Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 55
ISSUE 2
December
2012

The exemplar design features in creation of the series of types

P. Gendarz, D. Rabsztyn*
Institute of Engineering Processes Automation and Integrated Manufacturing Systems,
Institute of Engineering Materials and Biomaterials, Silesian University of Technology,
ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding e-mail address: dominik.rabsztyn@polsl.pl

Received 12.10.2012; published in revised form 01.12.2012

Analysis and modelling

ABSTRACT

Purpose: The paper presents way to designate the exemplary design features by optimizing the features by means of the Finite Element Method. The subject of optimization are the qualitative and quantitative geometrical design features: the geometrical design form and the geometrical dimensions.
Design/methodology/approach: The fallowing computer aided methods were used to support the engineering process: FEM analysis, geometry optimization, optimization of the dimension values using the variant analysis and relational parameterization. These stages were developed in TOSCA software and advanced graphical programs: NX and I-DEAS.
Findings: The result of research was the determination of exemplar design features that take into account consideration: technical expediency, economic expediency and production capacities. On the basis of design features and with the use of the relational parameterization, the series of types was established.
Research limitations/implications: Due to the iterative process, optimization based on Finite Element Analysis is time consuming.
Practical implications: The described method can be used in creating the series of types and modular construction systems.
Originality/value: The presented algorithm of optimization and analysis of the geometrical features with the use of the Finite Element Method, allows determining the exemplar design features, which are the basis for the development of an exemplar form of the series of types.
Keywords: Engineering design; Constructional design; Finite Element Method analysis; Series of types

Reference to this paper should be given in the following way:
P. Gendarz, D. Rabsztyn, The exemplar design features in creation of the series of types, Journal of Achievements in Materials and Manufacturing Engineering 55/2 (2012) 488-497.

1. Introduction

Preserving the competitiveness on the marked that changes in such a dynamic way may be possible only by meeting the requirements and expectations of the customers. Due to the accelerating technical development the designers and constructors are constantly facing new difficult challenges. They must create, in a very short time, a technical means that is customized to the clients requirements with the consideration of the technical usefulness, productive capability and the financial factors. In order to succeed in the modern market economy the design project process cannot limit itself to creating a single design of the technical means. The designers should aim at creating sets of designs that would embrace the wide scope of requirements for a given class of products. Having in mind the temporal and financial aspects of the production process, the fulfilment of the broad spectrum of needs may be reached with the application of the ordered design families, in particular the series of types based on the exemplar design.

2. The design project process in creating the design family

In a traditional design construction process (*pr- ks*) a given need (*po*) corresponds to a single design of the technical means. The *pr-ks* process takes place individually for each following need [1,2,3]. In the creation of ordered design families, from the very beginning a defined set of needs $po_i(i=1,i_n)$ is being considered. This set should be met by an optimally diversified set of designs $Ks_i(i=1,i_n)$ [1]. The design construction process of creating a design family (series of types, modular construction systems) starts with the definition of the sets of needs which are subsequently formulated as design project assumptions. The *pr-ks* assumptions consist of: the description of the future technical means in the form of a general system So_n and the characteristics features CCH_J [1].

Figure 1 presents the methodology of creation of ordered design families.

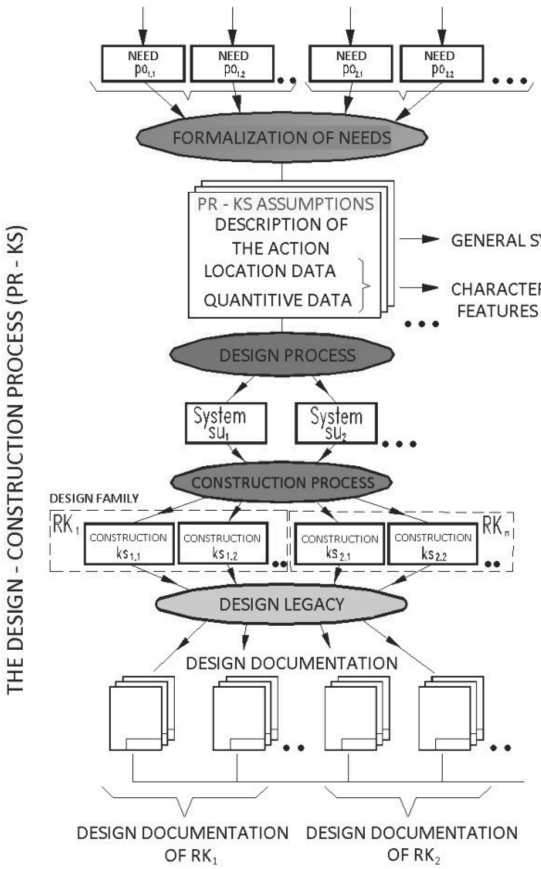


Fig. 1. The design construction process of creating the design family [1]

The foundation of the design construction process is the definition of the system. The system is a structure of relations of couplings and form changes that describe the operation of the future technical means [1,4,5]. The relations of couplings define how the future units, components or the elements of the designed product operate with one another. In the coupling relation the input I_j is equal (or nearly equal) to the output O_j $(I_j \approx O_j)$. Example of the above described relation: *„the coupling of a machine shaft with a gear wheel realized by means of a prismatic inlet”*.

