Systematic Improvement of a Product: A Case Study in Engineering Design Education

Karl Hain and Christoph Rappl
Faculty of Mechanical Engineering and Mechatronics
DIT Deggendorf Institute of Technology
94469 Deggendorf, Bavaria, Germany
karl.hain@th-deg.de, christoph.rappl@th-deg.de

Abstract

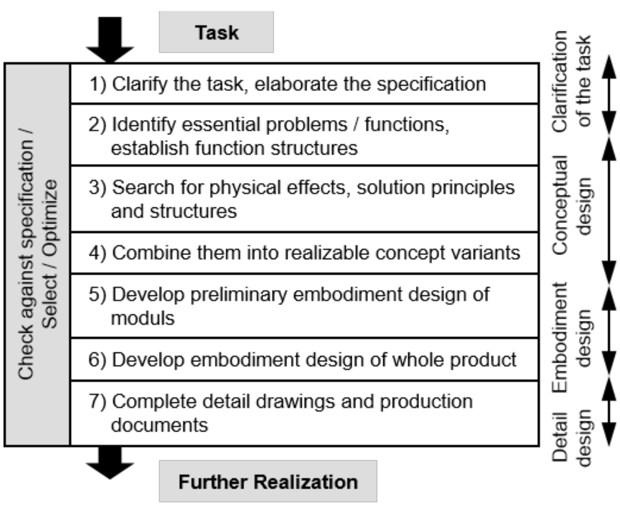
This article describes a case study with respect to the establishment of a so-called classification scheme in order to use it for the generation of ideas and concepts to redesign and improve an existing product. Besides, the application of specific TRIZ techniques is presented. These approaches are an essential part of the engineering design education within the Faculty of Mechanical Engineering and Mechatronics at the Deggendorf Institute of Technology (DIT), Germany. The described techniques aim at providing undergraduate students with examples and guidelines for systematic product development and fostering and stimulating student's creativity. It serves also as recommended practices for conducting engineering design projects embedded within the curriculum of their studies. The described procedures are based on existing design methodology and long term experience of the authors in giving respective design lectures and in conducting engineering projects with students and enterprises as well. The described case study focuses on the redesign and development of the installation process for a wall socket outlet.

Keywords
Engineering Design Education; Design Methodology; Classification Scheme; TRIZ; Creativity and Innovation.

1. Introduction

1.1 Systematic Design Process

A systematic/methodical design has a long tradition in Mechanical Engineering. The theory has been worked out and outlined in literature and publications (Pahl and Beitz et al. 2007, Roth 2012, VDI 1993, VDI 1997). According to the literature cited the design process utilizes several stages, beginning with the clarification of the task, followed by a conceptual design phase, an embodiment design phase and ending with detail design (Figure 1, left).



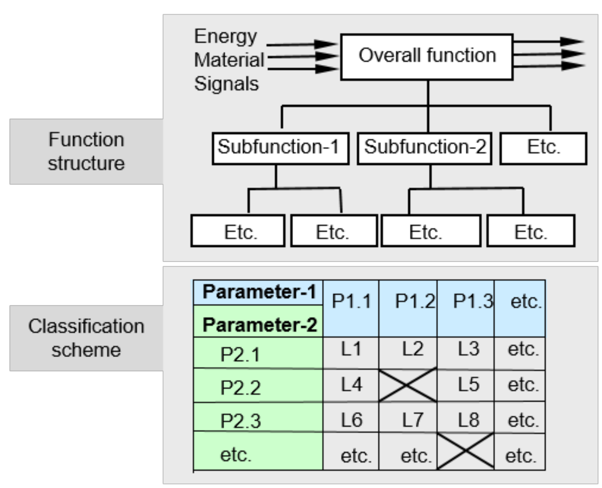


Figure 1. Systematic design process (left), function structure and classification scheme (right)

Actually design methodology describes a linear process, however, having the possibility for design loops at every design stage. The process itself is described on a high level, therefore quite abstract in order to fit every possible design task independent of any discipline.

It is often useful, to divide problems, tasks and functions into sub-problems, sub-tasks and sub-functions and to solve these individually (Fig. 1, above right). Once the solutions for sub-problems, sub-tasks or sub-functions are available, they have to be combined in order to arrive at an overall solution. In order to support the generation of solution variants and to handle the often huge number of possible solutions certain formal schemes are recommended for use in the design process like morphological matrix, compatibility matrix, and classification scheme (Fig.1, below right). While the morphological matrix allows the combination of sub-solutions for specific sub-functions in order to create an overall solution, the classification scheme may be referred to a specific sub-function, a group of sub-functions or could also represent overall solutions for the whole product. The choice of classifying criteria or their parameters is of crucial importance. The proposed classifying criteria and characteristics (Pahl and Beitz et al. 2007) listed in Fig. 2 can be useful when searching systematically for solutions and the variation of solution ideas for technical systems. They refer to types of energy, physical effects, manifestations (Figure 2, left), as well as the characteristics of the geometry, motions, and the basic material properties (Fig. 2, above right). It should be mentioned that these are recommendations for in general applicable characteristics, any other product criteria could also be applied.

Mechanical	gravitation, inertia, centrifugal force
Hydraulic	hydrostatic, hydrodynamic
Pneumatic	aerostatic, aerodynamic
Electrical	electrostatic, electrodynamic, inductive, capacitive, piezo-electric, transformation, rectification
Magnetic	ferromagnetic, electromagnetic
Optical	reflection, refraction, diffraction, interference, polarisation, infra-red, visible, ultraviolet
Thermal	expansion, bimetal effect, heat storage, heat transfer, heat conduction, heat insulation
Chemical	combustion, oxidation, reduction, dissolution, combination, transformation, electrolysis, exothermic and endothermic reaction
Nuclear	radiation, isotopes, source of energy
Biological	fermentation, putrefaction, decomposition

