International Journal of Modern Manufacturing Technologies
ISSN 2067–3604, Vol. VI, No. 2 / 2014

INTRODUCTION TO THE ORDERED FAMILIES OF CONSTRUCTIONS

Dominik Rabsztyn[1]

[1]Silesian University of Technology in Gliwice, Department of Mechanical Engineering
Konarskiego 18a Street, 44-100 Gliwice, Poland

Corresponding author: Dominik Rabsztyn, dominik.rabsztyn@polsl.pl

Abstract: The article aims at familiarizing the Reader with the method of creating ordered construction families in the form of series of types and modular systems. The method is being developed in the Institute of Construction, Management and Manufacture of the Silesian University of Technology in Gliwice. The publication presents the method of ordering the existing construction families, as well as describes stages of creating construction families from scratch. It lists and describes the stages of the design and construction process of creating new technical means in the form of series of types and modular systems. The paper provides a definition of quantitative and qualitative characteristics, which are the basics of construction solutions diversification in the given ordered construction family.
Key words: ordered family of constructions, series of types, modular systems, design and construction process of creating the families of constructions.

1. INTRODUCTION

Competitiveness on the dynamically changing market may only be retained by meeting the expectations of Clients. The accelerating technical development poses significant and difficult challenges for the designers and design engineers. They have little time to develop the technical measures adjusted to the demands of the Clients, taking into account the criteria resulting from the technical advisability as well
as economic and technical feasibility (Dietrych, 1985; Dietrych 1995). In order to succeed in today's market economy, the design and construction process cannot be only limited to the development of just one construction of the technical measure (Beitz and Paul, 1984; Osinski and Wróbel, 1995; Tarnowski, 1997). One should aim at creating sets of constructions encompassing the broad spectrum of demands for the particular class of technical measures (Gendarz and Cielniak, 2013; Gendarz, 2013). The best way to satisfy a wide range of needs with no increase in time and production costs is to use the ordered families of constructions, such as series of types and modular systems.

2. DEFINITION OF CONSTRUCTION FAMILY

A construction family RK_n (Gendarz, 2009) is understood as a set of technical means designs $Ks_n\{ks_k;(k=1,kz)\}$ that is assigned to a set of defined needs $Po_n\{po_i;(i=1,iz)\}$ and corresponds with the identical general system SO_n .

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

An example of construction families is a set of designs of: electric motors, gear drives, pneumatic or hydraulic cylinders etc.

3. PROCESS OF ORDERING FAMILIES OF CONSTRUCTIONS

Ordering families of constructions may involve the existing construction families where we can observe the excessive diversification of the design characteristics. This process is undertaken, above all, due to the perceptible effects of the excessive diversification of the existing technical measures characterized by the identical general system. Transition from the unordered family of constructions to the ordered one requires transformation on two levels: the level of needs and the level of construction.
In case of the level of needs we are talking about the Cartesian product of the characteristic features CCH_n. However, in case of the level of construction we are dealing with the Cartesian product of the design features CK_n (Gendarz 2013). Figure 1 presents the status of the construction family before and after the process of ordering.
In the unordered family of constructions, one need corresponds with the subset of the technical measure design. This assignment is the sign of the unjustified diversification of constructions.

$$Po_n\{po_j;(i=1,iz)\} \Rightarrow Ks_n\{ks_k;(k=1,kz)\},\ iz<kz \quad (2)$$

where:

- iz – a number of needs,
- kz – a number of constructions.

The result of the process of ordering construction families is the ordered set of needs and the set of optimally diversified constructions, where one need corresponds to precisely one construction.

$$Po_n^u\{po_j^u;(i=1,iz)\} \Rightarrow Ks_k^u\{ks_k^u;(k=1,kz)\},\ iz \geq kz \quad (3)$$

The presented correlation provides the precondition for the process of ordering the construction family.
Another method of ordering is creating the construction from scratch, with the benchmark construction set as a reference point that is verified both theoretically and practically. This solution allows the elimination of unjustified diversification of construction features in the earliest stage of creating the construction families.