The form change relations are related to the change of the input signal I_j into the output signal O_j $(I_j \rightarrow O_j)$ of the information, energy or mass. There are two kinds of form change relations: conversion and transformation. The relation of conversion is the change of the form of the information, energy or mass. For instance: *„the change of the hydraulic oil energy into the mechanical energy of the plane motion*” realized by means of of a hydraulic cylinder. The relation of transformation, on the other hand, consists in retaining of the form of the information, energy or mass, but changing its parameters.

The relation of transformation may be illustrated as: *„a change of the torque value M_{wej} into the the torque value M_{wyj} by gear unit”*.

Each system relation corresponds to a certain elementary operation of the future technical means. The most compact way of describing the operation of the product is a general system reduced to a single relation of a coupling or a form change. The exemplification of a SO_n reduced to one coupling relation is a general system of a gripper: *„grabbing the elements in order to displace them”*.

Apart from defining the general system of the future technical means, the design project assumptions should also denote the characteristic features of the design family CCH_j [1]. The characteristics features are the properties that should characterize the future product considering its coupling with the environment. They correspond to the situational and quantitative data and are closely related to a particular design family RK_n. The characteristic features have a considerable influence on the choice of the design features *CK* and, consequently, on the design diversity in the series of types or the modular system of construction. Depending on the CCH_J value one distinguishes the qualitative and quantitative characteristics. The qualitative group of characteristics include such situational data from the design project assumptions as: purpose, working conditions, fastening method, position etc. They directly affect the diversity of the qualitative design features in the design family. The quantitative characteristics, defined as parameters Pa_a of the design family of constructions represent in a quantitative and explicit way the needs po_i. These quantitative characteristic features include among others: transferred power, gear ratio, input speed, overload value etc. The parameters are represented as real numbers and affect mainly the choice of quantitative design features. This has an operational significance in the process of creating and applying series of types and modular design systems.

The starting point of the design construction process is determining the coupling and form change relations of the future technical means with the possibly greater accuracy. In result of this accuracy sets of specified systems are being created, where the degree of details that must be provided depends on the complexity of the future technical means. Depending on the creativity and experience of the constructors and designers various concepts of specified systems are being designed, on the basis of which a system structure SS_n of a design family is being build.

This structure is crucial in the selection of design features of the components of the future technical means [1,6]. Excerpt from a system structure ofa design family of a pincer gripper is presented in Figure 2.

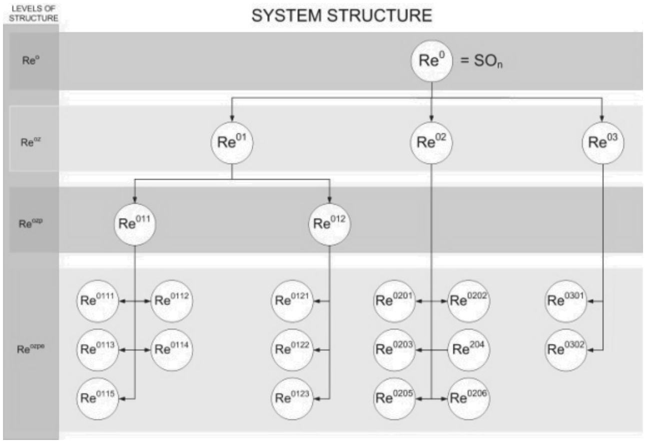


Fig. 2. System structure of a pincer gripper

A general system described as relation Re^0 is first being specified on the lower level of the system structure sets such as:

- Re^{01} - transformation of the compressed air energy into the energy of the plane motion of the piston in a pneumatic cylinder,
- Re^{02} - transformation of the linear motion of the piston into the angular motion of the pincers,
- Re^{03} - the coupling of the displaced element with the pincers.

Next, the defined relations are being further specified on lower levels of the structure until the lowest level of relations of the particular elements Re^{ozpe}.

On the basis of the design system structure a hierarchical structure is being build, where the given design forms such as: units, subunits and elements of the future technical means correspond to defined relations of different levels of the structure [1,6]. An excerpt of a hierarchical structure of a design family of pincer gripper is presented in Figure 3.

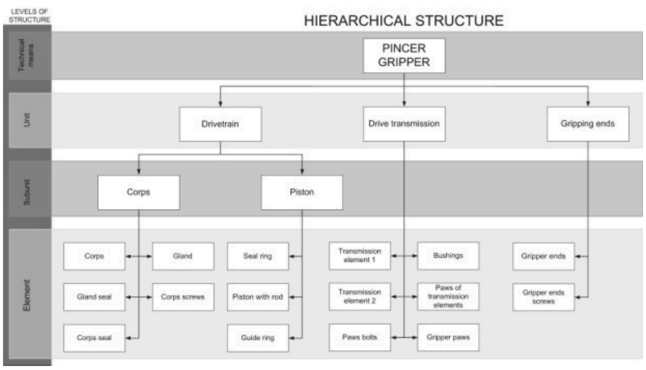


Fig. 3. Hierarchical structure of a pincer gripper

By means of hierarchical structure the basic components of the design of the future technical means are being determined.