Surfaces	*Type*	point, line, surface, body
	Shape	curve, circle, ellipse, hyperbola, parabola, triangle, square, rectangle, pentagon, hexagon, octagon, cylinder, cone, rhomb, cube, sphere, symmetrical, asymmetrical
	Position	axial, radial, tangential, vertical, horizontal, parallel, sequential
	Size	small, large, narrow, broad, tall, low
	Number	simple, double, multiple, undivided, divided
Motions	*Type*	stationary, translational, rotational
	Nature	uniform, non-uniform, oscillating, plain or three-dimensional
	Direction	in x/y/z direction and/or about x/y/z axis
	Magnitude	velocity
	Number	one, several, composite movements
Material properties	*State*	solid, liquid, gaseous
	Behaviour	rigid, elastic, plastic, viscous
	Form	solid body, grains, powder, dust

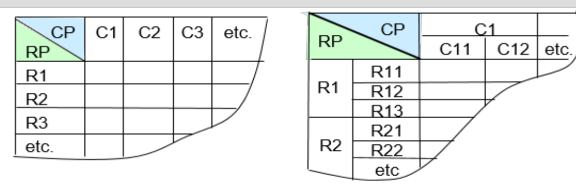


Figure 2. Classifying criteria and scheme structures

With respect to the structuring and arrangement of rows and columns a number of classification schemes have been drawn up, all with a similar basic structure. The usually two-dimensional scheme consists of rows and columns of parameters used as classifying criteria which the designer has to determine and which are in general identified by analyzing known solutions or derived from initial solution ideas. This structure is illustrated in Fig. 2, middle below. If necessary, the classifying criteria can be extended by a further hierarchical breakdown of the parameters or characteristics (Fig. 2, below right). Examples for the application of classification schemes can be found e.g. in Lindemann (2011) and Hain and Rappl (2021).

1.2 TRIZ Techniques

The inventive problem solving method TRIZ was developed by G. Altshuller by analyzing millions of patents all over the world (Klein 2014). The research's primary discovery was that an innovative solution is an outcome of a problem that had a contradiction in some form. Technical contradictions are typical engineering trade-offs, when something gets better (improving feature) something else gets worse (worsening feature). Therefore, he developed a Contradiction Matrix which contains in the rows and columns 39 conflicting technical parameters. To resolve and eliminate the contradictions 40 Inventive Principles have been identified and derived from the patent analysis. Each Inventive Principle has been assigned a specific number 1 to 39, and the respective numbers can be found in the intersection box of the conflicting parameters in the matrix. Besides, Altshuller identified also physical conflicts, which refer only to one technical parameter, i.e. a situation where one parameter has contradictory or opposite requirements (something should be big, but also small for certain reasons etc.) and defined 4 Separation Principles to resolve the contradiction. This theory proposed by Altshuller was based on the hypothesis that there are universal heuristic principles and certain abstract repetitive patterns that govern creative innovations. Extensive research has been done on TRIZ over the past decades and modifications and extensions have been carried out on the theory. Figure 3 shows an overview of the TRIZ theory and most important tools, which can be structured in Knowledge section, Analysis/Systematics section and Vision and Products section.

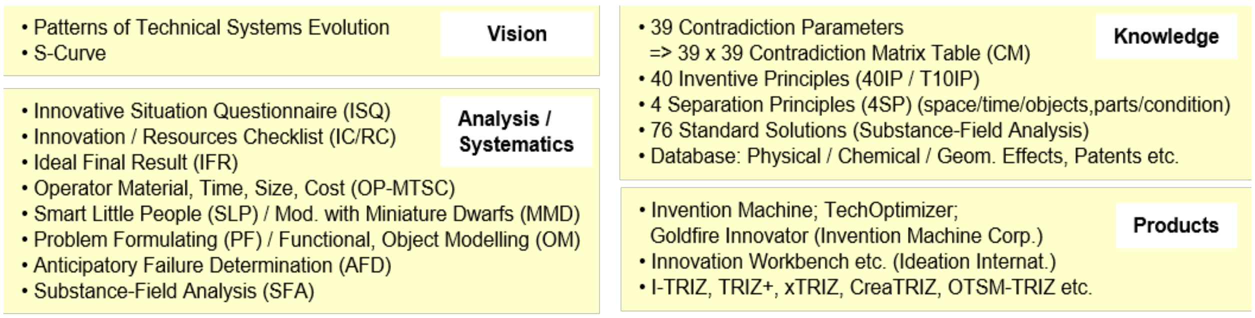


Figure 3. TRIZ – Inventive problem solving overview

The Knowledge section contains essentially the prior described Conflict Matrix (CM) with 39x39 parameters, 40 Inventive Principles (40IP) and the 4 Separation Principles (4SP), furthermore 76 Standard Solutions for a Substance/Field-Analysis. Additionally, a database is available which includes a substantial set of physical effects and devices that inventors can use to achieve particular purposes, i.e. a compendium of stock solutions or raw materials for innovations involving physical phenomena and effects, similar to design catalogues. The Analysis/Systematic section provides methods which represent quite an abstract and inventive approach to problem solving with the prerequisite that not all constraints have to be taken strictly into account. Some of them are shortly described in the following. The Ideal Final Result (IFR) demands a hypothetical question for a system, that provides the required functionality in an optimal way, i.e. the highest degree of ideality. Note: The best solution is to avoid the development of a system completely, but having the functionality at hand. The Operator Material/Time/Size/Cost (OP-MTSC) demands a confrontation with a hypothetical situation by increasing/decreasing parameters, i.e. the availability of material, time, size, cost is limited or unlimited. The Smart Little People (SLP) method transforms products and processes to activities done by smart little people in an optimal way. The Anticipatory Failure Determination (AFD) demands the provoking and inversion of failure situations in order to develop means to avoid them. The usage of the method Use Resources (UR) guarantees to reason about available and potentially useful facilities and capabilities.

According to the experience of the authors especially the TRIZ-methods IFR, OP-MTSC, SLP, and AFD are suggested to use within the early stages of a design task or in the case of original design. By applying of these methods a broad vision of the problem is permitted and the predetermined ways of conventional thinking are avoided which usually leads to a variety of ideas. In the case of adaptive respectively variant designs the methods CM and 40IP are mostly applicable, i.e. rough solution concepts have already been developed and the objective is a systematic variation and optimization. The identification of design conflicts is often a challenge, because the TRIZ matrix offers 39x39-39=1482 conflict options. Therefore, it is recommended to check step by step the Inventive Principles for applicability in order to benefit from them, thus implicit but hidden design conflicts are automatically eliminated.