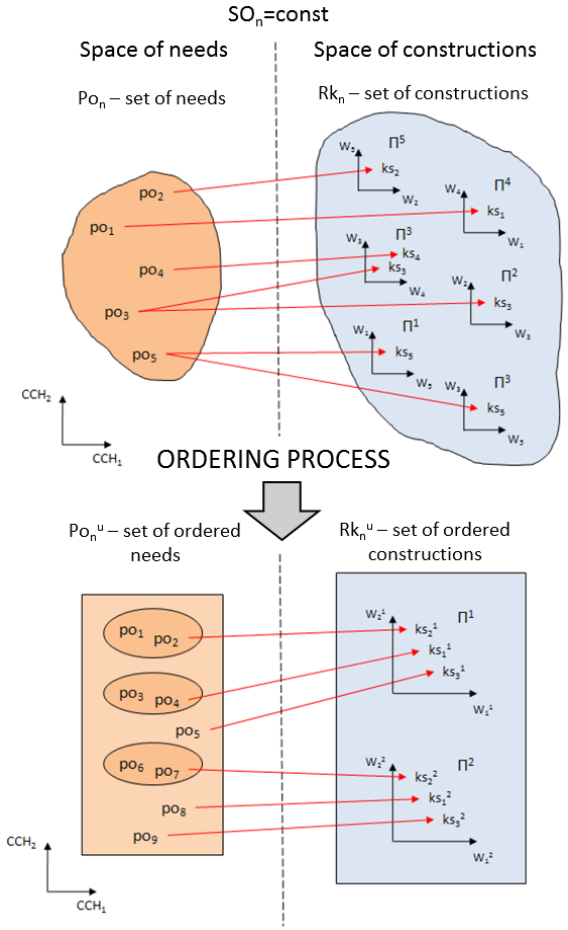

Fig. 1. Process of ordering a family of constructions, (Gendarz, 2009)

The results of the process of ordering construction families may be presented in the form of (Gendarz 2009):

- sets of repeatable constructions,
- series of types,
- modular systems,
- catalog and standardised constructions.

The terms defined for the process of creating construction families should clearly separate sets of needs and sets of constructions and specify the interdependencies between them.

4. A DESIGN AND CONSTRUCTION PROCESS IN CREATING OF CONSTRUCTION FAMILIES

With a traditional design and construction process (*pr - ks*), a defined need *po* is assigned to one technical means design. A *pr – ks* process is undertaken individually for each subsequent, defined need. The process of creating ordered construction families RK_n^u begins with examining the ordered set of needs $po_i(i=1,i_n)$, that needs to be satisfied by the optimally diversified set of designs $Ks_i(i=1,i_n)$.
Fig. 2 presents a design and construction process of creating an ordered construction family.

