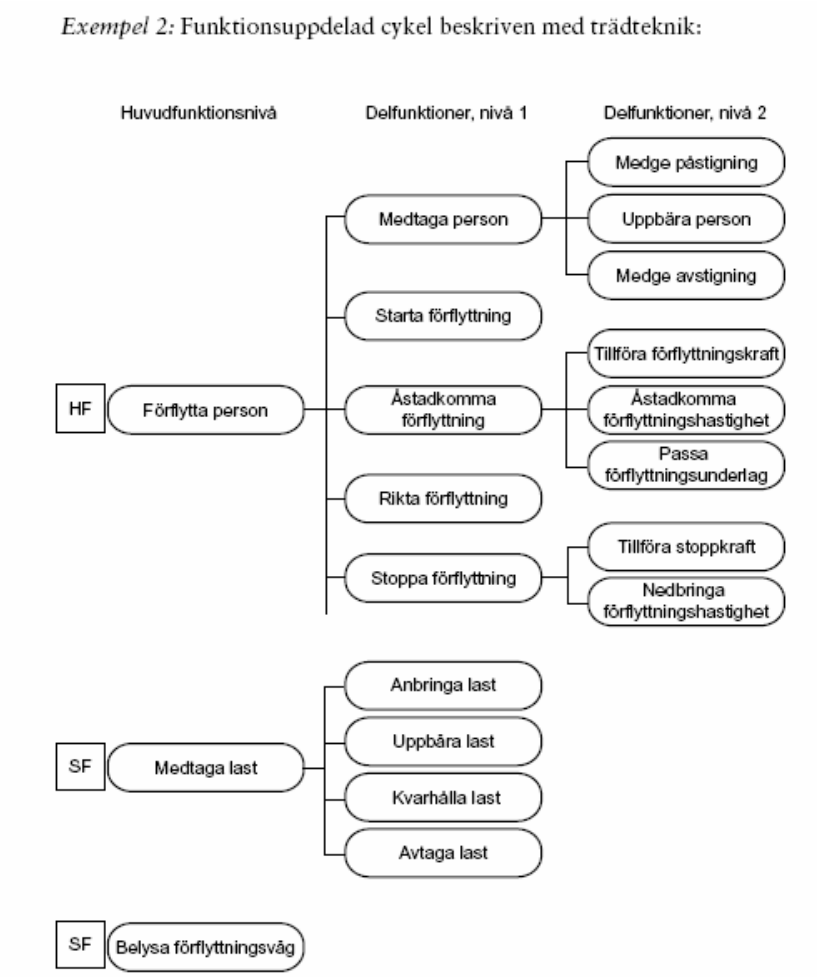


Figure 10. Example of graphic description of tree technique for analyzing of the use of a bicycle. Main function level, sub function level 1, sub function level 2

Computer support and model driven design

Chapter 9 presents different forms of computer support; basics of CAD (solid modeling, surface modeling and drawings) and CAE. Figure 11 shows one example of a drawing prepared from a CAD solid model of a cast bearing casing for a truck gearbox.

After an introductory general discussion of modeling, CAE tools (figure 12) including theory background and modeling techniques, using FE and MBS software, as well as lumped models with functional blocks (Simulink) are discussed, with some application examples (figures 13-14).

Optimization methods and geometry synthesis are also discussed, as well as methods for rapid prototyping and rapid tooling from CAD models. Virtual reality, “Gestaltung” and interpretation of pictures are discussed, and finally a short overview of administrative tools for product data, PDM- /PLM-systems and requirement handling.

