AEDS 2004 WORKSHOP
11 – 12 November 2004, Pilsen - Czech Republic

NEW KNOWLEDGE FOR SYSTEMIC DESIGN ENGINEERING OF TECHNICAL PRODUCTS

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Keywords: engineering design, technical system, life cycle, property, quality

1. Introduction

Traditional approaches to engineering design of technical products/systems (TS) tend towards traditional intuitive ways of using knowledge which has been acquired both from theory and (more and more in the course of time) from practice. Practising engineering designers in general 'do not like' the more systematic (or often in fact only empirical or mnemonic) approaches, which have been till now recommended or even strongly demanded, because of their 'rigidity', which they find to be incompatible with their own creativity. In the presented sub-project of the Research Plan MSM 23210006 we looked at how this situation should be dealt with in order to obtain better results in engineering design research, education and practice.

2. The need for Engineering Design Science

It is obviously not effective or efficient to burden the memories of practising engineering designers and of course engineering design students with acquiring engineering design knowledge exclusively in its specialised forms. They then need to use a great deal of their creativity for painstaking step by step discovery of analogies and applications of such specialised forms within the area of their work. Traditional methodical approaches to engineering design procedures improve this situation. But if they are considered by themselves, they resemble more formal algorithms, rather than the needed systematic 'workbench' of knowledge and tools for the creative work of engineering designers. There is no doubt that this situation also negatively influences engineering design students' understanding of connections among the many subjects of their studies, the time needed for 'ripening' engineering design novices, and even the flexibility of many skilled practising engineering designers.
Research and scientific works in the area of design engineering [Banse 1997, other references and many other WDK-Heurista, books (1981-200) including the Proceedings of the International Conferences on Engineering Design – ICED (1981-2003)] have proved that many pieces of knowledge concerning all technical products/systems (TS) and their design engineering, including CAD, have general validity and use, just as in other sciences.
Engineering Design Science (EDS), i.e. the complex open system of both general and specialized knowledge about and for design engineering, should form an optimal basis for its effective research, teaching, use and further development, just as any other science. The term 'Engineering Design Science' (or 'Konstruktionswissenschaft' in German) has been used very rarely in the Czech Republic. It has been rather refused, because engineering design is generally considered mostly as a human activity, which is based only on creative talent and skills, which are supported by 'real' sciences such as mathematics, mechanics, etc.

3 Application and development of the concept

In the nineties, through our newly established co-operation within the framework of the International Society for Science in Engineering Design – WDK, Zurich, we had the opportunity to become acquainted with concepts of the main 'world engineering design schools' to compare and evaluate them. We soon decided to apply and develop the concept of engineering design knowledge (EDS) based on the 'Theory of Technical Systems' (TTS) published as a significant part of works by Professors V. Hubka and W. E. Eder [Hubka 1996 and many others], their predecessors, colleagues and followers, mostly members of WDK Society, Zürich. The principal reason was that the crucial concept of this approach is the philosophy of the basic triad of "Theory - Subject - Method ", which brings to EDS the needed transparent links among these three fields making this approach different from the others.

The whole system of the crucial EDS knowledge topics (Figure 1.), which has been presented in this form for the first time in *[Hosnedl, S. et. al. "Theory of Technical Systems in Design Education", Proceedings of the ICED 99. TU Munich and WDK Zürich, 1999. Vol. 2, p. 905-911. ISBN 3-922979-53-X],* and broadly applied in *[Eder, W. E., Hubka, V., Hosnedl, S. "Manual of Design Engineering", 2004, 500 pp, manuscript]* and in *[Hosnedl, S.: "Systemic Design Engineering of Technical Products", Pilsen: UWB, 4. issue, 257 pp, 2004]* is clearly arranged and mutually related as follows:

1. Theoretical -Descriptive knowledge related to Technical Systems (TTS):
    - Theory of Transformation Systems (TTrfS) including the role of Technical Systems (TS)
    - Theory of Transformation and Technical Procesess (TTrfP, TTP) - based on TTrfS
    - Theory of Life Cycles of TS (TLTS) - based on TTrfP, TTP, etc.
    - Theory of Structures of TS (TStrTS)
    - Theory of Properties (X) of TS and their relations (TXTS) - based on TLTS and TStrTS
    - Theory of Quality of TS (TQTS) - based on TXTS, TLTS, etc.
    - Theory of Evolution of TS (TEvTS) - based on TQTS, TXTS, etc.
2. Methodical - Prescriptive knowledge related to Technical Systems (MTS):
    - Design for Properties (X) for synthesis and analysis TS (DfX) - based on TXTS, etc.
    - Prediction of Evolution of Properties of TS (PrEvX) - based on TEvTS, TQTS, etc.
3. Theoretical - Descriptive knowledge related to the Engineering Design Process (TDesP):
    - Theory of Engineering Design Processes (TDP) - based on TTrfS, etc.
    - Theory of Hier. Struct. of Eng. Design Operations (Y) (TStrY) - based on TDP, etc.
4. Methodical - Prescriptive knowledge related to the Engineering Design Process (MDesP):
    - Strategies and Tactics (Methods and Principles) developed by/for Engineering Design Operations (Y) (DbY) - based on TDesP, MTS, and thus linked with the whole TTS.
    - General Procedural Model of Engineering Design (GMD) - based on DbY, thus on TDesP, MTS and thus again linked with the whole TTS.

The main characteristics of this system, apart from the above mentioned use of the 'Theory - Subject – Method' philosophy, are as follows:

- The designed object, i.e. technical product, is represented by the highest abstraction of a TS which is considered as subjected to all its life processes
- The final aim is neither 'methodical procedure of design engineering' nor 'drawings of designed TS', but the required output of the working process (TrfP) of the designed TS
- The characteristic form for representation of all the covered topics of knowledge is a flexible system ('workbench') of generally valid and mutually related compatible graphic based pattern models ('masters'), suitable for effective and creative use in research, education, engineering design practice, and its own further development.
- The system is strongly based both on theory and practice, so thus mirrors all past and current levels of design engineering and creates a rational basis for its future development.

We have further discovered, partly improved and/or developed, and applied both theoretical and practical advantageous properties of the system. It concerns e.g. its 'unlimited' openness and compatibility with all pieces of scientific and practical knowledge, ability of concretization to any special TS professional branch, flexibility for intuitive ways of thinking, strong support of creativity, understanding and support of CAD including its development, etc.