2. Wall Socket Outlet Survey and Requirements List for Socket Installation

2.1 Wall Socket Outlet Survey

Power plugs and sockets connect electric equipment to the alternating current power supply in buildings and at other sites. Electrical plugs and sockets differ from one another in voltage and current rating, shape, size, and connector type. Nowadays about 20 different standard systems of plugs and sockets are in common use around the world (Wiki 2021). Figure 4 shows a dismantled socket outlet version, i.e. from the DELTA product line of Company Siemens/Regensburg/Germany (Siemens 2019) which is intended for flush-mounting in building walls. The whole socket assembly consists of a socket box (Fig. 4, left), an insert module (Fig. 4, middle) and socket covers (Fig. 4, right). The socket outlets are designed in a way to serve multiple functions and to provide reliable functionality.

Usually, the socket outlets have a modular design in order to facilitate easy and secure mounting. Even if the insert is crooked or not evenly fitted and even under difficult wall conditions, e.g. in the case of uneven wall gaps, a certain flexibility of the flush-mounting has to be guaranteed. The design of the insert has to be compact to provide space for cables and connections. Cables have to be accessible for electrical measurements. It should be possible to retrofit socket outlets that are already installed at any time with additional auxiliary modules, e.g. support the implementation of overvoltage protection and status display. The use of combination screws for Torx/slot headed screws and screw drivers shall ensure that there is no slipping on the screwdriver blade. The screw is screwed with metric thread into the metal. Minimum torques are favorable for the secure fastening of the insert even when mounted manually using a screwdriver. In order to repeatedly dismantle or remount the unit self-retracting claws are required. For that reason, a rod spring is used which ensures that the retracting claws are reversible and resistant to ageing. Note: Earlier versions used an elastic rubber ring between the two claws. For hollow-wall mounting the units are not equipped with claws. Socket outlets are available in a lot of different standards and country specific versions, e.g. according CEE 7/3 (SCHUKO®, type F) which has two grounding clips or also according CEE 7/5 (type E) which features a round earth/grounding pin, this version is shown in Figure 4.

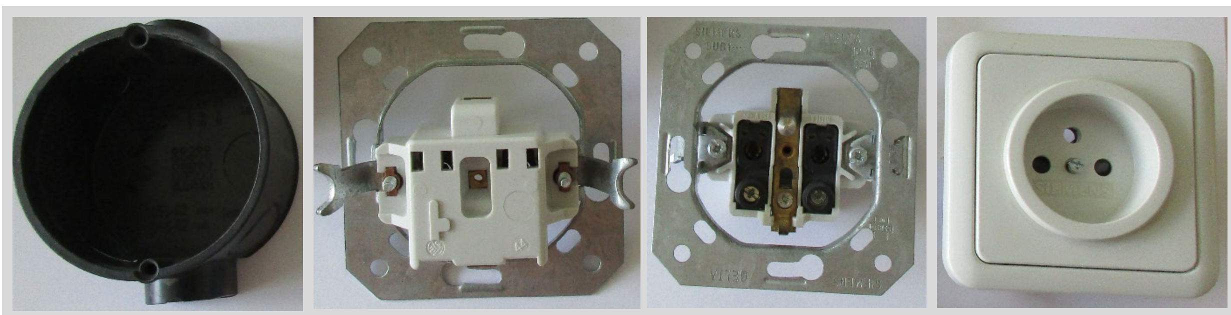


Figure 4. Socket box (left), insert module (middle), and socket covers (right)

Figure 5 shows CAD-models of the wall socket outlet assembly. The exploded view in the middle shows the order of the installation. The insert module is pre-assembled and consists of the insert base, a sheet metal frame, two claws and two screws to mount and spread the claws within the socket box after having spatially aligned the complete insert module. Then two additional screws are used to mount and secure the metallic frame onto the box at the front. Figure 5 (right) shows also the installed insert base when the spreading claws have been fastened with the screws, in this view the metallic frame is hidden for reason of clarity. Finally covers are attached by using a central screw which is mounted onto the base of the insert module.

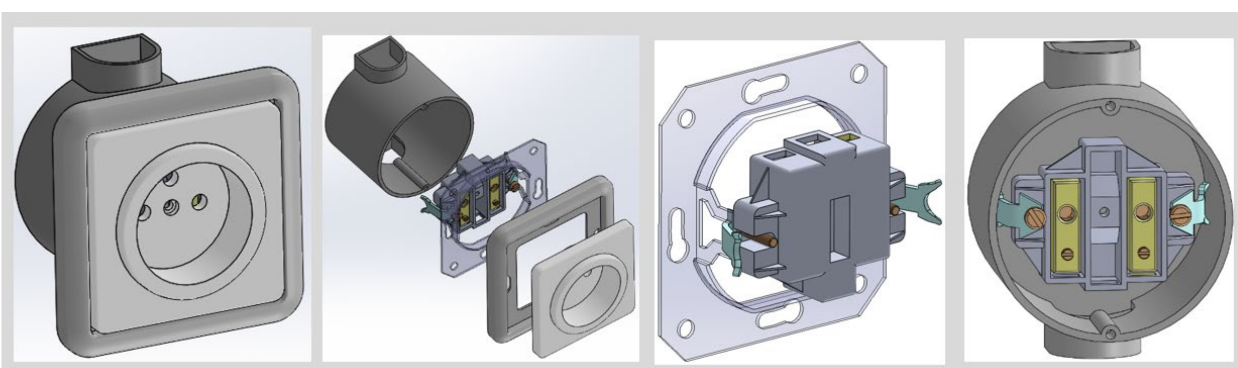


Figure 5. Socket outlet assembled (left), exploded view (middle), and module installed (right)

