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Constructional similarity in process of ordered construction families creating

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Analysis and modelling

ABSTRACT

Purpose: The main reason for starting research concerning theory of constructional similarity was need to substitute traditional method of creating ordered families by new algorithmic methods orientated on computer aiding.
Design/methodology/approach: The following paper treats about development and putting into practice rules of theory of constructional similarity as a main method realizing γ assignation (which determines relations between parameters of the future technical feature and its design features).
Findings: The main achievements presented in this paper are developed theory of constructional similarity orientated on computer aiding, and used in designing process of new technical features. Moreover, method is highly susceptible to parameterization.
Research limitations/implications: Analyzed methods develop algorithmisation of designing environment and support integration with the process of preparing the production. Intense research on the theory of technological similarity is being made nowadays.
Practical implications: Described methods were being developed on practical examples of creating the module systems of hydraulic cylinders used in mining, slag cars used in metallurgy and gears series of types. Nowadays the gripping devices series of types is being made.
Originality/value: Presented in the paper method of construction similarity is basis of selection of design features in the process of ordered construction families (series of types and module systems of constructions) creating. Presented method supports intensive development of the types of technical features and affects their competitiveness on the ready market.
Keywords: Engineering design; Constructional design; The theory of constructional similarity; Series of types

1. Introduction

The selection of elements dimension values is one of basic problems of ordered construction families creating. It is the most susceptible stage to algorithmisation and computer aiding.

In the process of the creating ordered construction family four groups of transformation were distinguished [1, 2]:
α – assignation requires constructional solutions,
β – assignation of constructional solutions to constructional forms of elements,
γ – assignation requires values of element dimension,
δ – assignation requires number of ordered components of the construction family.

The γ assignation is the object of consideration in this paper.

Following methods of selection of quantity design features are as distinguished:

- traditional method,
- method of the constructional similarity,
- algorithmic method,
- neural networks application method.

The theory of constructional similarity is the object of consideration in this paper.

2. Ordered construction families

The most popular forms of ordered families of constructions:

- technical means of series of types created basing on simple rules of selection; constant constructional forms are typical for assemblies [3, 4, 5],
- technical means of module systems of constructions created basing on complex rules of selection; constant or variated constructional forms are typical for assemblies [3, 4, 5].

Components of specified ordered families of constructions are elements of series of types or elements of series of module systems creating congruent constructions.

Series of types of technical means (Fig. 1) represented by ordered family of constructions is a set of constructions $Ts_n\left\{ks_k^t;\left(k=1,\ldots,kz\right)\right\}$ with a constant constructional form $\left(\Pi^t=const\right)$ and variational values of dimensions $\left(w_{kl}^t=\mathrm{var}\right)$.

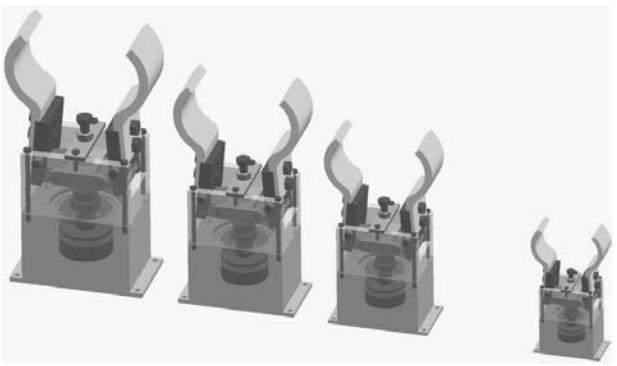

Fig. 1. Gripping device series of types

3. The theory of constructional similarity

The basis of creating ordered family of constructions with use of construction similarity is a standard construction $ks_0\left\{y_{ol}^{e_j};\left(l=1,\ldots,lv_j\right)\left(j=1,\ldots,jz\right)\right\}$ with set of standard needs $\overline{X}_0\left\{x_{0a};\left(a=1,\ldots,az\right)\right\}$. On a base of standard construction and needs the families similar in a geometrical form $ks_i\left\{y_{il}^{e_j};\left(l=1,\ldots,lv_j\right)\left(j=1,\ldots,jz\right)\right\}\in RK_n$ are being created in order of matrix of needs $\overline{X}_i^u\left\{x_{ia}^u;\left(i=1,\ldots,iz\right)\left(a=1,\ldots,az\right)\right\}$ with maintained identical relations of conjugations and relations of transformations. Values of dimensions are matched to normal numbers [1, 6, 7].