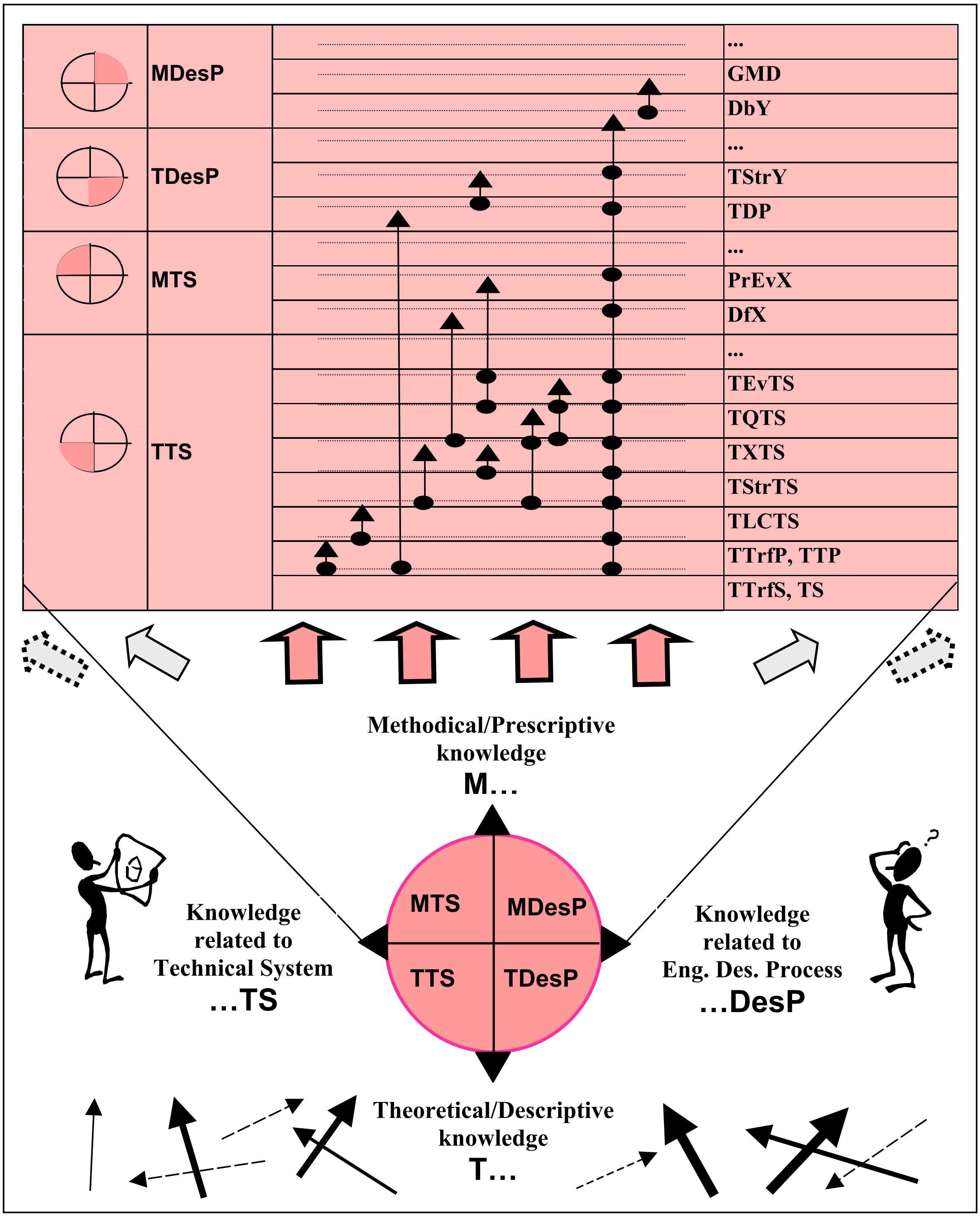


Figure 1. Structure ('map') of Engineering Design Science (EDS) knowledge based on the Theory of Technical Systems(TTS)

In our presented sub-project of the Research Plan we have mainly focused in continuing close co-operation with Professors V. Hubka and W. E. Eder *[Eder, W. E., Hubka, V., Hosnedl, S. "Manual of Design Engineering", 2004, 500 pp, manuscript]*, and other members of the WDK Society and its epigonous Design Society (from 2000), Glasgow, on the further development of the following topics related to the applied concept of EDS knowledge as a part of a general information system *[Eder, W., E., Hosnedl., S. „Information – a Taxonomy and Interpretation",*

Proceedings of the Design 2004, Volume 1, ISBN 953-6313-60-X, Zagreb Univ and Design Society Glasgow, 2004, p. 169 – 176.].

4. TS properties, quality and engineering design competitiveness

Any TS and its life cycle processes needs to meet many requirements [ISO 9000:2000]. These are not only requirements concerning the TS operational/transformation functions, their parameters and connection interfaces, but also high product safety and health protection, good appearance, easy manufacture, transport, maintenance and liquidation, low price, short delivery time, and many others. Some of these requirements concern the TS operational process (the TS operational/ transformation functions and their parameters, etc.). Some pertain directly to the TS constructional structure (locations, forms and dimensions of connection interfaces, etc.). Some are more concerned with the TS conformance to other life cycle processes (easy manufacture, transport, operation, maintenance, liquidation, etc.). Some have to be fulfilled 'implicitly' within all these processes (high product safety, health protection, environmental compatibility, etc.) and some result from previous processes (low price, short delivery time, etc.). The reason for this diversity is the fact that these requirements have to cover all the important (partial, subtotal and total) TS 'multiple overlapping' properties related to all the TS life cycle processes. Furthermore, only a minor part of these requirements is available to engineering designers as the explicitly stated requirements. Most of them are generally implied or obligatory [ISO 9000:2000], and very often so inapparent, that, even for very skilled engineering designers and/or researchers, it is very easy not to consider them in time or to omit some relevant points.

In the past (before Releaux) it was believed that there were countless numbers of classes of TS properties, which were, moreover, different for respective areas of TS. In such a case the required/considered TS properties of the designed product can depend on the use of faulty intuitive or methodical supports mentioned above. However, the TS properties and their relations exist objectively, i.e. independently of the minds of engineering designers, customers, researchers, etc. It is, therefore, optimal to develop a complex and self-consistent system/'map' of 'all' classes of the existing TS properties.

Our hypothesis was to derive classes of the so called external TS life cycle properties objectively using the model/'map' of TS life cycle phases and to add to them the classes of so called internal TS properties, which can be defined axiomatically [Hubka 1996]. The chosen way for the development of a theoretical model/'map' of TS life cycle using models from [Eekels 2000 and Hubka 1996] is depicted in Fig. 2. The resulting system of classes of external TS properties has the simple table form shown in Figure 3. The important feature is that the top of Figure 3. ***- Part B*** related to operators, represents 'columns' of the matrix, the 'rows' of which are 7 life cycle processes shown on the right of Figure 2. The classes related to the operational process, and environment and management operators have been doubled in Figure 4. because they each have two significant and different roles.

On the other hand the four 'potential' classes related to engineering design, technological & organisational and manufacturing processes have been merged here in only one class due to their close relationships. The complementary system of classes of internal TS properties [Hubka 1996], which are carriers of all the inherent TS external properties related to the mentioned classes, is shown at the bottom of Figure 3. ***– Part B***.