The design is an arrangement of the internal and external structure layouts and the product phases defined by the geometrical C_g, material C_t and assembly C_m design features CK [1,4,5].

$$CK = C_g \cup C_t \cup C_m \tag{1}$$

The design is a model of the future product that describes its properties.

The geometrical design features C_g describe the external structure as well as the macro-structure of the product. They include the design form $\prod_g$ and geometrical dimensions W_g.

$$C_g = \prod_g \cup W_g \tag{2}$$

The geometrical (design) form $\prod_g$ is a qualitative feature that describes the typology of the technical means. It is dependent mainly from the: specified system, parameters of the future product and the production technology.

The geometrical dimensions W_g are the quantitative features that build the dimension system of the technical means according to the principles of: explicitly, completeness and consistency. They depend mainly on the parameters of the future product. It is mainly the geometrical features that in the exemplar construction design project process are the subject of computer-aided optimization with the use of CAE or CAD software.

The material design features C_t define the internal structure of the designed element. They include the material form $\prod_t$ and the material dimensions W_t.

$$C_t = \prod_t \cup W_t \tag{3}$$

The material form is a qualitative design feature that describes the micro-structure of the product. The material dimensions are one of the quantitative design features that describe the properties of the material from which the elements of the product will be produced. The set of material dimensions consists of: stereomechnical, physical, chemical properties and the percentage composition of the alloy's components.

Such features are usually presented as symbols in the drawings of the design documentation. On the ground of the symbolic representation the material dimensions may be read from the signatures or catalogues.

The assembly design features C_m concern the co-working elements, which conditions denote their proper functioning. The features are determined usually during the assemblage of the units and components of the technical means. The assembly features include: the moment of tightening the screw, the pressing force in a snap joint, temperature in a heat or cold shrink joint etc.

The process of designing consists in deciding the geometrical, material and assembly features. In the process all the necessary features of the technical means that meet the utility, production and recirculation criteria must be defined. This applies to both, the qualitative and quantitative design features. The result of the design are the design sets which, due to the general system are divided into design families RK_n described in the design documentation.

3. Design family of construction

A design family of construction RK_n is a assigned to a set of defined needs $Po_n\{po_i;(i=1,iz)\}$ set of designed of technical means $Ks_n\{ks_k;(k=1,kz)\}$ that corresponds to an identical general system SO_n [1].

$$Po_n\{po_i;(i-1,iz)\} \Rightarrow Ks_n\{ks_k;(k=1,kz)\} \equiv RK_n \qquad (4)$$

An example of a RK_n is a design set of: hydraulic cylinders, gear units, pincer grippers etc.

3.1. The stages of creating an ordered design family of construction

In the process of creating an ordered design family one distinguishes the preparatory stages and the main stages [1]. The preparatory stages denote the analysis of the existing design families of construction that were created by various design offices. There are two preparatory stages:

- selection of the design family for the purpose of ordering or the exemplar design on the basis of which the design family will be ordered,
- characteristic features analysis of the existing design family on the basis of: the system, hierarchical and variant analysis as well as the record of the feature variability and evaluation of the design solutions.

Figure 4 presents the preparatory stages in the creation of an ordered design family.

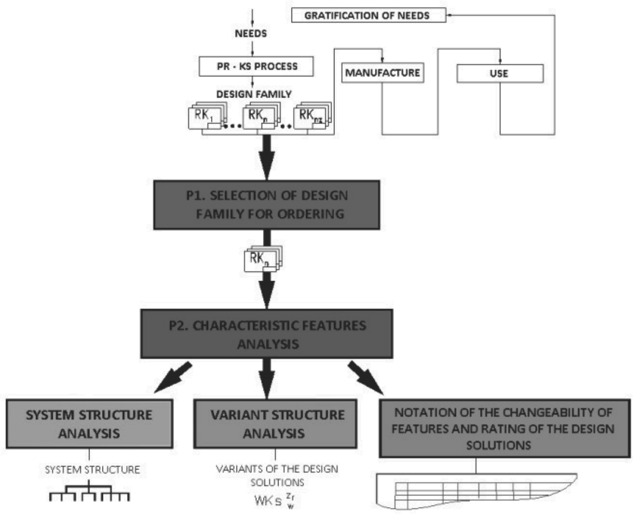


Fig. 4. The preparatory stages in the creation of a design family of construction [1]

The main stages in a design process include:

- unification - reduction and ordering of the values of the characteristics,
- typification - selection of the typical design solutions treated as binding within the design family,
- creating typical design forms of the elements,
- preparation of the system of dimensions,
- selection of the dimension's values,
- optimization of the diversity of the dimension's values
- defining the rules of selection of the ordered components of the design family,
- recording the design in the form of a design documentation

The main stages of creating ordered design families are presented in Figure 5.