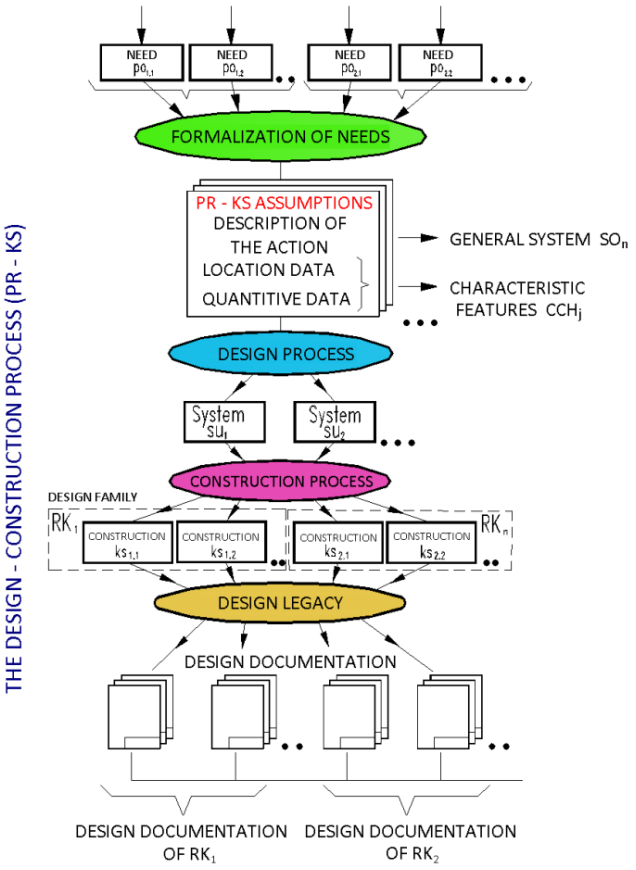

Fig. 2. The design construction process of creating the design family (Gendarz, 2009)

A design and construction process of creating a construction family (both series of types and modular construction systems) should begin with defining the ordered sets of needs that then need to be formulated into design and construction objectives. The objectives *pr – ks* are determined considering the following: description of the planned technical means operation principle, registered in the form of general system SO_n and optimal diversification of the characteristic features CCH_J.

Characteristic features CCH_J are the features that the planned product will be characterized by due to its connection to the environment. They correspond with the situation and quantitative data and are closely related to the defined construction family RK_n. Most of all, these features influence the selection of design features CK_s, and at the same time have impact on the design diversity within types of series or modular construction systems. Characteristic features have been divided into qualitative and quantitative characteristics. Qualitative characteristics CCH_j^{ja} include situation data of design and construction objectives, such as: purpose of a given technical means, operation conditions, assembly method, position etc. They mostly influence the variability of qualitative characteristics in the formed construction family. Quantitative characteristics CCH_j^{il} , defined as parameters Pa_a of the constructed family of constructions, quantitatively represent the needs po_i. The characteristics include: torque, linear or rotational speed, transmitted force, overload figure etc. Parameters are defined by means of real numbers and influence the selection of quantitative characteristics (values of geometry and material related dimensions). They have the operational meaning in the process of creating and applying series of types and modular construction systems.

The basis of the design process is defining the constructed technical means, which means determining the coupling and transformation relations as precisely as possible. The results of the design of process are sets of specified systems su_n, whose degree detail depends mostly on the degree of complexity of the planned technical means. Depending on the experience and creativity of designers, different concepts of the detailed systems are created and they are used as a basis for system structure SS_n of the construction family. System structure is the basis of the proper selection of design features for the planned technical means components. The construction process involves defining geometry, material and assembly related design features (Gendarz 2009). During the process, all the features essential to manufacture the future technical means and satisfying the performance, manufacturing and recirculation related criteria, as well as design and construction objectives, are defined. This applies both to qualitative and quantitative design features. The result of the construction process are ordered sets of constructions that, due to the defined general system, can be divided into construction families RK_n and are saved in the form of the construction documentation.

5. PHASES OF THE PROCESS OF CREATING ORDERED CONSTRUCTION FAMILY

The process of creating ordered construction families includes the preparatory and main phases.

Fig. 3 presents preparatory phases of creating the ordered construction family.