To summarize, the presented system/'map' of the classes of TS properties includes 13 external (6 process related + 7 operator related) + 3 internal (i.e. 16 altogether) simply to understand and remember 'categories' for classes of TS properties only. However, due to the matrix form of the operator-related classes it covers $6 + 7 \times 7 + 3 = 58$ (in fact only 55 due to the irrelevance of some intersections within the mentioned matrix) real classes of TS properties.

Considering both general and actual priorities of classes of the TS properties (mostly the operation and safety related classes of TS properties, typed in bold, have the highest priorities) this system/'map' can effectively serve as a reference for the establishment of the systematic list of requirements on designed TS and for all other related engineering design activities.

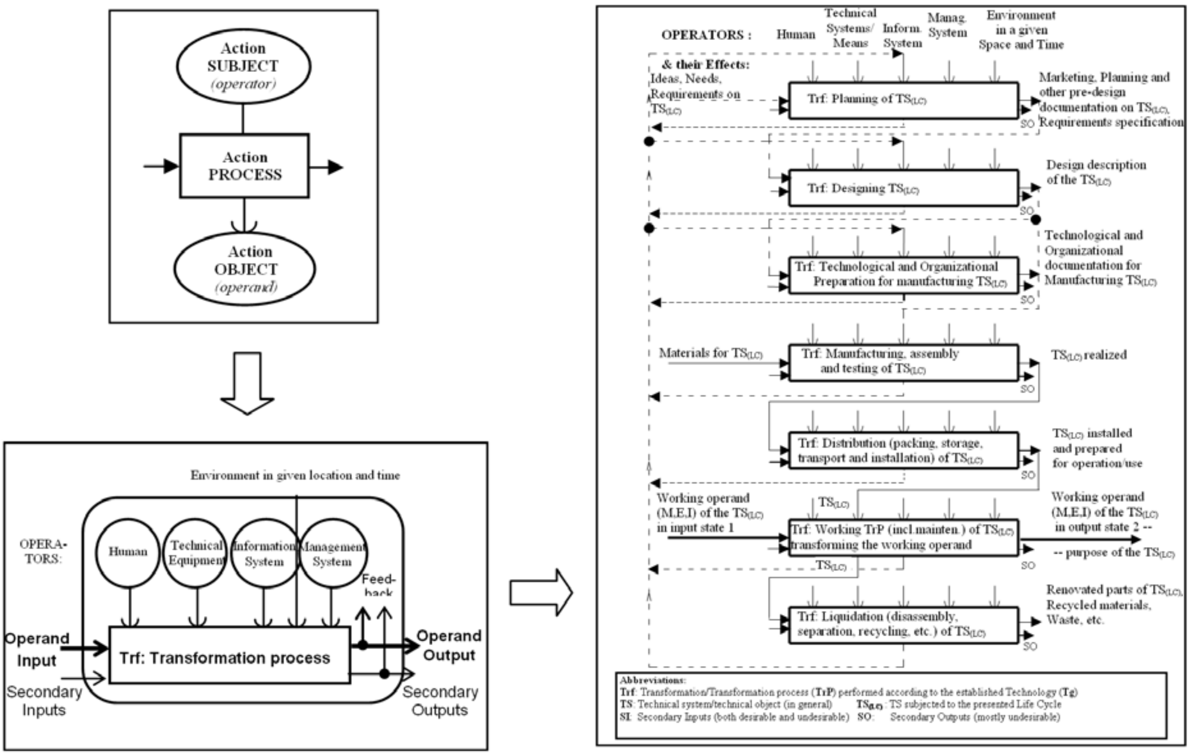


Figure 2. Model of TS Life Cycle (right) composed from the Models of Transformation Systems [Hubka 1996] (bottom left), paradigm of which creates a Model of Action [Eekels 2000] (top left)

Our analyses proved that 10 representative publications from the references mentioned below present from 7 to 28 (on average 16,2) classes of the TS life cycle properties, which include from 16 % to 80 % (where on average 28,9 % is explicitly defined/stressed and 20,6 % is mentioned only generally) of the TS properties covered by the presented system/'map' shown in Figure 3. On the other hand, all these reference publications cover altogether 96% of the properties (where 78% is explicitly defined/stressed only) covered by and defined/stressed in the presented system/'map' and, what is important, do not mention any TS property that cannot be included in this system/'map'.

CLASSES OF EXTERNAL TS PROPERTIES
TS PROPERTIES RELATED TO TS LIFE CYCLE (LC) PHASES / PROCESSES
Properties for Planning - constructional suitability for company's product, production, human, technical, information/knowledge, license, market, sales, service, policy, constraints and identity
Properties for other Origination Phases – constructional suitability for the required engineering design, technological and organisational preparation of manufacturing, manufacturing (incl. co-operations, purchasing, assembly and testing), etc.
Properties for Distribution – constr. suitability for required packaging, storage, transport, etc.
Function Operational Properties or (more generally) *Effect Properties* on the transformed operand– constructional suitability for required clamping, moving, heating, etc. *(including their functionally determined properties/parameters–* constructional suitability for required power, speed, rpm, etc.*)*
Other Operational Properties – constructional suitability for required operational safety, space and energy needs, service life, reliability, etc.
Properties for Liquidation – constr. suitability for required disassembly, separation, recycling, etc.

Figure 3. – *Part A* Process related Classes of External Properties of Technical System (TS) based on the TS Life Cycle model (Figure 2.)

TS PROPERTIES RELATED TO OPERATORS OF THE RESPECTIVE TS LC TRANSF. PROC.
Properties for Humans – constructional suitability for required operator safety, ergonomics, agreeability to humans, including aesthetic appearance, low noise, etc.
Properties for other TS – constructional suitability for required use of easily accessible TS, few demands on necessary new technical means/TS, etc.
Properties for Information – constructional suitability for required needs of easily accessible/provided information/knowledge, etc.
Properties for Environmental Material and Energy – constructional suitability for required ecology, i.e. society, nature and space, etc., compatibility
Properties for Environmental and Management Information – constructional suitability for keeping laws, regulations, required culture, customs, etc.
Time Properties for Process Management – constructional suitability for keeping required deadlines (including delivery time), duration of processes/operations, etc.
Economic Properties for Process Management – constructional suitability for required production, operational cost/price, effectiveness, etc.
CLASSES OF INTERNAL TS DESIGN PROPERTIES
General Design Properties –TS strength, stiffness, hardness, corrosion resistance, etc.
Elementary Design Properties – TS structure, and shapes, dimensions, materials, types of manufacture, tolerances, surface quality, etc., of its elements
Design Characteristics – TS working principles, crucial functions, features, etc.

Figure 3. – *Part B* Operator-related Classes of External Properties of Technical Systems (TS) based on the TS Life Cycle model (Figure 2.) and Classes of Internal TS properties [Hubka 1996]

Besides these achievements it is important that the presented graphic model-based approach (compared to the difficult to remember 6 enumeration-based and 4 methodical schema-based approaches in the mentioned reference publications) is user-friendly as explained above.