Relations may be represented by a centralised set of mathematical functions which describe a physical phenomenon, stereomechanical states (critical stress) and simple states (geometrical relations between dimensions of conjugate elements).

Fulfilment of the theory of constructional similarity within stereomechanical states is called the Cauchy problem [8]. In mechanical engineering the Cauchy problem rules maintenance of the level of effort of material, a strain and a safety number in every new construction

The standard construction is a construction verificated by practical and experimental methods and used once in a process of production. Product complied with this conjugation fills all set of criterions in the best possible way [1, 9, 10].

The standard construction for the sake of precision of computations of dimensions values should be represented by a centre of a set of created family of constructions.

The analysed method uses numbers of similarity:

- similarity of parameter $\varphi_{ia}^u=\dfrac{x_{ia}^u}{x_{0a}}$,
- similarity of dimension $\varphi_{il}^{e_j}=\dfrac{y_{il}^{e_j}}{y_{0l}^{e_j}}$.

There is a strict relation between digitization of characteristic features which generate sequence of parameters $\vec{X}_a^u\left(x_{1a}^u,\ldots,x_{ia}^u,\ldots,x_{iza}^u\right)$ and digitization of a variable dimension which generates a sequence of dimension $\vec{Y}_l^{e_j}\left(y_{1l}^{e_j},\ldots,y_{il}^{e_j},\ldots,y_{izl}^{e_j}\right)$ [1, 6, 7].

4. FEM strength verification and variational analysis

Along with researches concerning rules of the constructional similarity theory, researches concerning FEM aided strength analysis were done, as useful aid of process of ordered construction families creating. Studies on an OPTIMIZATION tools from application SIMULATION of I-DEAS software were taken as enabling an optimization of quantitative constructional features considering specified of criteria [11]. Obtained solutions of an optimization can be basis for the standard construction researches, which is input of the process of ordered families creation following the rules of the constructional similarity theory (Fig. 4) [9, 10, 3, 12].

FEM applications are also very useful for a process of analysis because of abilities of a strength verification of elements of created family [14, 5]. FEM analysis enables analysis of construction families according to the Cauchy's problem (Fig. 5).

The basis for variational analysis is a model of elements, a set of criteria (minimization of mass, minimization of displacements, maximisation of effort of material etc.) and a set of parameters (geometrical, material and physical types) prepared to optimization. Settings of the solution sequence (number of iteration, variation range of parameters etc.) are important for solution's process and precision [13, 5, 12].

An optimization of values of complex constructions dimensions contains many elements demanding systematical and ordered proceeding [2, 11, 14]. The conjugation relation graph allows recognition of identity relations of dimensions of construction cooperating elements (Fig. 2, Fig. 3).