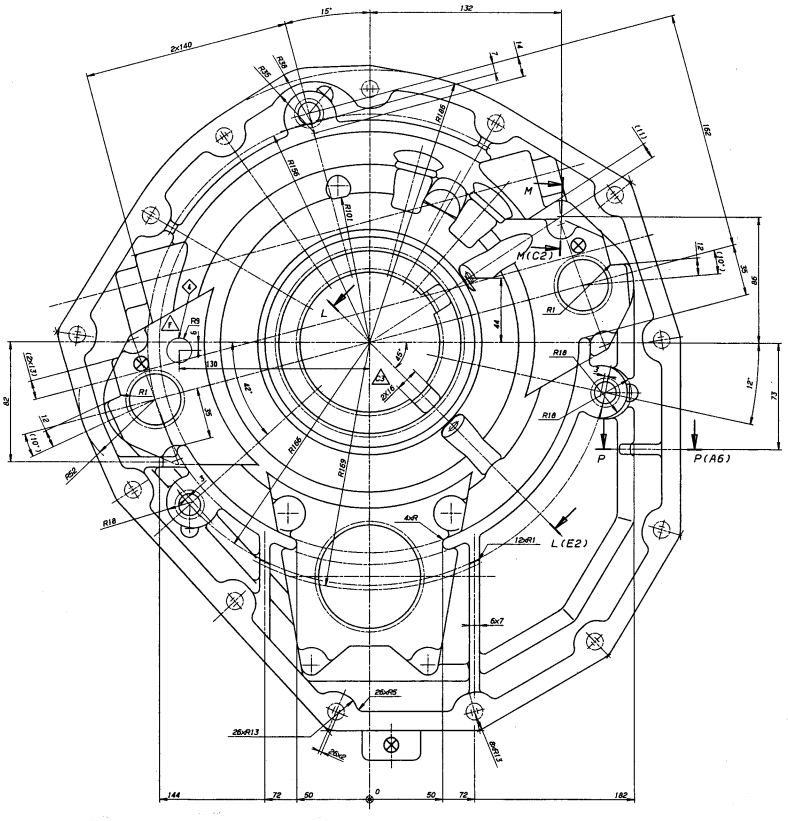


Figure 11. Example of drawing created from a CAD model. Bearing casing for a truck gearbox