The presented comprehensive system of TS property classes has been linked to our original definition of the process dependent values of each TS property. Both of them have brought a new systemic, transparent and user-friendly view to this crucial, but traditionally very fuzzy, area of design engineering. It contributed together with other mentioned EDS knowledge topics to the next development of transparent relationships to the TS quality and engineering design competitiveness, e.g. *[Hosnedl S., Vanek, V., Stadler, C. “Properties and Quality of Technical Systems“, Proceedings of the Design 2004, Vol. 1, pp 279 – 284. ISBN 953-6313-61-8, Zagreb University and Design Society, Glasgow: Dubrovnik, 2004]*, and to the systemic development of other engineering design knowledge as follows in the following chapters.

5. DfX knowledge system

The developed system of TS property classes (Figure 3.) can serve as a direct basis for the structure of “Design for X” (DfX) knowledge (where X means a TS property class). This also has brought a quite new systemic, transparent and user-friendly view to this very important, however, traditionally very fuzzy design engineering area again. These results, including the relevant basic knowledge related to all property classes X, have been broadly applied in teaching texts *[Hosnedl, S.: “Systemic Engineering Design of Technical Products”, Pilsen: UWB, Department of Machine Design, 4. issue, 257 pp, 2004]*, which, however, have not been published yet.

A new, related and unconventional method for optimization of TS property values has been adopted and evaluated *[Němec, L. “Variant of the Gradient-based Optimization Method with applications to Technical problems”, Strojnicky casopis, ISSN 0039-2472, 51, No 4, 2000, p. 197-202]*.

Promising results of the development and tests of an original general DfX method for early prediction of the value of a TS property, which can be expressed numerically, however cannot be simply calculated (e.g. production costs). The results were published in *[Hosnedl, S. a Nemec, L. "A black-box Estimation of further values depending „don't know-how" on set of assigned vector variables" Proceedings of the MCE 2000. Neukirchen: TU Erlangen-Nurnberg,.2000. p. 16-26]* and *[Hosnedl, S., Nemec, L. "Estimation of the Value of a Product Property based on Similarity of its Parameters." Proceedings of the Design for X, ISBN 3-9808539-0-X, Neukirchen: TU Erlangen-Nurnberg and Desing Society, 2002, p. 77 – 83]*.

6. Methods for Design Engineering

A new concept for the enhancement of both traditional and modern methods for design engineering including a number of implementations has been developed and proved using the TTS published e.g. in *[Hosnedl, S., Vanek,V. Borusikova, I., "Higher Quality of the TQM Methods for Engineering Design Practice", Proceedings of the ICPR–16, ISBN 80-02-01438-3, CD-ROM, index L2.2, 12 s.], and Proceedings of the ICPR-16 Summaries 5, Streams 6+8, p.73. CVUT Prague and IFPR, 2001], [Hosnedl, S. "Engineering Methods and Life Cycle Properties of Technical Products". Proceedings of the 5. Magdeburger Maschinenbau-Tage. ISBN 3-89722-650-2, Otto-von-Guericke-Universitat Magdeburg, 2001. p. 185-194]*, *[Stadler, C., Hosnedl, S.: "Development and Application of Modular Function Deployment Method". Book of Abstracts of the Design 2002, ISBN 953-6313-47-2, 4, p. 1267, Zagreb Univ., Dubrovnik, 2002, Proceedings of the Design 2002, Volume 2, ISBN 953-6313-45-6, p. 1273 – 1278]* (Figure 4.), *[Vanek, V. "Mathematical Modelling of the Gear Systems", Conference OMSZ, Acta Mechanica Slovaca, ISBN 1335-2393, Kosice, 2004, p. 97-100 (in Czech)], [Vanek, V., Nemec, L., Hosnedl, S.: Mathematical Modelling of the Elementary Shaft Assembly", Proceedings of the the AED 2004 on the CD-ROM, s.n.:0014, ISBN 80-86059-41-3, 2004]* (Figure 5.), *[Kratky, J. "Methods for prediction of deformation properties for Connection Machine Elements", Proceedings of the KCMS, ISBN 80-7078-919-0. Ostrava: VSB, 2001, p. 161-164 (in Czech)],* and *[Moravec, J., Hosnedl, S. "Innovation of Engineering Design of Bolt Connection", Proceedings of EAN 2004, ISBN80-239-2964-X. Kasperske Hory: Czech Society for Mechanics, branch Pilsen, SKODA VYZKUM, 2004. p. 177-180 (in Czech)]* (Figure 6.) Too early presentation of this innovation prevented the protection of the solution by patent. The mentioned results have also stimulated research in other projects, e.g. research and application of theory and SW support of Engineering Design Specification based on the theory of TS properties *[Bartak, J., Hosnedl, S. "Methodical computer support of engineering design specification in automotive industry". Proceedings of the AED 2004 on the CD-ROM, s.n.: 0014, ISBN 80-86059-41-3, Glasgow, 2004.]*.