2.2 Requirements List for Socket Outlet Installation

At the Deggendorf Institute of Technology every undergraduate student has to conduct either a general project (in the 4th semester, 2 ECTS) or a design project (in the 5th semester, 6 ECTS) in the Mechanical Engineering course. The projects are terminated to about 16 weeks. Many project ideas emerge from local enterprises thus getting university approaches validated by case studies from industry. An intense cooperation supports not only the exchange of experiences of scientific personnel, students and practitioners but also guarantees customer satisfaction and user feedback. The following describes the redesign respectively optimization of the installation of wall socket outlets. This project has been defined and delivered by the Co. Siemens/Regensburg. The intention was to generate and develop ideas and alternatives for the socket module installation process. The project starts with collecting all the requirements and a clarification of the task, then setting up a requirements list according to the recommendation for systematic design. Fig. 6 (left) shows part and most important aspects of the specification, which was structured into several headings like "Geometry", "Kinematics/Forces/Energy", "Safety", "Material/Production/Costs" and so on. By doing so all relevant aspects of the design are considered.

Main characteristics	Type	Requirements
1. Geometry		Cylindrical design space (socket box), i.e.
	D	Diameter: Ø60 mm
	D	Height: 40 mm
	W	Only minor changes of the existing parts and modules
2. Kinematics, Forces, Energy	D	Reduced installation time
	D	Installation forces max. 50 N / 1 Nm
	D	Spatial alignment of socket insert module ca. 3 mm in each direction, minimum plaster compensation 2 mm
	D	Socket turnable 90°
	W	Different installation depths of socket insert module
	D	Tighten and loosen of socket module with usual tools
	D	Socket modul pull-out force min. 200 N
3. Safety	D	Distance between metal parts and live wires/parts at least 3 mm
	D	No electrical connection to the protective conductor
4. Material, Production, Costs	D	No loose or losable parts
	W	Few parts, easy to produce
	W	Use of standard / repeated parts
	W	Cost-effective
Etc.		Etc.

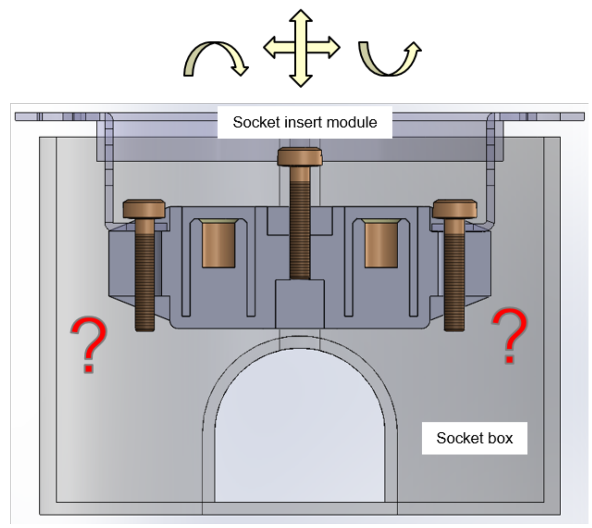


Figure 6. Requirements list (left) and task clarification (right)

The desired socket outlet installation process has to take into account already existing parts, that is the socket box and the socket insert module (Fig. 6, right). Note: The Figure shows the socket outlet in a horizontal orientation, but in most cases the sockets have to be installed in a vertical alignment. The task is to position and orientate the insert module within the socket box in a way so that any irregularities of the building wall (not shown in Fig. 6) and/or position of the socket box can be spatially compensated, i.e. axially, radially and angularly to a certain extent. Therefore, the available design space is defined and limited to the space between the socket box and the insert module. If possible, the modification of the existing parts should be avoided, but if inevitable, only minor changes should be considered. The three screws and threads of the socket insert module may be utilized, but any other installation mechanism could be incorporated. A key requirement is the reduction of the installation time. Further requirements like necessary alignment parameters, installation forces, tools to be used, minimum socket module pull out force, safety aspects etc. are specified in the requirements list.

3. Development of classification scheme for socket outlet installation

3.1 Solution elements and classification scheme

After having worked out the complete requirements list and having analyzed already existing solutions standard brainstorming sessions and/or educational workshops have been conducted. The outcome of these more intuition based methods are usually a few basic ideas which incorporate more or less complex mechanical elements and mechanisms in order to produce forces or a pressure between the socket box and the socket insert module associated with different kinds of installation procedures. The aim at this stage is to identify certain characteristics of the designs in order to derive a systematic classification. It could be found that every proposed mechanism featured a mechanical system where a manually applied installation force or torque is converted, i.e. increased, decreased transferred or deflected, in order to gain the spatial alignment of the socket insert module. Therefore, basic mechanical mechanisms have been collected and several solution catalogues containing such elementary mechanisms have been looked up to get a comprehensive overview. Figure 7 shows this collection of solution principles. It contains essentially single-stage force converting effects like e.g. different kinds of levers, knee-levers, wedges, eccentric wheel, spindle, and mechanisms with different spring stiffness.