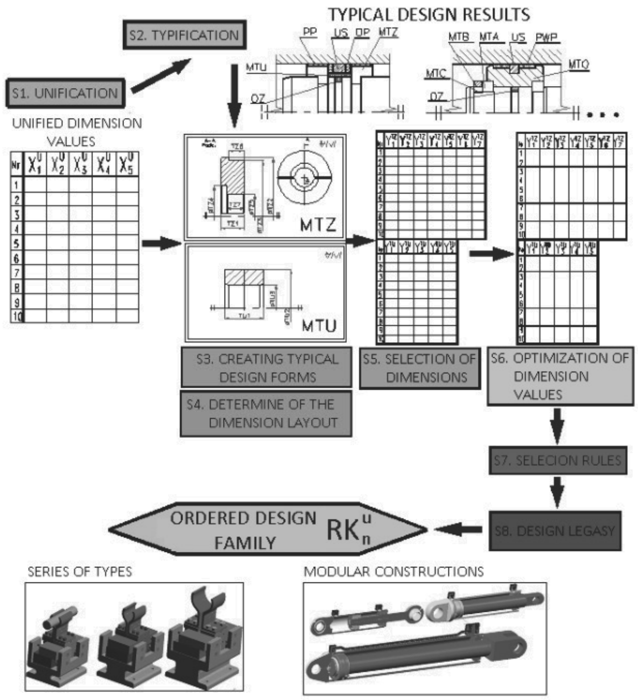


Fig. 5. The main stages of creating a design family [1]

As a result of the above presented stages an ordered design family RK_n^u is created, which takes the form of a series of types or modular systems of constructions.

4. Series of types

In a design project process with constant values CCH_j^{ja} and variable values CCH_j^{il} it is rational to create a design family in the form of a series of types [1,7].

A series of types Ts is an assigned to a set of unified needs, set of designs of a constant geometrical form ($\prod^t = const$) and variable dimension's values (based on the simple rules RG_n of selection of the typical element dimensions).

$$Po_n^u\{po_i^u;(i=1,iz)\} \Rightarrow Ts_n\{ks_k^t(k=1,kz)\} \equiv RK_n^u \qquad (5)$$

The variability of the quantitative design features depends mainly on the variability of the parameters pa_i^u. Fig. 6 presents the series of types of vice grippers.

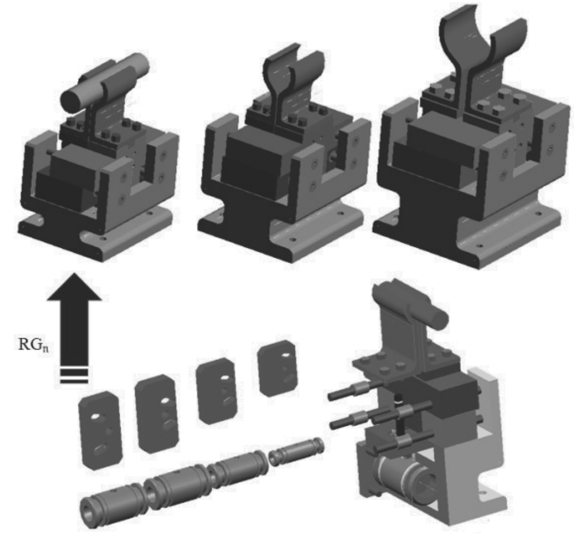


Fig. 6 Series of types of vice grippers [1]

The process of the creation of a series of types consists in ordering the set of needs Po_n^u and the set of designs in the form of a series of types $RK_n^u = Ts_n$. In this process what is transformed is not only the characteristics but also the quantitative design features.

As a result one receives an ordered design family in the form of a series of types.

The *Ts* comparison to the modular design features are not characterized with variability of design solutions.

5. Modular design systems

When creating ordered design families for a wide spectrum of variable values of characteristics CCH_j (whether quantitative of qualitative) rarely one receives a single design form $\prod^t$. Most often one receives several typical design forms $\prod^p$, what if typical of modular design systems [1]. A modular design system SM_n is a set of various design modules $\{mk_m^{rwe_j}(j=1,jz),(m=1,mz)\}$ together with complex selection rules RG_n^{SM}.

$$SM_n[\{mk_m^{rwe_j};9m=1,mz),(j=1,jz)\}\cup RG_n \Rightarrow Ks_n^m\{ks_k^m;(k=1,kz)\}\equiv RK_n^u \qquad (6)$$

The reason of the variable geometrical form in modular systems are the variable qualitative characteristics. An example of a modular system of hydraulic cylinders is presented in Figure 7.

The modular designs characterize with a wide range of possible variants and flexibility of the design solutions.

The starting point of creating series of types and modular design systems is defining the exemplar design.

Fig. 7. A modular system of hydraulic cylinders [1]

6. The exemplar design form

The exemplar design form Ks_0 is a design practically verified in respect to operations (computer-aided simulation of the motion), verified with the usage of numerical methods (especially in respect to the durability) and analyzed regarding the production process. A design is being recognized as exemplar when the product produced on its basis meets the most of the criteria of the experimental verification (prototypical research) [1,8,9].

There are two methods of defining the exemplar design form that differ mainly in the searching method.

The first method consists in choosing the Ks_0 on the basis of the existing set of technical means that fulfill the given need. A practical evaluation of the available design solutions is being conducted according to criteria described by experts in the field: designers, constructors, technologists, users and repair workers. On the basis of this evaluation an optimal selection is made with some modifications of the design solution if need be and the exemplar design is being chosen. The main goal of this method is broadening of the scope of need for a given class of technical means.