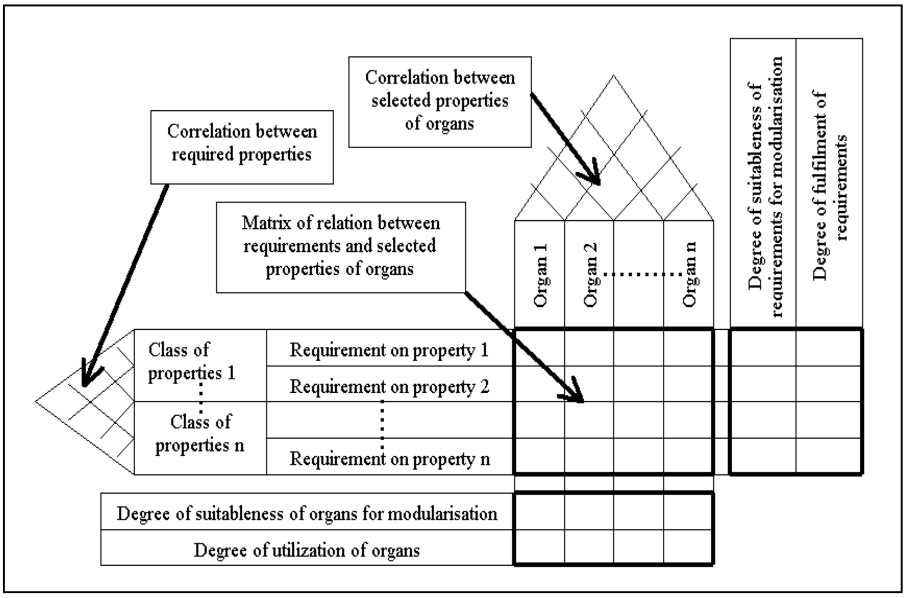


Figure 4. The House of Modularity

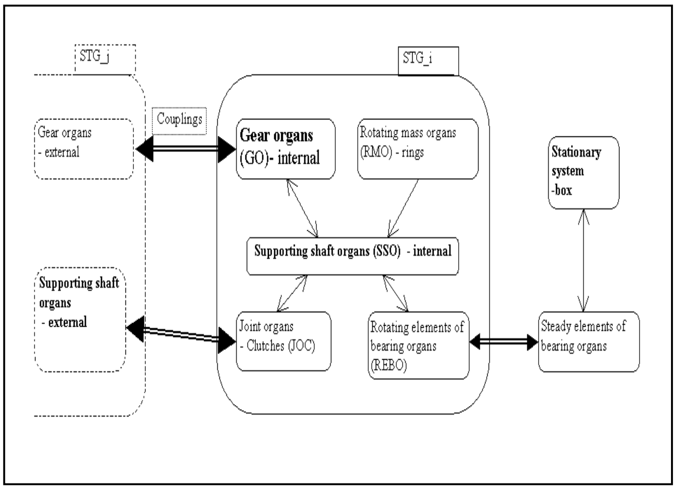


Figure 5. Organ structure of a Shaft Type Assembly System

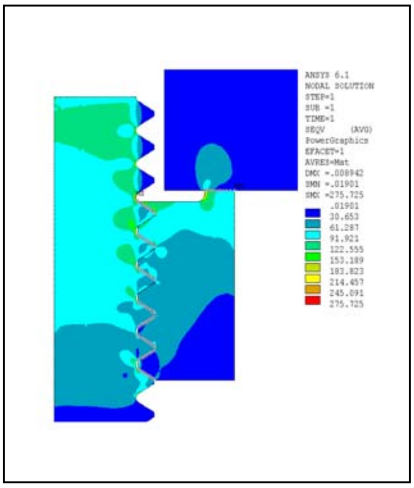


Figure 6. Bolt connection with improved properties

7. General Procedural Model of Design Engineering

To find out, understand and keep relationships of the applied General Procedural Model of (and for) Design Engineering (GMD) based on the TTS [Hubka 1996], its interface with the traditional methodical procedures of the main engineering design 'world schools' has been developed (Figure 7.). It has proved that the GMD is fully compatible with all known 'world schools', however vice versa they are thought to be more or less incompatible with the more sophisticated and theoretically based GMD. To prove GMD rationality and validity its mathematical model has been developed (Figure 8.).
For better understanding of and future development of the GMD, comprehensive guidelines with many explanations related to practice, and a number of Case Studies have been developed. These results have been applied in the teaching texts *[Hosnedl, S.: "Systemic Engineering Design of Technical Products", Pilsen: UWB, 4. issue, pp 257, 2004]*, and in the report aimed at supporting primarily engineering design Diploma theses *[Hosnedl, S. "Procedure and documentation of Engineering Design Project", Pilsen: UWB, Department of Machine Design, 4. issue, pp 57, 2004]*, which, however, have not been published yet.

8. Knowledge Integrated Engineering Design

The 'Trial and Error' method can be assumed to be a 'zero' level approach to finding solutions of a problem. A series of trials (attempts) should find the solution by individual steps. Appraisal (evaluation) of the suitability of the solution for the situation is then necessary. It is obvious that the achieved quality of results is accidental and the possibility exists that no result could be found in this way. The time required is likely to be considerable. Perhaps the only advantage is that 'almost no' previous knowledge and experience of the problem to be solved is required. These levels could be structured very roughly as follows:
(I) 'Intuitive approaches' based mainly on previously acquired knowledge and experience.
(II) 'Methodical-empirical approaches' based mostly on prescriptive or normative instructions. These are usually in the form of previously acquired summarised general knowledge, special theories and practical experience of their authors, arranged differently.
(III) 'Systemic approaches' based mainly on a framework of theoretically based structured knowledge – Engineering Design Science (EDS) - obtained by scientific 'mapping' both from theory and practice. Of course each mentioned subsequent higher hierarchical level includes the previous lower level(s) (Figure 9.), and the real situation is in any case rather vague. When analyzing the compatibility of these four levels, i.e. possibility of flexible use of an optimal level appropriate to the solved problem we can easily find great discrepancies among methodical level II and theoretically 'lower' levels I and 0.