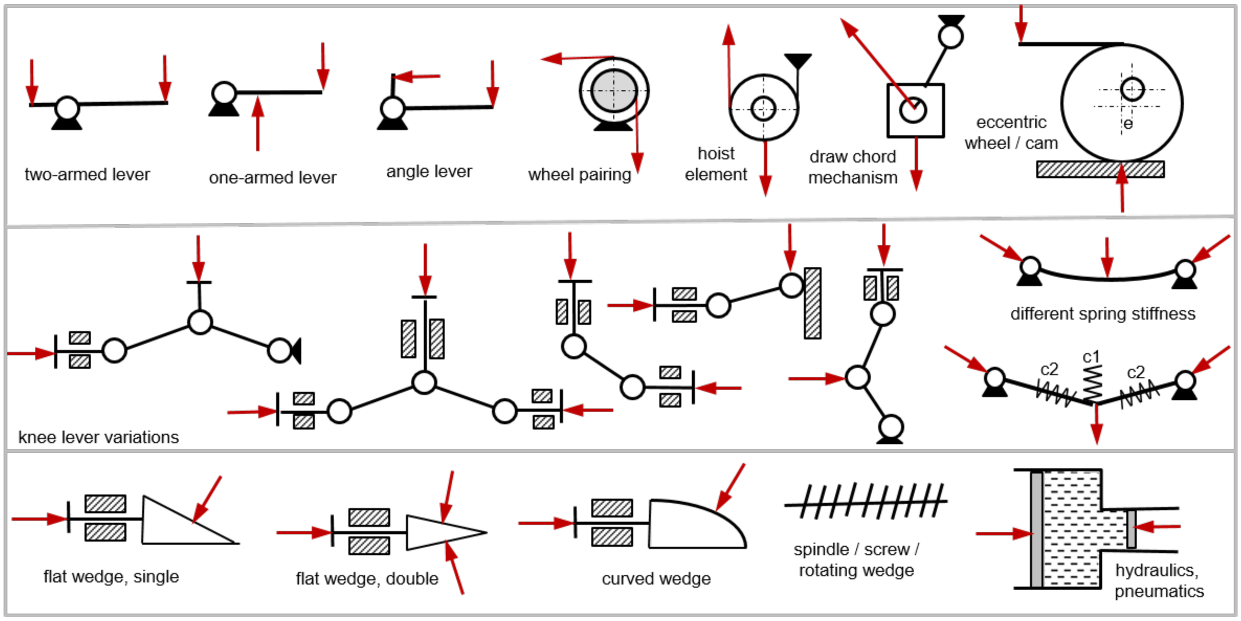


Figure 7. Solutions principles to increase/decrease/transfer/deflect forces

The prerequisites for the concepts development are as follows: Use different types of solution principles to increase, decrease, transfer and deflect forces given in the design catalogue, combine and arrange them in various directions within the available working space and taking into account the existing positions of the three screws as a manual operation input area. Subsequent brainstorming sessions led to some further vague solution ideas and rough sketches based on the mechanisms provided by the solution catalogue. The following design characteristics respectively criteria could be derived from the initial rough sketches:

- Force Transfer Mechanism: lever / knee-lever / wedge / eccentric wheel / different spring stiffness
- Force / torque input position: two-sided / centered

At this stage, having found distinctive design characteristics, a systematic representation of possible solutions was aspired by drawing up a classification scheme to get a comprehensive overview. Therefore, a two-dimensional scheme with the found characteristics has been drawn up (Fig. 8). The basic ideas resulting from the initial brainstorming sessions were inserted into this scheme, e.g. the state of the art solution represented by variant 1.1.1. The subsequent task is to complete the blank fields in the classification scheme according to the identified criteria. The great benefit of establishing a classification scheme is that it stimulates the search for further solutions in various directions. This leads to a generation of further solution principles by a successive combination of the characterizing parameters, i.e. the step by step completion of blank boxes. Additional mechanical machine elements might be used to connect force transfer mechanisms or also to deflect the forces in a requested direction. At first the variants should be kept as simple as possible in order to get reasonable, economic and easy to use products. For reasons of clarity any components which allow to return to initial positions when the unit has to be disassembled (springs etc.) are omitted. Sometimes more than one solution fit conceptually in a certain box of the scheme as a result of applying methods of systematic variation, that is variation of type, shape, position, size, number specifically. These versions should represent preferably minor changes of the design. Version 1.1.1 represents the already presented claw mechanism (see chapter 2.1), which actually utilizes two-armed levers and having the input installation force on two sides, which might be realized by screws. Version 1.2.1 allows the activation centrally. Versions 1.1.2 and 1.2.2 using one-armed levers for the generation of pressure and versions 2.1. and 2.2 employ knee-levers. Versions 3.1 and 3.2 pull wedges in an upward direction which then have effect on additional pivot-mounted elements. Version 4.1.1 features rotatable eccentric wheels around a vertical axis, in version 4.1.2 around a horizontal axis, the versions 4.2.1 and 4.2.2 allow the respective central activation. The versions 5.1.1, 5.1.2 and 5.1.3 make use of elastic and flexible properties of respective thin materials which are preformed and then deformed in a way so that the pressure can be applied when activated from two sides. Version 5.1.2 allows the central activation e.g. by a screw.