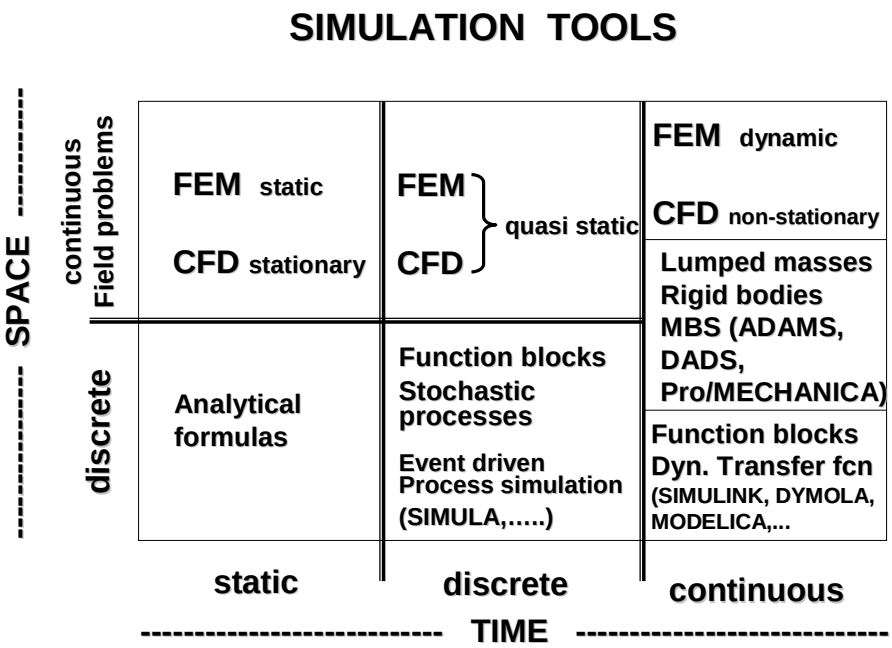


Figure 12. Overview, computer tools for CAE and simulation

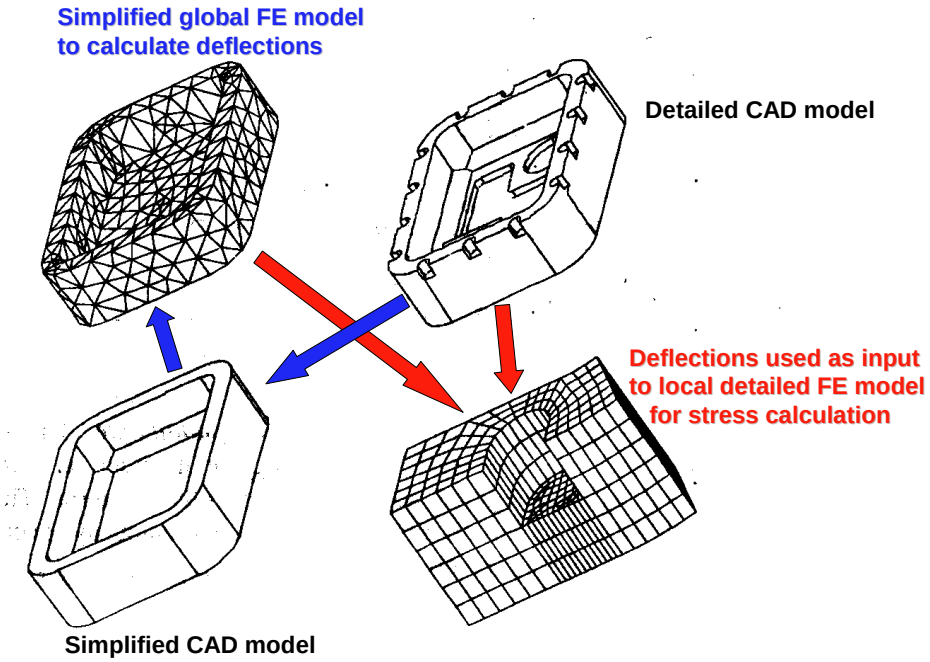


Figure 13. FE modeling, "cut out" technique for detailed calculation of stress concentrations: Simplification of detailed CAD geometry – FE calculation of global deformation – calculated deformations as boundary conditions for stress calculation in local detailed FE model

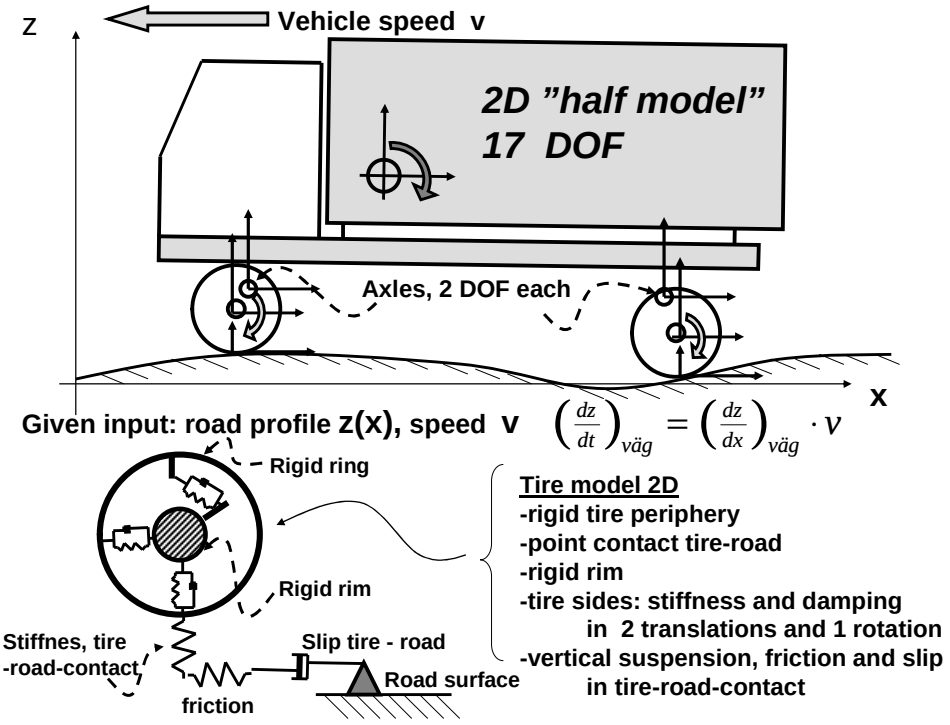


Figure 14. 2D rigid body (MBS) truck model, "half model" with 5 rigid bodies and 17 DOF

Supporting areas: project handling, cost calculation, and intellectual property rights

Chapters 11, 12, and 13 present basics of important non-technical support functions closely related to PD. In chapter 11, general methods for economical calculations as cost-income analysis, fixed and variable costs, investment calculus and methods for product cost calculation; absorption (full) costing or variable costing (figure 15), and Activity Based

Costing; are covered. Chapter 12 is directed to project work, project handling and project planning. Finally, in chapter 13, basics of intellectual property rights, patents, and pattern protection are presented.