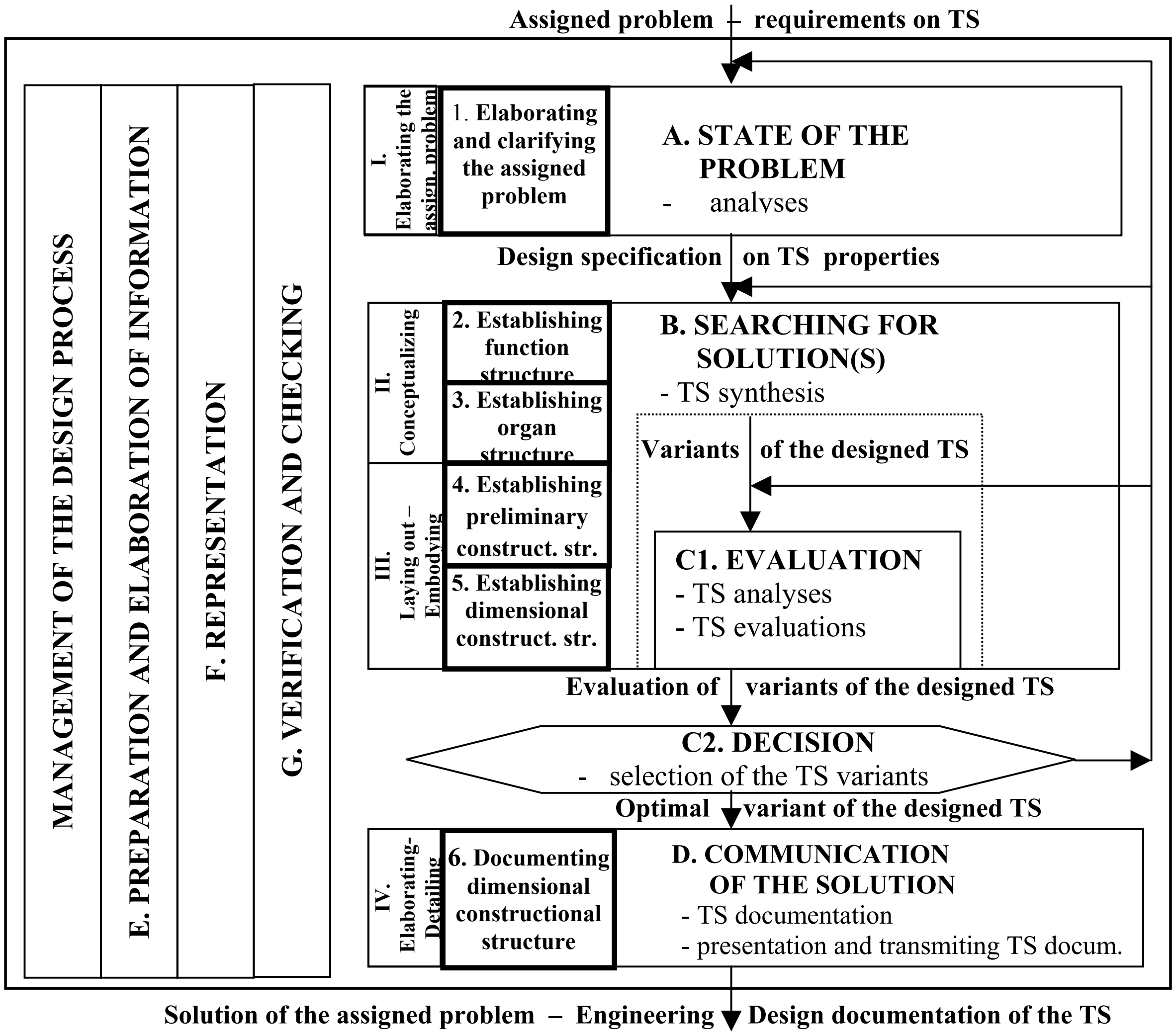
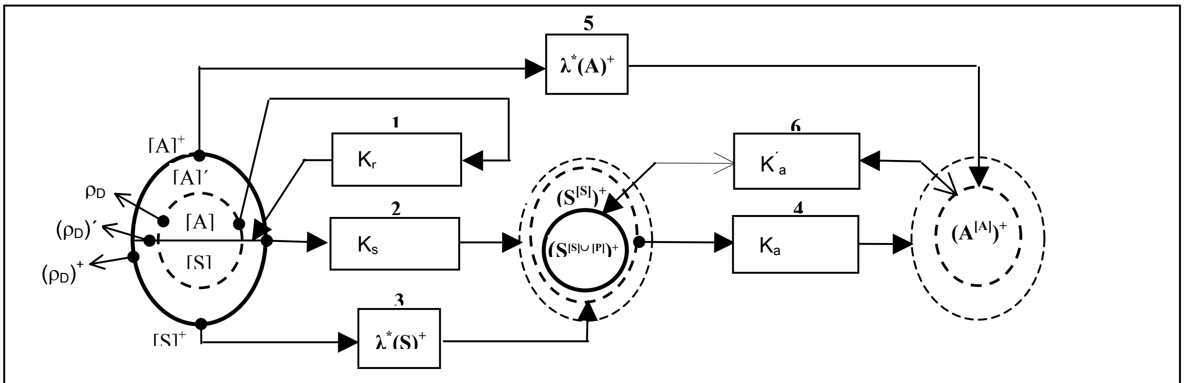


Figure 7. Basic Structure of the General Procedural Model of the Design Engineering (GMD) of Technical System (TS) (1.-6. Theory of Technical Systems-based Phases)
(I. – IV. Traditional Engineering Design Methodical Etaps, A.-G. General Problem Solving Steps)



1. $\forall \rho^d \, \exists K_r$ $\quad K_r : \rho_d \rightarrow (\rho_d)'$ $\quad \rho_D = \lambda(S,[S]) \wedge \lambda(A,[A])$ $\quad [R]^i = [S]^i \cup [A]^i$

$(\rho_D)' = \lambda(S,[S]') \wedge \lambda(A,[A]')$, $\quad [S]^+ = [S] \cup [S]'$

2. $\forall (\rho^d)^+ \, \exists K_s$ $\quad K_s : (\rho^d)^+ \rightarrow (S)^+$ $\quad (\rho_D)^+ = \rho_D \wedge (\rho_D)'$, $\quad [A]^+ = [A] \cup [A]'$
3. $\exists (S^{[S]})^+[\lambda^*(S)^+] \subseteq S$ $\quad$ **if** $(S^{[S]})^+ = \Phi$ **go to 1** $\lambda^*(S)^+ = \lambda((S^{[S]})^+, [S]^+)$ if $\lambda((S^{[S]})^+, [S]^+) = 1$
4. $\forall (S^{[S]})^+ \, \forall [A]^+ \, \exists K_a$ $\quad K_a : S^{[S]+} \rightarrow (A)^+$
5. $\exists (A^{[A]})^+[\lambda^*(A)^+] \subseteq (A)^+$ **if** $(A^{[A]})^+ = \Phi$ **go to 1** $\quad \lambda^*(A)^+ = \lambda((A^{[A]})^+, [A]^+)$ if $\lambda((A^{[A]})^+, [A]^+) = 1$
6. $\forall A^{[P]+} \, \exists \underline{(S^{[S]\cup[A]})^+}$ $\quad K_a : (S^{[S]\cup[A]})^+ \rightarrow (A^{[A]})^+$

<u>$(S^{[S]\cup[A]})^+$ **… all solutions satysfying to requirements** $[R]^+ = [S]^+ \cup [A]^+$ **(ie. satysfying that** $(\rho_D)^+ = 1$**)**</u>

Figure 8. Mathematical description of the General Proc. Model of Design Engineering (GMD)

The reason is that methodical level II provides us with no support when returning from these levels back to level II. It is obviously the main reason for the above mentioned difficulties in accepting the methodical approaches in practice. However, the systemic level III, which provides us with a transparent 'map' of theoretically based knowledge on (and for) design engineering, has a great compatibility with all lower levels, thus enabling us to find an easy 'right' location in this 'map' after returning from the lower levels (including methodical level II) (Figure 9., left).
This led us to the formulation of the original concept of the Knowledge Integrated Engineering Design (KID) (Figure 9., right). *[Hosnedl, S., Vanek,V., Borusikova, I.: "Design Science for Engineering Design Practice". Proceedings of the – ICED 01. Glasgow, IMechE, London, 2001. Vol 3, ISBN 1 86058 1, pp 363-370.]*. Our knowledge and experience gained from implementation of these principles in teaching design engineering has been published in *[Vanek, V., Hosnedl, S. a Nemec, L.: Knowledge integrated engineering design education. World Transactions on Engineering and Technology Education. UICEE – UNESCO. Melbourne 2003, Vol. 2, No 2, pp 295-298.]*.