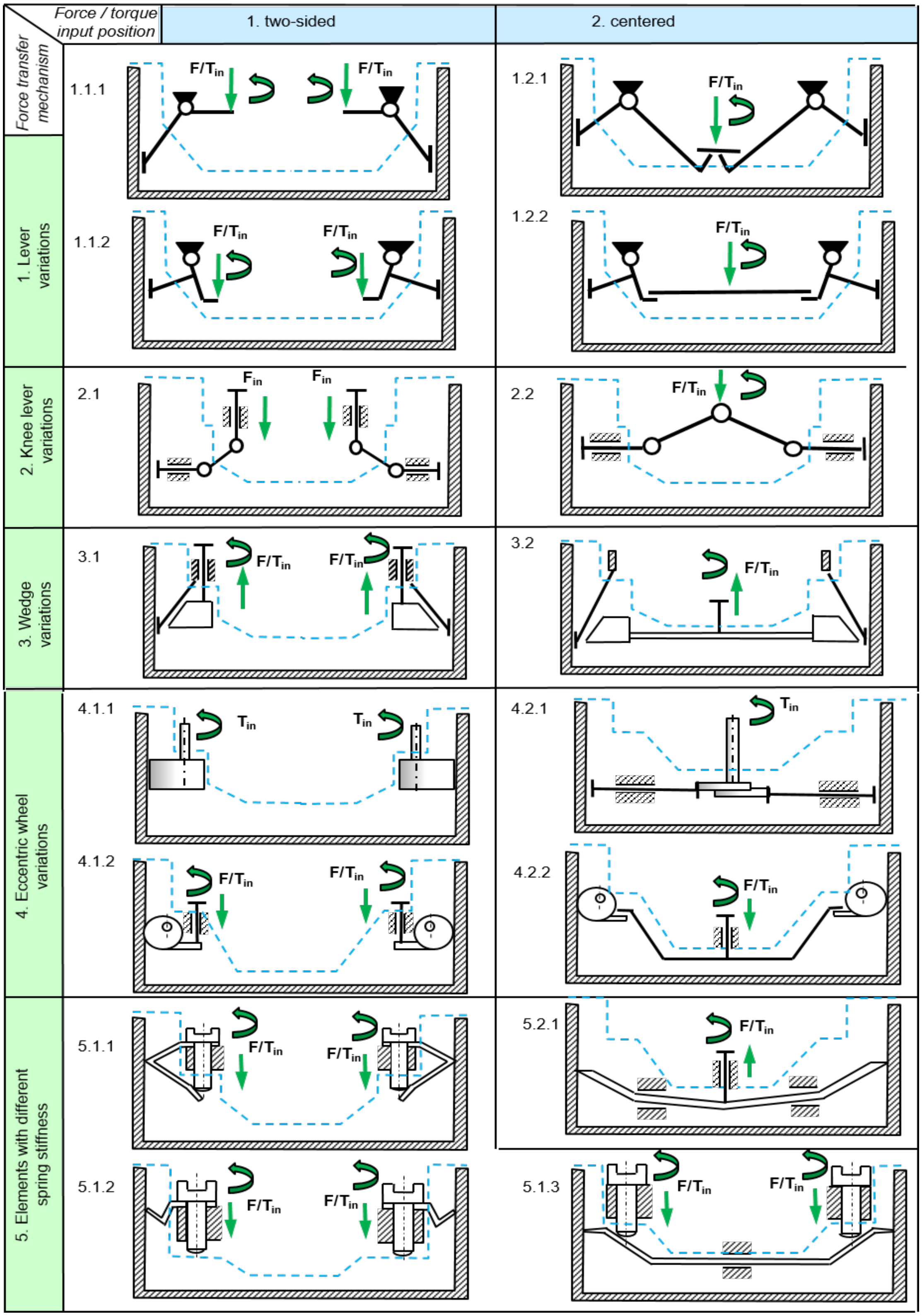


Figure 8. Classification scheme for socket outlet installation

It shall be annotated that the completion of a classification scheme is a good starting point for a pre-selection among variants taking into account if they fulfil demands and are realizable in principle.

3.2 Application of TRIZ-techniques

The concepts generated with the use of a classification scheme are also a good starting point for the successive application of TRIZ-techniques. In the following the exemplary application of a small selection out of the TRIZ-toolbox is described:

Ideal Final Result (IFR): A mechanism who allows the easy, quick, safe and cost effective positioning, alignment and mounting of a socket insert module in a socket box.

Use Resources (UR): Use the existing equipment and components, e.g. screws, holes, threads, socket insert base, socket insert frame, socket box etc. that could potentially be useful to achieve the ideal final result. Use the recesses and openings of the sheet metal socket frame (usually waste) for further designs, e.g. for claws.

IP-05: Combining / integration / merging: The versions 5.1.1, 5.1.2, 5.1.3 and 5.2.1 represent already this inventive principle by incorporating flexible parts in order to integrate single components. This leads to solutions with a reduced number of parts and elements which are able to serve several functions concurrently.

IP-09: Do it in advance / prior action: The application of this inventive principle is shown in Figure 9 (above left). It refers to the version 5.1.1 in the classification scheme with the idea to use a pre-tensioned spring-like element, which is produced from a thin material and appropriately formed and release the spring force manually by turning the screws. This approach requires a modification of the spring and also of the installation screws. The bolts (without threads) are flattened close to the lower end at each side and the spring has a specific shaped cut out (see Fig. 9). When turning the screws 90 degrees the spring force gets abruptly released and positions the socket insert module in the socket box.

IP-09: Do it in advance / prior action: The further application of this inventive principle refers to the prior version 5.1.1mod (Fig. 9, above right) with the idea to use again a pre-tensioned spring-like element, but this time the lock and release mechanism is accessible from above using a respective modified screw, spring end or a screwdriver blade. Some ideas for the modified end to allow tensioning, locking and releasing are also shown in Figure 9.

IP-13: The other way round / inversion: The version 1.1.1mod refers to the version 1.1.1 in the classification scheme and is characterized by a reversed installation force when using a two-armed lever, i.e. one arm is pulled instead of pushed to activate the claws. The same applies for the versions 2.2mod and 5.2.1mod shown in Figure 9 (below). With the version 2.2mod the knee-lever is used in a reverse direction compared to version 2.2, with version 5.2.1mod the spring-like element is bended upwards instead of downwards compared to version 5.2.1 which leads to opposite installation forces. The picture shown in Figure 9 (below right) again represents the application of “The other way round” in such a way that not the socket insert module gets equipped with the whole mechanisms for positioning, aligning, and fastening of the unit but the socket box is considered to contain the necessary elements. Therefore, a unit which allows rotation and translation could be installed at the bottom of the socket box and be connected with the socket insert module. Furthermore, at the inner wall of the socket box might elements be attached which provide a connection to the insert unit. These elements should feature deformable, elastic zones in order to fit and adapt themselves to the respective shapes of the counterparts.

IP-17: Moving to a new dimension: The application of this inventive principle leads to the idea to use the whole available hollow space between the socket insert module and the socket box and not to be limited to a certain section plane. This could be achieved by filling the space with installation foam, specific adhesives, self-curing materials etc.

IP-35: Parameter change / changing properties: All parameters of the mechanical mechanisms which have been employed for the concepts development are subject to change in order to ensure their suitability and optimize their operation mode. This relates e.g. to pivot positions, length of lever arms, lever angles, eccentricity, tension of springs, forces, torques etc. Therefore, the most promising concepts have to be investigated and calculated with respect to the mechanical behavior, stiffness and robustness.