The second method consists in creating from the scratch the design of the future technical means which is then treated as the exemplar design of the newly created design family. The construction design process of defining the exemplar design is being extended with the introductory research with the application of computer-aided Finite Elements Method (optimization of design features and dimension's values) and prototypical research. A design that was approved theoretically and practically is accepted as the exemplar design. The advantage of this method is the possibility of creating technical means that realize in optimal way a broad spectrum of *pr-ks* assumptions. The disadvantage, on the other side, is are the costs and duration of the project realization.

The process of defining the exemplar design form of a new design family is reduced to determining the exemplar qualitative and quantitative design features.

6.1. Determining the exemplar geometrical features by means of the optimization of the design form

The computer-aided methods of optimization of the design form have been recently widely developed with the application of the CAE class software. The tool supporting the determination of exemplary design features was implemented in the TOSCA optimizing software as well as in the graphic programs of the CAD/CAE class such as: NX 8.0 and Inventor 2013.

The optimization consists in finding the minimal or maximal function or the aim functional with simultaneous fulfillment of certain number of restricting conditions. In the analysis of the design form the Finite Elements Method was applied [10,11].

The optimization takes places in the project region determined by the designer or constructor (determined input design form) where, during the iterative calculative process, sub-regions filled with material and sub-regions without material are created according to the rule „ no stress, no material".

The optimization is being performed with regard to the following: maximal strain of the material without exceeding the limits of maximal stress, not exceeding the limits of the maximum allowable deformations, the minimal element mass and other boundary conditions, determined on the basis of the qualitative and quantitative characteristics.

As a finite result of the optimization the designer receives a design form determined for defined material features with an optimal material distribution in the defined design region. Figure 8 presents an optimal design form of a bracket,determined with the application of the advanced graphic software NX 8.0.

Fig. 8. Optimal design form of camera handle

In the process of determining the optimal design form the following stages were defined:

- defining the design form of the input model,
- defining the material features,
- creating the FEM model
- defining the boundary conditions, states of strains and the objective function
- conduction the optimization of the input model
- displaying the optimization results.

The transition of the optimal design form into the exemplar (determined on the basis exemplar qualitative and quantitative design features) ought to be conducted with the consideration of the principle of uniting the partitions as well as the reasons of technical expediency, economic expediency and production capacities.

The definition of the exemplar design features on the basis of the optimal design form is performed by means of a CAD program [12]. The process of creating the exemplar design on the basis of a input model is presented in Figure 9.

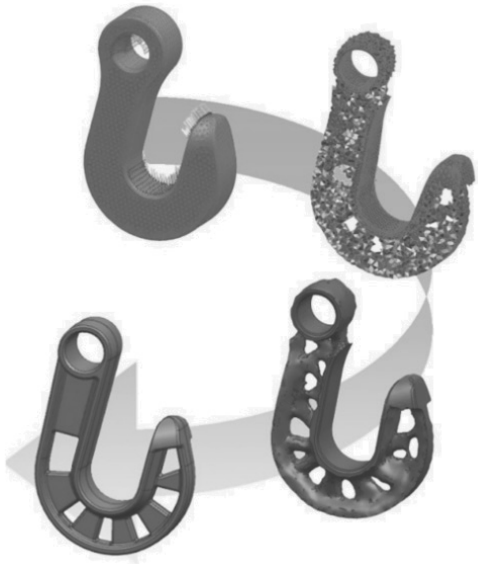


Fig. 9. Determining the exemplar design features in the advanced graphic software NX 8.0

When creating an ordered design family a full parametrization of the exemplar design is required. On the basis of the parametric record of the exemplar quantitative geometric features, with the preservation the a constant design form series of types or modular systems are created, where the constant exponent is the design form and the variables are the dimension values.

6.2. Determining the exemplar quantitative geometric features by means of the Variational Analysis

The definition of the optimal value of the design dimensions on the basis of the by designers defined design form of the initial model can be obtained with the application of the Variational analysis of the selection of the quantitative geometrical functions [1,8,9,13].

The module of Variational Analysis was implemented in a advanced graphic software I-DEAS. As in the case of the software used in the optimization of design form in the VA the FEM was applied. The optimization process was divided into 3 main stages: preparatory stage, sensitivity analysis and parametric analysis.

The preparatory stage consists of the following procedures:

- preparation of a parametrized 3Dmodel in the Master Modeler module,
- determining the material features of the element,
- creating the FEM model,
- generating the net of finite elements on the model,
- defining the boundary conditions,
- defining the states of strains.

The sensitivity analysis determines the impact of the optimized dimensions on the given criteria such as: K_σ - keeping within the limits of maximum stress, K_δ - keeping within the limits of allowed deformations, K_M - minimal mass of the component elements of the technical means.

The result of the analysis is a histogram of the dimension sensitivity to given criteria. During the parametric analysis diagrams of the variability of dimensions are generated depending on the iteration of calculations. On the basis of the analysis of the variability of stresses, deformations and mass optimal values of dimensions are being determined. Due to the relative- graphic parametrization the initial model is automatically updated to the design form of a optimized value of dimensions. Next the quantitative geometrical features received in the VA should be unified. The optimal in concern of the K_δ, K_δ, K_M criteria exemplar design should be additionally verified in regard to the criterion of stressed dimensions identity. The final stage of the process is the analysis of the strains and deformations with the application of the FEM in order to verify the design according to the durability criteria.