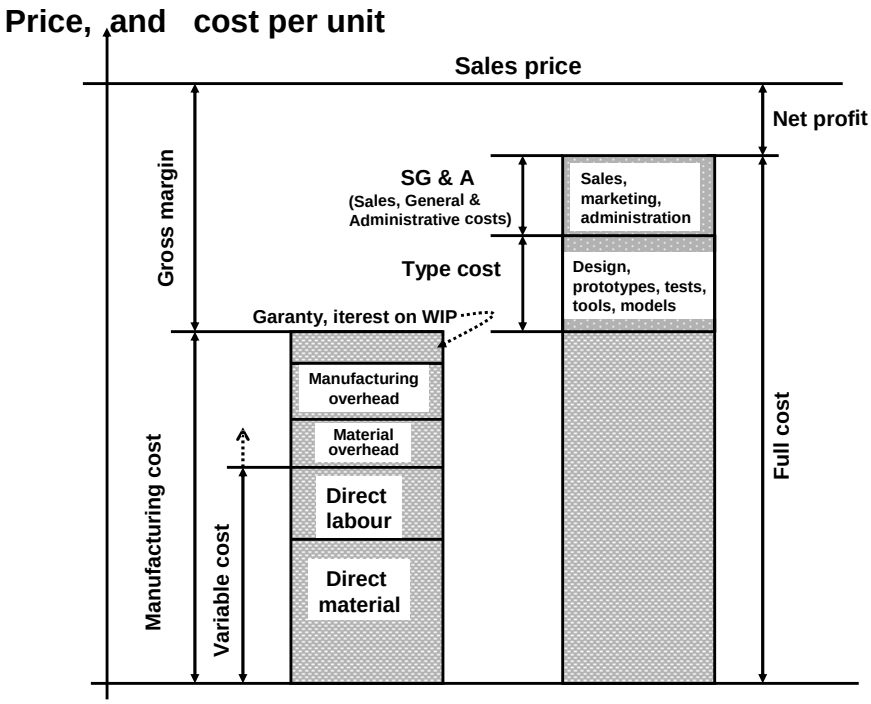


Figure 15. Product cost calculation. Comparison of variable costing and absorption (full) costing

Use of the book, and students feed-back

This textbook was primarily intended for the shorter (bachelor) engineering programs directed to product development and design. The book has however also been used at the masters level, and throughout the entire "civilingenjör" programs at Chalmers University of Technology, KTH and Luleå University of Technology. Besides use at these universities, the book has so far been purchased as course literature by some of the regional university colleges in Sweden. At Chalmers, the book has also been used for PD courses within continuing education for engineering designers in industry.

Exercises are not included in this textbook. Design projects are considered to be handled separately in the design courses, with this textbook used as background literature and as a reference book.

During the spring semester 2005, Mechanical Engineering students at KTH, participating in the Advanced Course in Integrated Product Development, made an analysis of Product Development (PD) literature [5]. The following citation (translated from Swedish) concerning the new textbook is taken from this evaluation report:

" This book gives a very good, and broad holistic view of the field of PD. The authors have been successful in their ambition to write a book covering a wide topic. As a great number of methods and concepts within PD have been covered, the depth is however sometimes a bit limited. With the comprehensive subject list, the book is well adapted for an orientation within the field. The chapters are written separately, which is considered an obvious advantage, as the book can then be used as a reference book. It is comprehensive, well structured and easy to read.

……As compared to recent PD literature in English [6], (and [7], [8], [9] – authors comment), concentrating on the PD process, the book Produktutveckling – effektiva metoder för konstruktion och design – also (besides the PD process) covers various technical subjects, such as dimensioning and materials selection. It is also one of the few books written in Swedish, on the PD topic. …..
…… A very good introduction and overview for students within the field of PD and Design. ….
….. This book has a wider scope on PD, thanks to an historic overview. It was also useful to read of PD from another perspective. Concepts not fully understood from reading of PD process literature in English, became clear after reading the Swedish book ”

The book has also been announced and briefly analysed, in the Swedish journal “Mekanisten” [10], as follows, figure 16:

Bokanmälan

Produktutveckling - effektiva metoder för konstruktion och design

”Boken avser att fylla behovet av en modern, grundläggande och syntesinriktad basbok för högskoleutbildning inom industriell produktutveckling, konstruktion och design. Området karaktäriseras av tvärvetenskaplighet och syntes och skiljer sig från högskolornas traditionella teknikvetenskapliga analysämnen.

I boken speglas den utveckling av produktutvecklingsmodeller och stödmetoder för konstruktion och design som har drivits både inom den akademiska världen och inom industrin.

Utöver produktutvecklingsprocessen behandlas i boken relaterade kunskapsområden ur konstruktions- och designperspektiv: kreativitet, visualisering – kommunikation, ergonomi, materialteknik, tillverkningsmetoder, hållfasthetsdimensionering, produktkalkylering, projektplanering och immaterialrätt.

Bokens författare är erfarna lärare och forskare inom området och de har också lång erfarenhet av industriell produktutveckling och samarbete med industrin. Hans Johannesson och Jan-Gunnar Persson är professorer i Maskinkonstruktion vid Chalmers respektive KTH och Dennis Pettersson är professor i Industriell Design vid LTU i Luleå”.