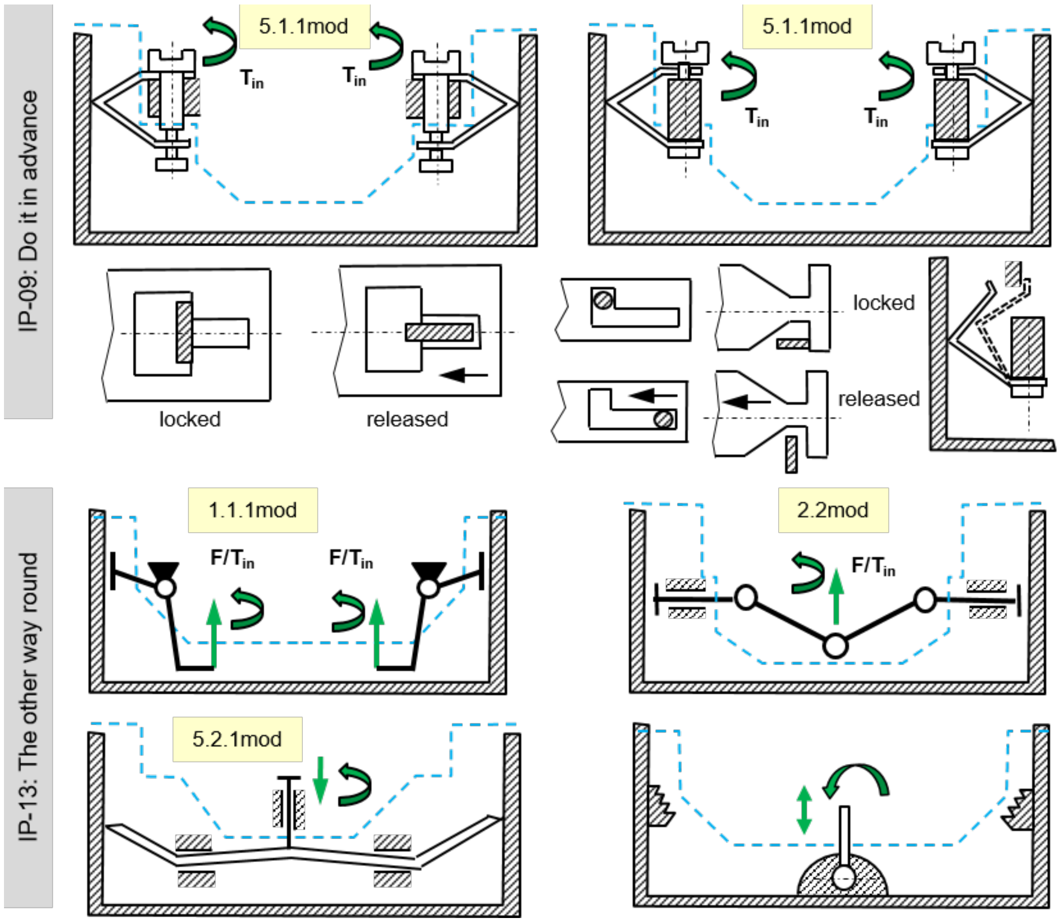


Figure 9. Application of TRIZ-techniques

4. Embodiment design of selected solutions

Embodiment design stage requires many details that need to be clarified, confirmed, or optimized. This includes functional assessment and prototyping of the various design concepts developed in earlier stages. According design methodology each concept solution variant needs to be detailed such that sufficient quantities of components can be produced to evaluate all functional and mechanical considerations identified previously. This will allow the designer to ensure that the technical product or system reliably meets the function, strength, and compatibility requirements (Pahl and Beitz et al. 2007).

After having finished the conceptual design phase for the socket outlet installation an evaluation and selection of the generated concepts took place. Several concepts have been considered to be worth for a closer investigation and thus for embodiment design as per the requirements list (see Fig. 6) taking into account the true dimensions of existing parts and the available design space. Figure 10 (left) depicts the embodiment design of the concept version 5.2.1, shown as an exploded view of a CAD-model. It consists mainly of a single clamp with two sharp peaks at each end. The clamp extends across the bottom of the socket insert module and is kept in position and pulled by a central screw. For that reason, an intermediate component with a central threaded hole is installed in between. The dimensions of the clamp are determined in a way, that if in an un-tensioned condition, the positioning and alignment of the socket insert module within the socket box is possible. After tightening the central screw, the clamp is bended back, therefore expands and the pointy tips penetrate into the inner wall of the socket box. Figure 10 (middle) shows the back view of the socket insert module before the installation, Figure 10 (right) shows the installed unit, whereby the metallic socket frame is hidden for reason of clarity. The advantages of this solution are the simplicity regarding the design and installation. No modifications on existing parts are necessary which is a good premise to retrofit socket units.

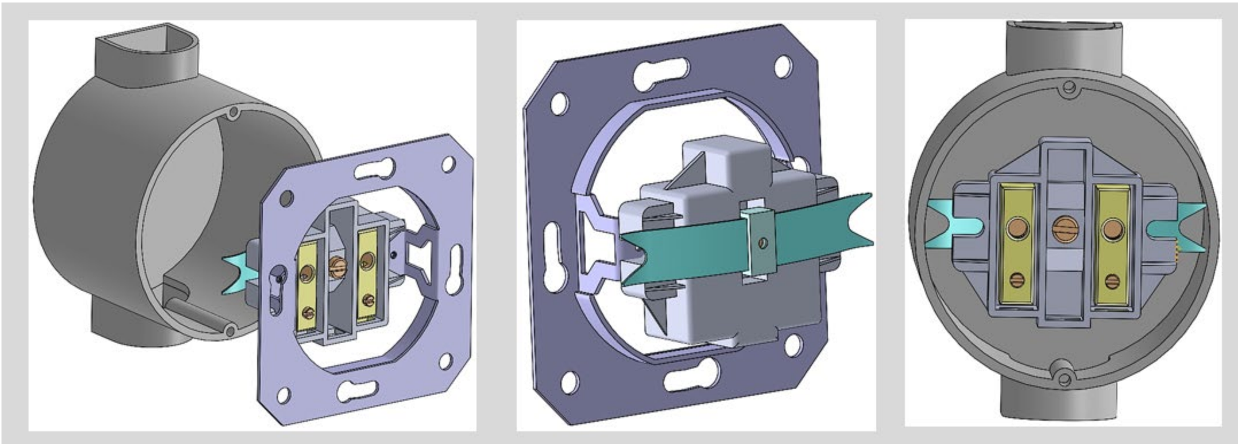


Figure 10. Embodiment design of version 5.2.1

Figure 11 (left) shows yet another embodiment design of a concept, namely version 5.2.1, shown as an exploded view of a CAD-model. It consists mainly of two rotatable eccentric wheels with groove marks at one end. The eccentric wheels are shaped and adapted in a way so that only necessary functional surfaces remain. Each wheel is torque proof connected (usual hub/shaft-connection) to an axis which has a slotted head. The slot is intended for use of a screwdriver and indicates the position of the respective wheel. When turning the screwdriver 90 degrees the wheels expand and the sharp edges penetrate the inner wall of the socket box. Figure 11 (middle) shows the back view of the socket insert module before the installation, Figure 10 (right) shows the installed unit, whereby the metallic socket frame is hidden for reason of clarity. The advantages of this solution are again the simplicity regarding the design and installation. Only minor modifications on existing parts are necessary.