The optimization by means of the VA ought to start from those elements of the technical means that are mostly related from the quantitative characteristics (parameters) CCH_j^{il}. Figure 10 presents the course of the VA of a grabbing tip of a pincer gripper.

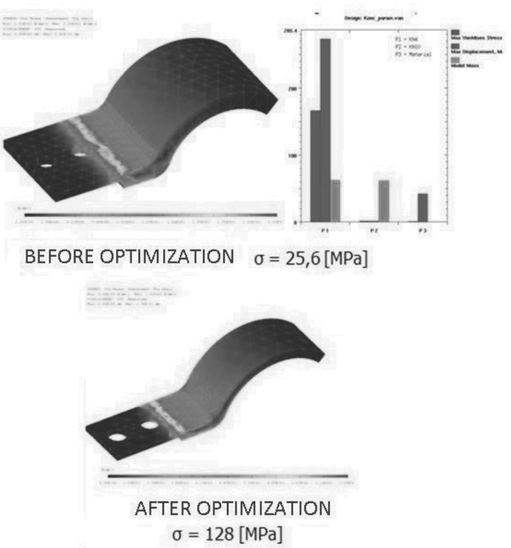


Fig. 10. Variational Analysis in an advanced graphic software I-DEAS [1,8]

By means of the application of VA in the optimization of chosen quantitative geometric features what was obtained was the reduction of the mass of the grabbing tip in 65% at the cost of the increase of stress from 25.6 MPa to 128 MPa, where the maximal allowed value of stress was defined on the level of 135 MPa).

On the basis of the defined exemplar design with the application of the theory of design similarity or the algorithmic methods ordered design families may be created in the form of series of types.

7. Theory of design similarity in the creation of series of types

The theory of design similarity allows the creation of ordered design families in the form of series of types which designs of elements are characterized with a constant design form $\prod_{tw}^{te_j}$ and variable dimension value [8,9,14].

In the theory of design similarity the exemplar design

$$Ks_0\{y_{0l}^{e_j};(l=1,lv_j)(j=1,jz)\tag{7}$$

together with the corresponding exemplar parameters $x\{x_{0a};(a=1,az)$ constitute a model.

On this basis similar geometrical designs

$$ks_i\{y_{il}^{e_j};(l=1,jz)\in RK_n\tag{8}$$

are being created with consideration of the vectors of the parameters

$$X_l^u\{x_{ia}^u;(i=1,iz)(a=1,az)\}\tag{9}$$

and preservation of the identical relation between the couplings and form changes that describe the system of the design family.

Regarding the accuracy of calculations of the dimensions the exemplar design is recommended as a representative of the medium range of ordered vectors of the needs.

During the creation of the design what is pursued is such choice of design features that give identical relations of couplings and changes of form of the system as in the exemplar design what creates optimally diversified sets of designs (Fig. 11).

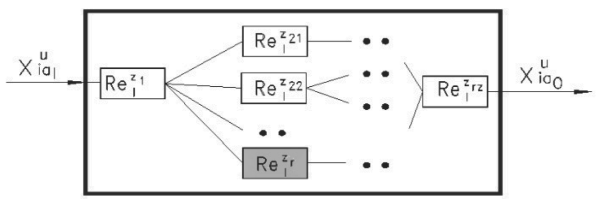


Fig. 11. A fragment of a system structure of a design family [1,8]

Preserving the identity of the physical states, stereomechanical and simple, defined by means of mathematical functions for particular system structure relations, the conditions of the design similarity are created (Fig. 12).

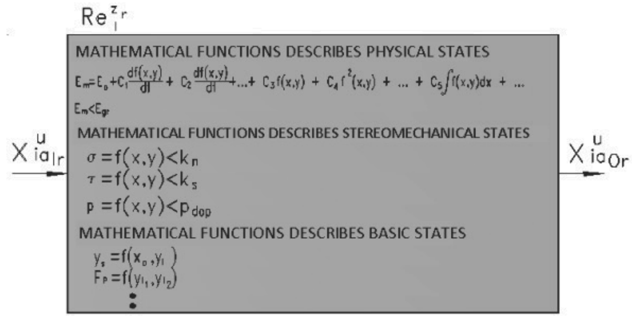


Fig. 12. Mathematical description of the states of the future technical means [1,8]

The functions are the framework for the selection of the design features of a new design

$$y_{il}^{te_j}(l=1,lv_{is}) = f_p(x_{ia}^u) \quad (10).$$

The parameter values as well as the quantitative values of design features of the elements, on the basis of the design similarity conditions, parameters and the dimensions of the exemplar design, can be determinated from the following relations:

- unified values of the parameters:

$$x_{ia} = x_{0a} \cdot (\varphi_{il}^i)^l \quad (11)$$

- the values of dimensions:

$$y_{il}^{e_j} = y_{0l} \cdot (\varphi_{il}^{e_j})^l \quad (12)$$

where:
x_{0a} - value of the ath exemplar parameter,
y_{0l} - value of the lth dimension of the exemplar design,
i - the value of the exponent describing the distance from the exemplar design (takes on the values: i = …, -2, -1, 0, 1, 2,…, where i = 0 corresponds with the exemplar design).