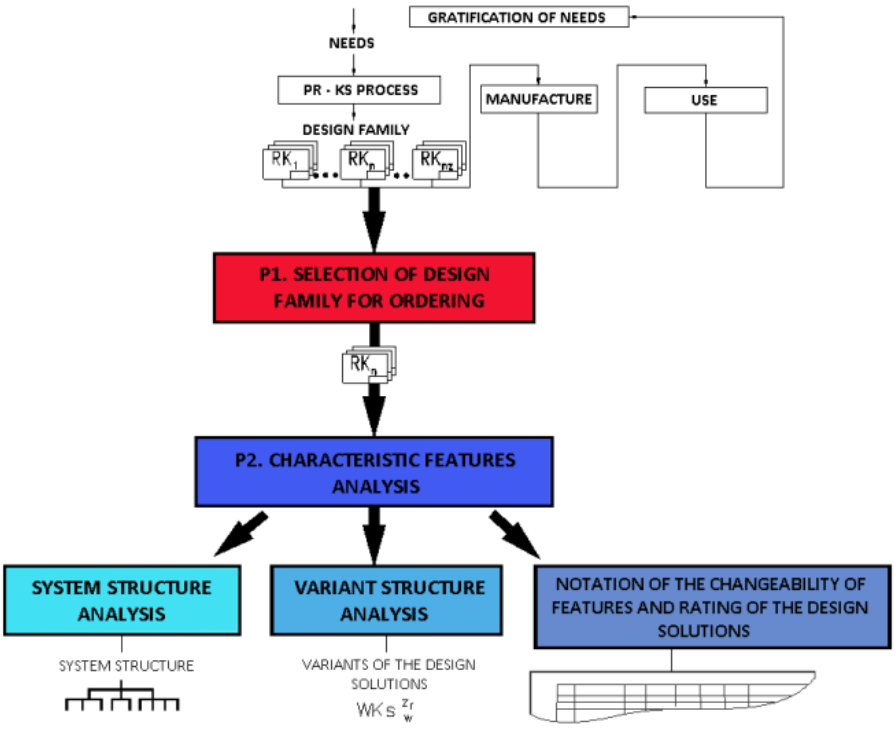

Fig. 3. The preparatory stages in the creation of a design family of construction (Gendarz, 2009)

Preparatory phases refer to the analysis of the existing design solutions for construction families. The following preparatory phases can be distinguished (Gendarz 2009):

- choosing the existing construction family to be ordered or choosing the model construction, that will be used as a baseline to create a new, ordered construction family,
- analysis of the feature diversity of the existing RK_n based on: system structure analysis, hierarchical and variant structures and record of the characteristics variability and design solutions assessment.

The main phases in the process of creating Rk_n^u are formed by such processes as (Gendarz 2009):

- unification – assignment and restriction of the characteristics values,
- typification – choosing design solutions treated as binding in a given construction family,
- creating typical construction forms of the construction family elements,
- developing the basic dimension system,
- selecting values of construction elements dimensions,
- optimization of the dimension values diversification,
- defining rules of selecting (simple and complex) ordered construction family elements,
- record of the construction family in the form of construction documentation.

Fig. 4 presents the main phases of creating ordered construction families.