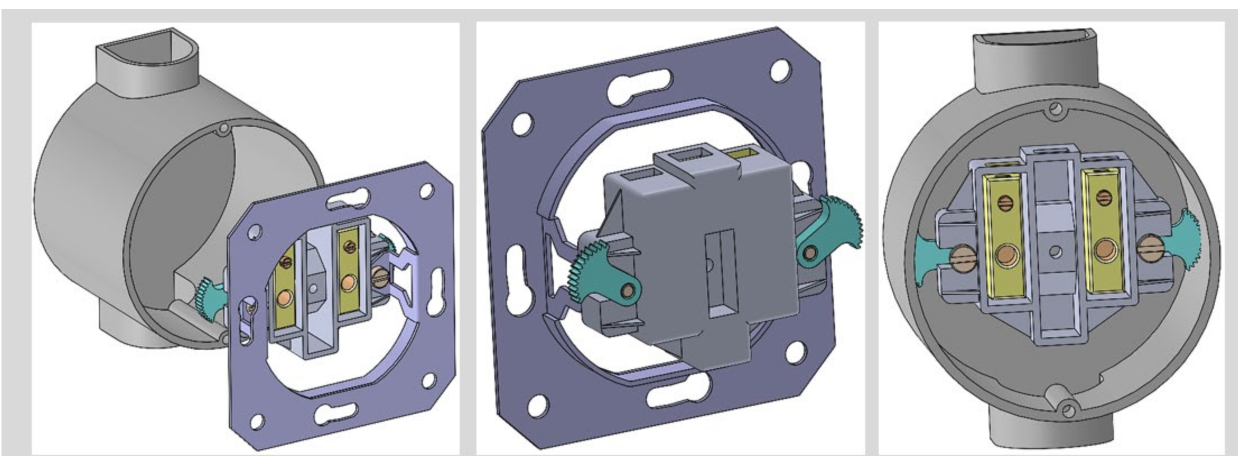


Figure 11. Embodiment design of version 4.1.1

A final evaluation and selection among the embodiment designs took place to reduce the number of possible solutions even further and to arrive at final solutions for detail design. Subsequent detailed design can lead directly into production. Further planning includes the manufacturing of prototype mechanisms using different materials, e.g. metal, plastic etc. and a step by step improvement of the components dimensions. These then will be used to verify the applicability and convenient handling. So far it can be stated that the achieved results were to a high degree acknowledged by the customer.

5. Outcome and Conclusion

By using complementary design techniques an alternative mechanism for the installation of socket outlets has been developed. It has been demonstrated how the selective and combined usage of several methods generates plenty of solution possibilities and different states of information. As design methodologies propose a wide range of different techniques for use in the design process, obviously the key to a successful design is knowing when to apply each of these to best effect. In the present case the goal was at first to draw up a classification scheme which represents a formal depiction and documentation of solutions in a table and whose blank fields have been successively filled with novel solution concepts by systematic combination of product characteristics. These could be found by analyzing a similar existing product and noting its key features. The additional application of selective TRIZ-techniques to the concepts of the classification scheme extended the solution spectrum considerably. This approach led to promising and satisfying solutions which have been worked out more detailed.

By conduction several engineering projects with students in cooperation with local industry partners it has been experienced that the quality of the final design is higher when a variety of solution concepts are developed, either for a whole task or also for single sub-tasks. This increases the probability of having proper variants from which the best can be selected afterwards. For that reason, the conduction of further comprehensible and well elaborated engineering design examples is desirable for training future design engineers and for pointing out the benefits of systematic approaches.

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Biographies

Karl Hain is currently a fulltime Professor at the Technische Hochschule in Deggendorf, Germany. He is the former study dean of the faculty Mechanical Engineering and Mechatronics. He earned his Diploma (Dipl.-Ing.) in

Mechanical Engineering from Technical University Clausthal, Germany and PhD (Dr.-Ing.) in Mechanical Engineering from Technical University of Karlsruhe. He worked several years in industry, e.g. at the company MTU (Motoren- und Turbinen-Union, Friedrichshafen / Germany) as a design engineer and at the company OPEL as a project leader responsible for worldwide data exchange. He has published journal and conference papers. His research interests include engineering design, design methodology, CAD and simulation. Prof. Hain has done several research projects with local companies around Deggendorf, Lower Bavaria. He is a former member of the Advisory Board of INTED/IATED (International Technology, Education and Development), one of the largest international education conferences for lecturers, researchers, technologists and professionals.

Christoph Rappl is currently a fulltime Professor at the Technische Hochschule in Deggendorf, Germany. He is the former dean of the faculty Mechanical Engineering and Mechatronics. He earned his Diploma (Dipl.-Ing.) in Electrical Engineering from Technical University Berlin, Germany and PhD (Dr.-Ing.) in Process Engineering from Technical University of Berlin. He worked several years in industry at the company Bayer (Automation of Chemical Plants / Germany) as a project engineer. He has published journal and conference papers. His research interests include mechatronic design, automation and control, simulation and embedded systems. Prof. Rappl has done several research projects with local companies around Deggendorf, Lower Bavaria. He is a former member of the Advisory Board of INTED/IATED (International Technology, Education and Development), one of the largest international education conferences for lecturers, researchers, technologists and professionals.