The values of parameters and dimensions can be determined analytically or graphically (by means of monograms with the coordinates in a logarithmic scale) [1]. The result are the quantitative geometrical values of a series of type obtained on the basis of the design similarity, which should additionally be normalized. An example of creation of an ordered design family of a sleeve of a hydraulic motor's piston with the application of the design similarity theory was presented in Figure 13.

Having determined the matrix of the dimension's values and parametrized the exemplar design model it is possible to generate automatically the technical documentation of a whole series of type of a design.

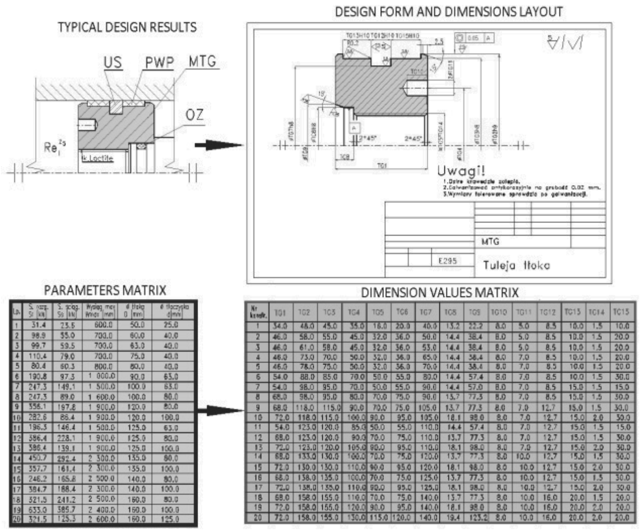


Fig. 13. Determining the values of the dimensions of a design series of type on the basis of design similarity theory [1,8]

8. The application of parametrization in the process of creating the design series of types

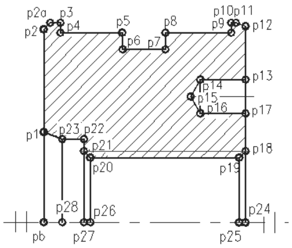
Parametrization is a computer-aided form of a design record. It is usually applied as a record of series of types with a constant defined design form ($\prod_g$=*const*) and variable dimension's values(W_g=*var*). By means of parametrization the constant qualitative geometrical features are combined with the variable quantitative geometrical ones. The variation of the values of dimensions in the parametric record affects the graphic record of the element [1,8].

In the CAD software there are the following kinds of parametrization available: dynamic, relational- graphical and sprogrammable. In the process of creating ordered design families the parametrization used mostly is the programmable and the relational-graphical parametrization.

The programmable parametrization is based on the integration of the programming language with the graphic CAD program (AutoLisp in AutoCAD, Grip in NX, etc.) The record of the design with the application of the described parametrization consists mainly in determining the characteristic coordinate points, and then connecting the determined points with lines what results in creating a design form of an element.

The coordinates of the characteristic points are determined by the function of the dimension's variables. They are calculated on the basis of the values of the quantitative geometrical features of the exemplar design and the conditions of design similarity. Figure 14 presents a record of a design form of a hydraulic motor piston's sleeve with the application of programmable parametrization.

In the relational-graphical parametrization the variation of the design record is being obtained by the application of the equation editor which determines the dimension's values on the basis of the defined equations of the conditions of design similarity.




```
;******************** POSTAĆ KONSTRUKCYJNA ********************
(defun POSTAĆ ()
(command "layer" "s" "0" "")
(setq pb (list (/ (- LX TG1) 2) 125))
(setq p1 (polar pb (kat 90) (/ TG9 2)))
(setq p2 (polar pb (kat 90) (- (/ TG2 2) 0.5)))
(setq p2a (polar p2 (kat 45) (* 1.4142 0.5)))
(setq p3 (list (+ (car pb) (- (/ (- TG1 TG13 TG12 TG15) 2) 0.5)) (cadr p2a)))
(setq p4 (polar p3 (kat 270) (- (/ TG2 2) (/ TG3 2))))
;
(command "pline" p1 p2 p2a p3 p4 p5 p6 p7 p8 p9 p10 p11 p12 p13 p14 p1 "")
(command "line" p1 pb "")
(command "line" p23 p28 "")
(command "line" p21 p27 "")
(command "line" p20 p26 "")
(command "line" p19 p25 "")
(command "line" p18 p24 "")
(command "line" p14 p16 "")
(command "line" p13 p17 "")
(command "layer" "s" "tl3" "")
(command "line" p21 p18 "")
;------------------------- KRESKOWANIE-------------------------
(command "layer" "set" "TL3" "")
(command "hatch" "ansi31" 30 0 p9 "")
(command "redraw")
```

Fig. 14. Programmable parametrization [2]