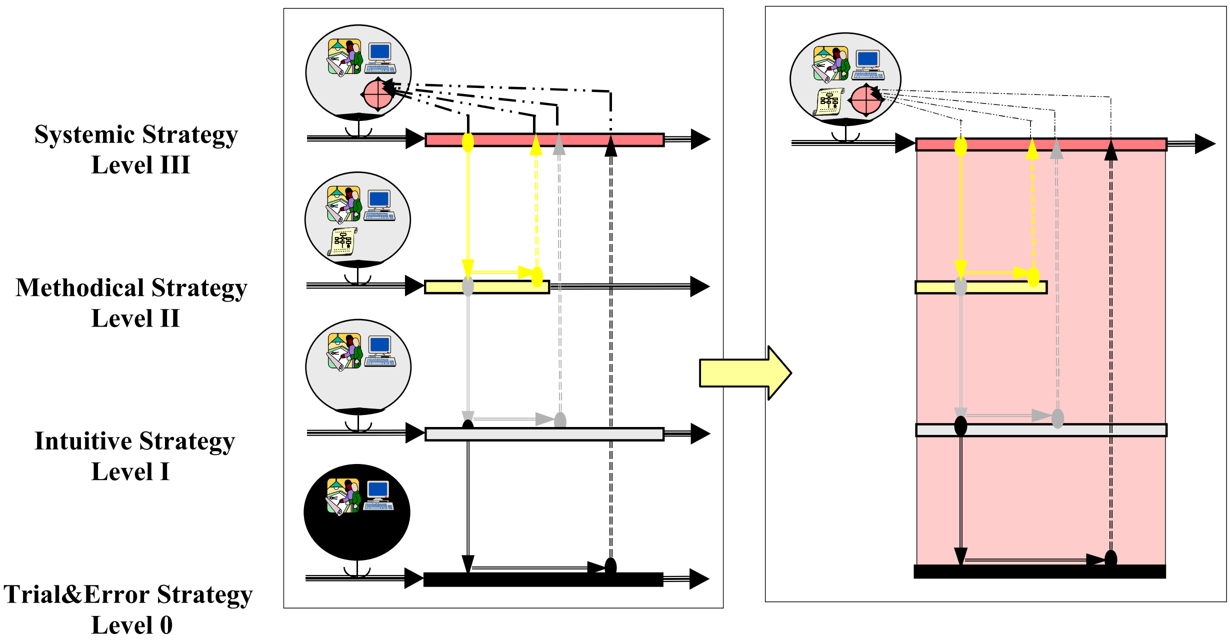


Figure 9. Compatibility of Systemic Strategy Level III with other strategy levels II – 0 (left) and resulting strategy of Knowledge Integrated Engineering Design – KID (right)

9. Implementations of EDS to Special Professional TS branches

Based on our pilot results *[Hosnedl, S., Kratky, J.. "Handbook of Engineering Designer – General Machine Elements 1 and 2. Praha: Computer Press, ISBN 80-7226-055-3 and ISBN 80-7226-202-5, 1999 and 2000. pp 356 and pp 198, in Czech], [Hosnedl, S., Kratky, J. a Borusikova, I.: "Theory of Technical Systems in Design Education". Proceedings of the ICED 99, Munich: 1999. Vol. 2, ISBN 3-922979-53-X, p. 905-911]. [HOSNEDL, S.: "Machine Elements as a specialized Theory of Technical Systems". Proceedings of the DESIGN 2000, ISBN 953-6313-38-3, Dubrovnik: Zagreb Univ., 2000, pp 733-738]* an innovative original concept for implementation of general Engineering Design Science knowledge into special professional TS branches has been developed. It is currently being implemented into the TS branches of Machine Tools, Forming Machines, Road Vehicles, Railway Vehicles and Steam Turbines within the framework of an educational project (Figure 10.) *[Hosnedl, S. and Stadler, C. "Systemic based Design Education using Information Technologies". Proceedings of the CADAM 2004. Book of Abstracts, ISBN 953-7142-02-7, Sibenik: Rijeka Univ., 2004, pp 25-26,], [Lasova, V. Stadler, C. "Teaching Engineering Design of Manufacturing Machines as a part of Systemic based Design Education", Book of Abstracts, ISBN 953-7142-02-7, Sibenik: Rijeka Univ., 2004]*.

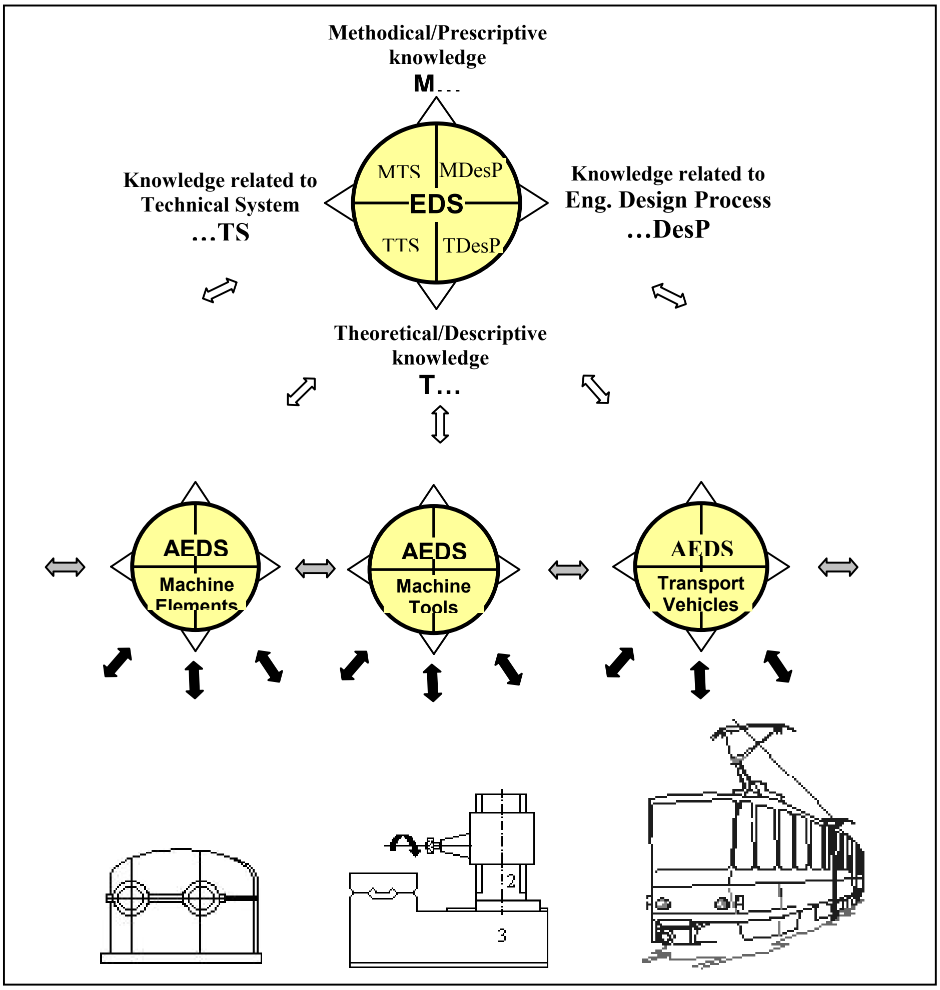


Figure 10. Systemic implementations of general Engineering Design Science knowledge into specialized TS branches