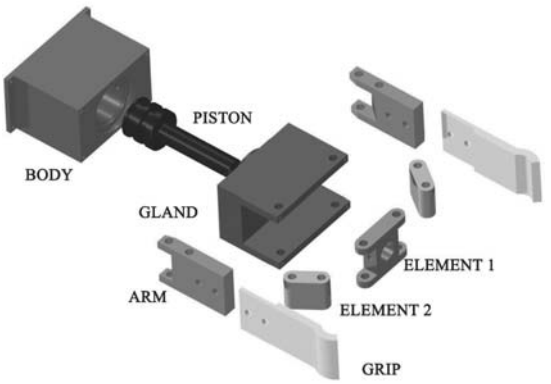

Fig. 2. Visualization of constructional form of gripping device elements

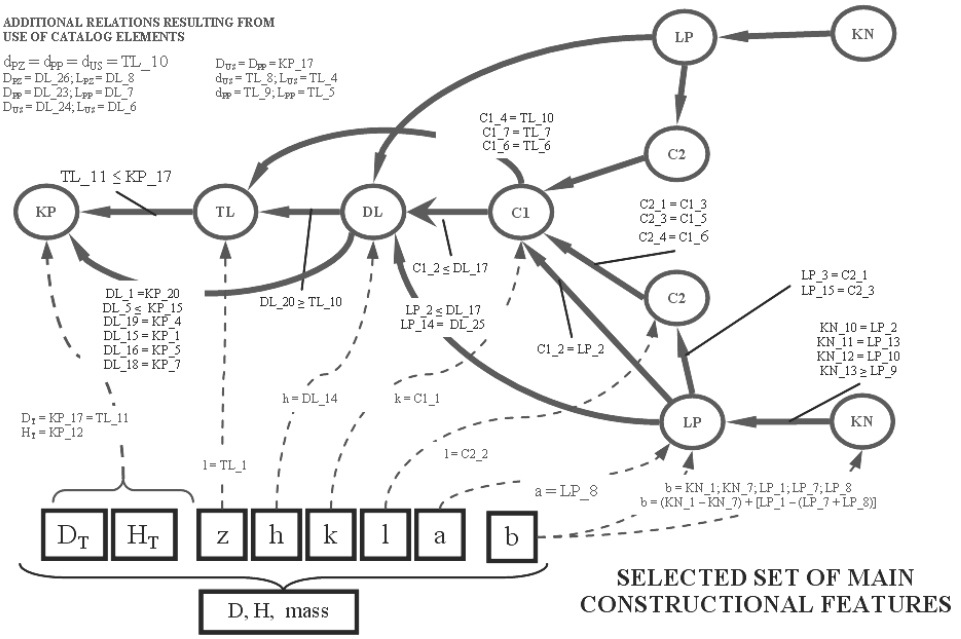

Fig. 3. Conjugation relation graph of gripping device with specified relations and direction of dimensions inheriting. Catalog elements: SR – screw, SW – bolt, TU – slide bearing, PZ – scrapping ring, PP – leading ring, US – seal ring

It is important to determinate order of an optimization of elements and the same to determine a direction of inheriting optimal dimensions values between them. It is recommended to start all optimization processes with extreme element of graph, having the strongest relation with technical mean's characteristic features (Fig. 3).

Optimization process of elements of a gripping device Fig. 2 was run according to the conjugation relation graph presented on Fig. 3 and was began with an optimization of grip KN.

5. Conclusions

For the reason of the dynamics developments of design techniques and computer aided methods it is important to devote major attention to methods considerations of flexible computer aiding rather than a creation of ordered construct families.

Computer aiding allows intensification of development and creation of algorithms of selection of dimensions value for ordered families of constructions. Additionally computer aiding enables fast conversion of a data for processes of manufacturing preparation.

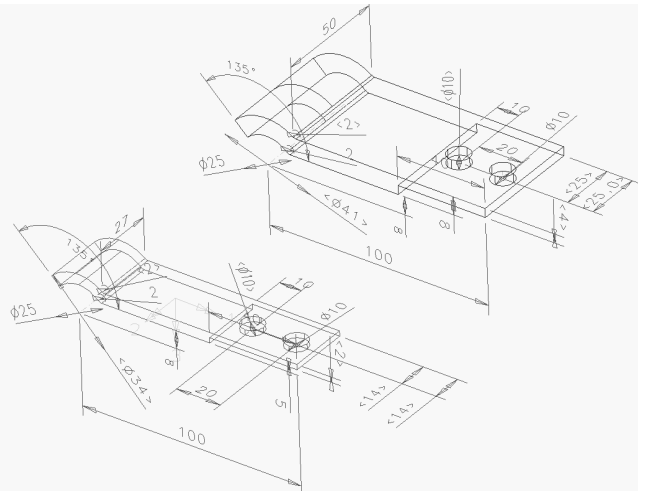

Fig. 4. Result of optimization of quantitative constructional features of griping device grip

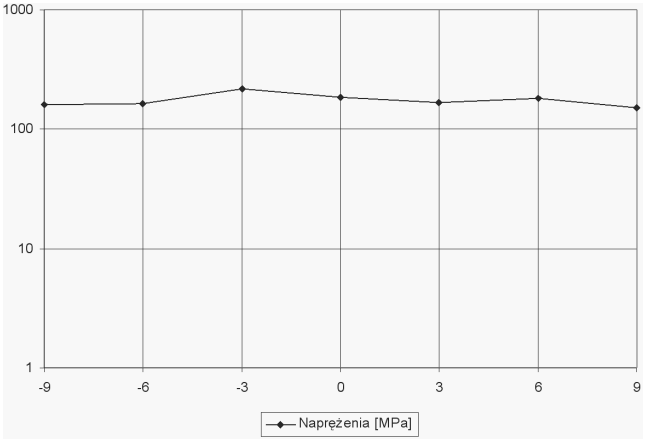

Fig. 5. Result of strength analysis of selected series of types of a grip (KN)

Algorithms based on the theory of constructional similarity allow computer aiding and algorithmisation of the creation of construction series of types.

The Variational Analysis is useful aid for the process of standard construction research. It's possible to use it for initial strength analysis preceding practical and laboratorial research.

Acknowledgements

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