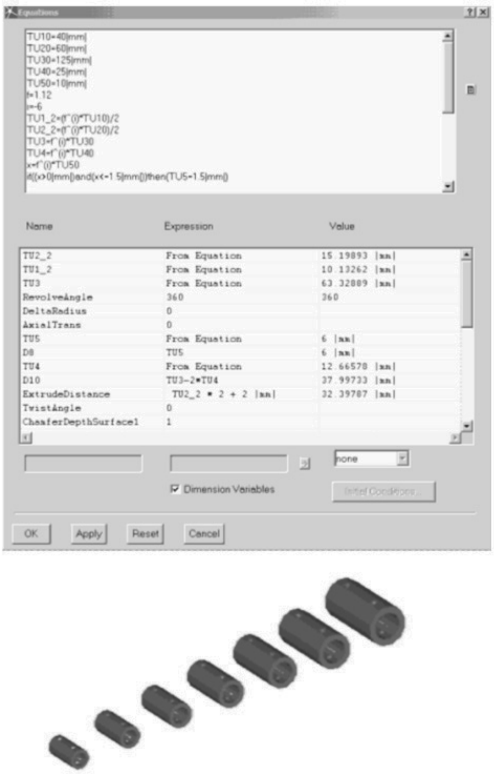


Fig. 15. Relational graphical parametrization [2]

This type of parametrization enables the change of the design record by means of modifying the dimension's values which are determined in a relational way to the given independent variable (the value of a characteristics, real dimension, number of the design similarity etc.)

After entering the given variable value, the editor calculates the values of dimensions on the basis of defined relational relations. Next the update of the existing record takes place. Most of the available graphic programs (NX, CATIA) enables the implementation of the external spread sheets on the basis of which the parametric record of the design family is created. Fig. 15 presents an example of a relational-graphic parametrization of the design series of type of a pegged clutch sleeve with the application of graphic software I-DEAS.

In the process of parametrization of the exemplar design what is especially significant is the creation of an adequate dimension's system. The determination of the base dimensions on the basis of which the rest of the dimension system is build is crucial. An inadequate system will cause errors in the record of the design of the future technical means.

9. Conclusions

The application of CAD software that uses the Finite Elements Method as a framework to support the engineering projects enables the definition of optimal qualitative and quantitative design features of the exemplar design.

The calculation software such as TOSCA or the Geometry Optimization module implemented in the advanced graphic program NX 8.0 makes it possible for the designers to determine the optimal geometrical design form in accordance to the principle: no stress → no material with the consideration of such criteria as: keeping within the limits of maximum stress and allowed deformations with the minimization of the mass of the element.

The optimization with the application of Variational Analysis in the advanced graphic software I-DEAS allows determining the optimal values of the dimensions of the elements of the technical means with a defined by the designer geometrical form considering the analogical criteria as in the optimization of the design form. Combining the presented methods of optimization constitutes an innovative method of determining the qualitative and quantitative exemplar design features where first the optimized design form is being adopted to the given technological process and subsequently the parametrized model undertakes an Variational Analysis of the dimension's values and the normalization of the quantitative geometrical features. The combination of the optimization of the geometrical form and the Variational Analysis enables determining the exemplar design features adequate for various technological processes.

On the basis of the parametrized exemplar design with the application of the design similarity theory it is possible to create in short period of time a series of types of a design of given technical means.

References

[1] P. Gendarz, Flexible modular systems, Publisher of Silesian University of Technology, Gliwice, 2009 (in Polish).

[2] W. Tarnowski, Basis of technical design, WNT, Warsaw, 1997 (in Polish).
[3] G. Pahl, W. Beitz, Construction science, WNT, Warsaw, 1984.
[4] J. Dietrych, Machines construction basis, WNT, Warsaw, 1995 (in Polish).
[5] J. Dietrych, System and construction, WNT, Warsaw, 1985 (in Polish).
[6] J. Wrobel, Z. Osinski, Construction Theory, PWN, Warsaw, 1995 (in Polish).
[7] P. Gendarz, D. Rabsztyn, The system structure, the hierarchical structure and the variant structure family of construction, Journal of Transdisciplinary Systems Science, 16/2 (2012) 131-142 (in Polish).
[8] P. Gendarz, Technical means series of types generation process with constructional similarity theory use, Journal of Transdisciplinary Systems Science 16/1 (2012) 187-198 (in Polish).
[9] P. Gendarz, Practical verification of constructional similarity theory, Journal of Transdisciplinary Systems Science 16/1 (2012) 175-185 (in Polish).
[10] S. Samuel, E. Weeks, B. Stevenson, Advanced simulation using Nastran NX5/NX6, Design Visionaries, USA, 2008.
[11] O.C. Zienkiewicz, Finite element method in engineering science, Publishing House "Arkady", Warsaw, 1972 (in Polish).
[12] D. March, Applied geometry for computer graphics and CAD, Springer, London, 2005.
[13] M. Halpern, SDRC'S Variational analysis, Computer Aided Engineering, Claveland, 1999.
[14] P. Gendarz, M. Cielniak, Computer aided generation of construction model for construction similarity theory, Journal of Achievements in Materials and Manufacturing Engineering 44/1 (2011) 80-87.
[15] R. Rząsiński, Databases and computer programs selection of technological features, Journal of Achievements in Materials and Manufacturing Engineering 49/2 (2011) 350-359.