Bokens målgrupp är:
Högskoleutbildning, produktutveckling inom industrin och produktion, konsultverksamhet, industriell design och myndigheter. Boken är tänkt att fungera både som handbok, uppslagsverk och som referenshandbok.

Titel: Produktutveckling - effektiva metoder för konstruktion och design, utgåva 1:2004 ISBN 91-47-05225-2

Boken är på 623 sidor och utgiven av Liber AB. Priset är 461 kronor (inkl moms) på Libers internetbokhandel (www.liber.se)

Vår bedömning är att:
• Boken ger en heltäckande överskådlighet och grundinsikter inom de viktiga områden som bokens tar upp

• Boken ger ett klart och kunnigt intryck och kommer att inspirera till fördjupande studier i produktutvecklingens ädla konst.

• Vi har även noterat att den har likheter med klassikern Karlebo Handbok dock med avsevärt större kunskapsdjup. Förhoppningsvis kan den få den omfattande spridning och livslängd som Karlebo Handbok uppnått.

• Vi tror också att boken, genom det systematiska upplägget, kommer att användas som uppslagsverk inte minst för de många fina definitionerna.

Övrigt

Boken saknar dock färg i det omfattande bildmaterialet. Vi förstår att det är en kostnadsfråga, men en möjlighet är att lägga ut materialet på Internet allt för att effektivisera utbildningen.

Conny Isaksson och Johan Bratthäll

Figure 16. Announcement of the new textbook in ”Mekanisten”, journal of SMR - the Swedish Society of Mechanical Engineers, Naval Architects and Aeronautical Engineers [10]

Further development

Some (usually minor) errors will be corrected for the next printing. In particular, the equations for energy balance for thermal systems, in section 9.2.2 of the book, have to be corrected. All corrections can be found on the publishers homepage [11].

For the next updated edition, Industrial Design Engineering, i.e. the integration between Engineering Design and Industrial Design, should be further discussed. Other topics that should be added or extended are e.g.: Electronics, opto materials and functional materials,

micro- and nano mechanics, automation and electromechanical, hydraulic and pneumatic actuators and systems. Also physical prototypes and mock-ups and a comparison between physical and virtual prototyping, as well as distributed development work, should be included.

The authors would certainly appreciate feedback from the use of this book and suggestions for further development and improvements, as well as possible extensions, for the next edition.

References

[1] Johannesson, H., Persson, J.-G. and Pettersson, D., ”Produktutveckling – effektva metoder för konstruktion och design”, *ISBN 91-47-05225-2*, 1st edition, Liber AB, Stockholm, 2004.

[2] Hubka, V. and Eder, W. E., “Design Science: Introduction to the Needs, Scope and Organization of Engineering Design”, Springer-Verlag London Ltd, London, 1996.

[3] Andreasen, M. M., “The Theory of Domains”, *EDC Workshop on Understanding Function and Function to Form Evolution*, Cambridge, 1992.

[4] Olsson, F., “Systematisk konstruktion”, *PhD thesis*, Lund, 1976.

[5] Wenström, J., ”Referat och analys av Produktutveckling – effektva metoder för konstruktion och design, av Hans Johannesson et al.”, *Literature seminar report*, KTH Integrated Product Development, Stockholm, 2005.

[6] Ulrich, K. T. and Eppinger, S. D., “Product Design and Development”, McGraw-Hill, Singapore, 2003.

[7] Clausing, D., “Total Quality Development. A Step-by-Step Guide to Word-Class Concurrent Engineering”, *ISBN 0-7918-0035-0*, The American Society of Mechanical Engineers, ASME Press, New York, 1994.

[8] Suh, N. P., “The Principles of Design”, Oxford University Press, New York, 1990.

[9] Ullman, D., “The Mechanical Design Process”, *ISBN 0-07-112281-8*, 3rd edition, McGraw-Hill, New York, 2003.

[10] Isaksson, C. and Bratthäll, J., “Bokanmälan”, *Mekanisten 1:2006*, Journal of SMR - the Swedish society of Mechanical Engineers, Naval Architects and Aeronautical Engineers, Stockholm, 2006, p. 45.

[11] Johannesson, H., Persson, J.-G. and Pettersson, D., ”Corrections, Produktutveckling – Effektva metoder för konstruktion och design”, http://www2.liber.se/hsk/prodstod/4705225_rattelser.pdf