An idea for utilizing systematically structured EDS knowledge for more effective and efficient knowledge transfer between different, even apparently very different, special TS branches has been realized based on the presented EDS principles (Figure 11.) and successfully applied *[Formanek, J., Hosnedl, S. "Transfer of Knowledge among Different Branches with use of the Theory of Technical Systems". Proceedings of the Design 2004, Volume 2, ISBN 953-6313-60-X, Dubrovnik: Zagreb Univ. and Design Society Glasgow, pp 1021 – 2026]*

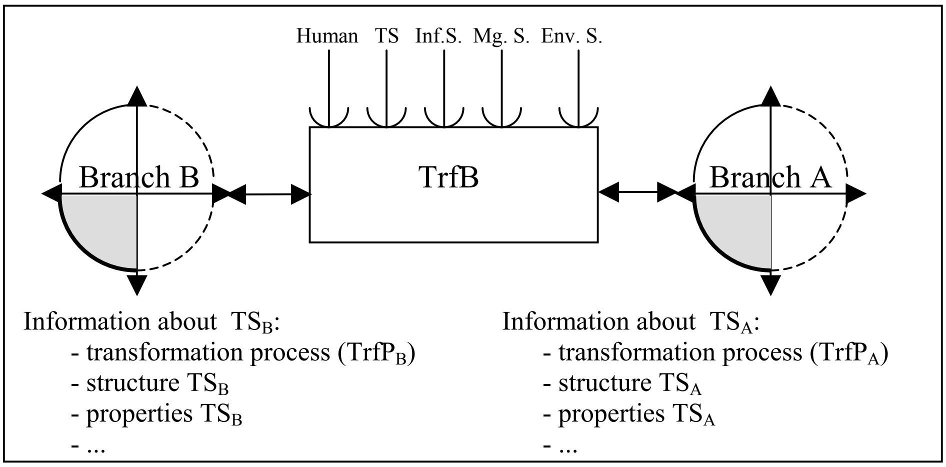


Figure 11. Principle of the systemic knowledge transfer between two professional TS branches

10. Engineering Design and different Professional Knowledge Interface

The ever-growing demands on interdisciplinarity and multidisciplinarity of knowledge for design engineering have induced in us the concept of a web supported network (Figure 12.) aimed at enabling effective and efficient knowledge transfers even among very different professional areas. Each member of such a network keeps their own professional autonomy including its traditional professional partners in research, education and practice. However, it receives new communication links, which enables them to address the engineering design community either directly with organizational support from the Engineering Design (ED) member (using the circle bus) or vicariously with professional aid from the ED member (using the straight links). The ED member will transform the received special knowledge into the 'speech of engineering designers', and store and disseminate it as a compatible element of Engineering Design Science knowledge. The opposite ways enable, vice versa, an effective knowledge feedback including new impulses recommending problems needing to be solved in special areas.

The presented network concept has been applied in its specialized form in the project of a new Research Plan, 'New Quality Characteristics of Engineering Products based on Advanced Materials and Innovative Technological Processes', which should be a follow-up to the concluding Research Plan of which the presented results are a part. The presented concept has been further applied and approved in its more general form as a communication network for members of the Special Interest Group (SIG) 'Applied Engineering Design Science' (AEDS), which was established at the University of West Bohemia in Plzen, Department of Machine Design in 2003 as an organizational unit of the 'Design Society, a worldwide community' mentioned above.

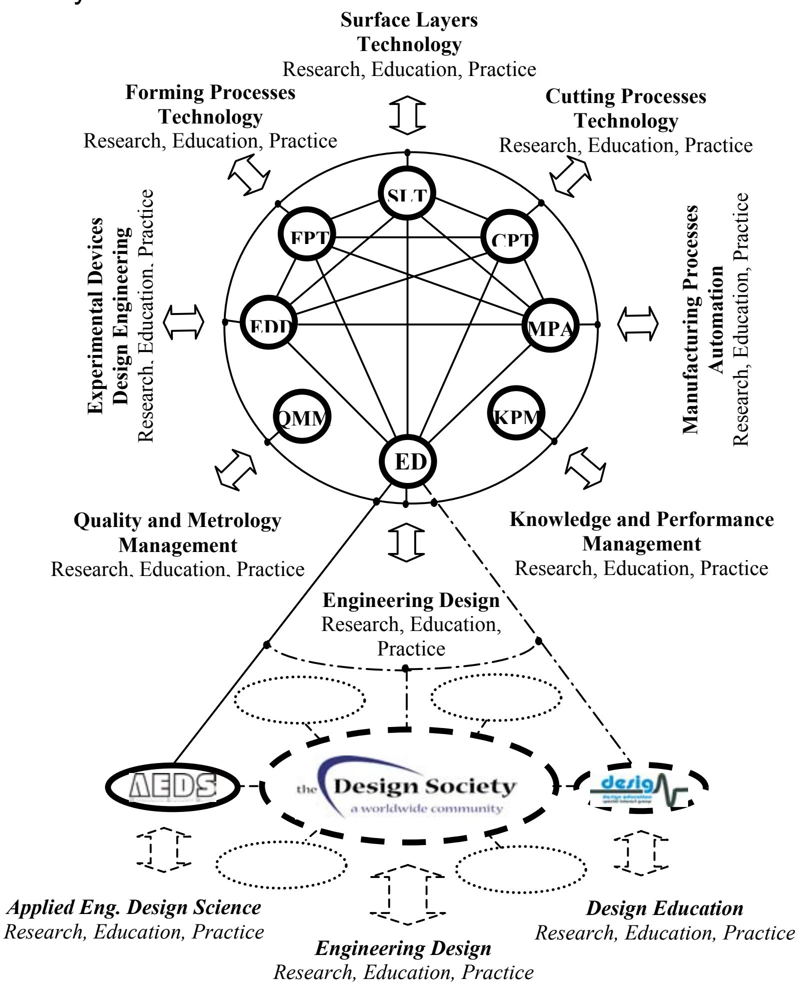


Figure 12. Concept of knowledge transfer from different professional fields to the engineering design area and vice versa

11. Conclusion

The presented results have been published in 2 books (in Czech), in 1 manuscript of a book (in English) and in more than 40 papers (mostly in English) in journals and conference proceedings as listed in the Annual Reports (1999-2004) of the Research Plan MSM 232100006 of which the presented partial project is a part. Although far from perfect, the achieved results can however be effectively used in engineering design research, education and practice. The results have already been applied and their usefulness proved in more than 10 engineering design subjects at the Department of Machine Design and in the scores of departmental engineering design diploma theses, which have been undertaken for industrial companies and successfully evaluated by their reviewers. The results have also affected research in almost 10 PhD studies (including 5 from other faculties), and developed a knowledge base for 2 PhD research projects and 1 Faculty educational project. The presented sub-project was directly linked with 4 PhD theses, 1 Assoc. Professorship theses and 1 Professorship thesis and had close links with other sub-projects of the Research Plan.

Acknowledgement

This research has been subsidised by the Research Plan of the Ministry of Education of the Czech Republic MSM 232100006.

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