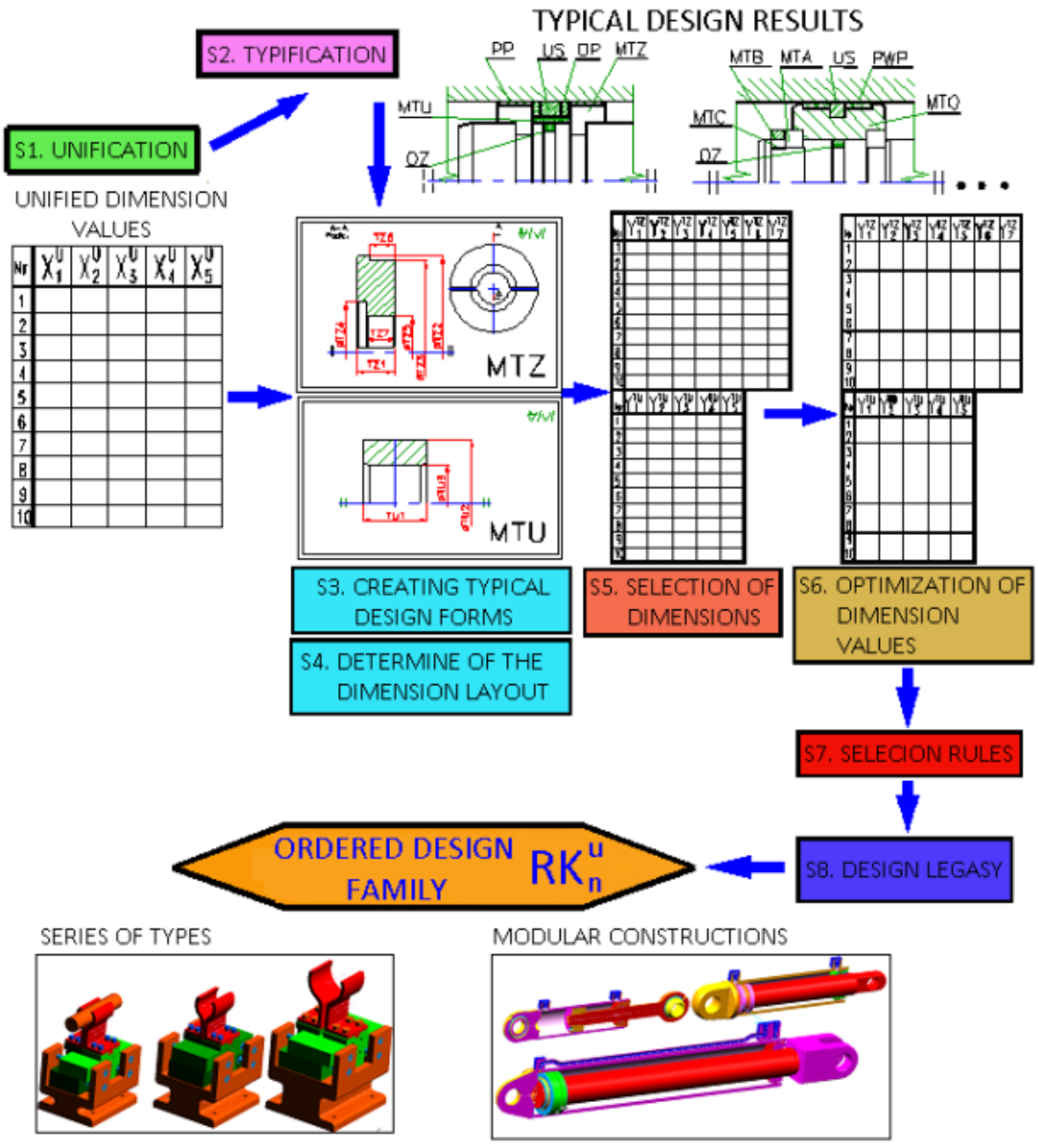

Fig. 4. The main stages of creating a design family (Gendarz, 2009)

The result of the presented phases is the created construction family Rk_n^u in the form of series of types or modular systems.

6. CONSTRUCTION SERIES OF TYPES

In the design and construction process, where constant qualitative characteristics ($CCH_j^{ja} = const$) occur for the entire construction family and the variable parameters are the quantitative characteristics ($CCH_j^{il} = war$), it is rational and justified to create construction families in the form of series of types.

A series of types for the construction *Ts* was defined as assigned to the set of unified needs $Po_n^u\{po_i^u; (i = 1, iz)\}$, a set of technical means designs $\{ks_k^t; (k = 1, kz)\}$ with a constant geometric form $\Pi^t = const$) and variable dimensions values ($W^t = var$), created following the simple rules RG_n^{Ts} of selecting type series for the elements (Gendarz 2013).

$$Po_n^u\{po_i^u; (i = 1, iz)\} \Rightarrow Ts_n\{ks_k^t; (k = 1, kz)\} \equiv RK_n^u \quad (7)$$

Variability of the quantitative characteristics depends, above all, on the variability of parameters values pa_i^u for the components of construction series of types.

Fig. 5 presents the series of types for the grippers used in hydraulic valves.

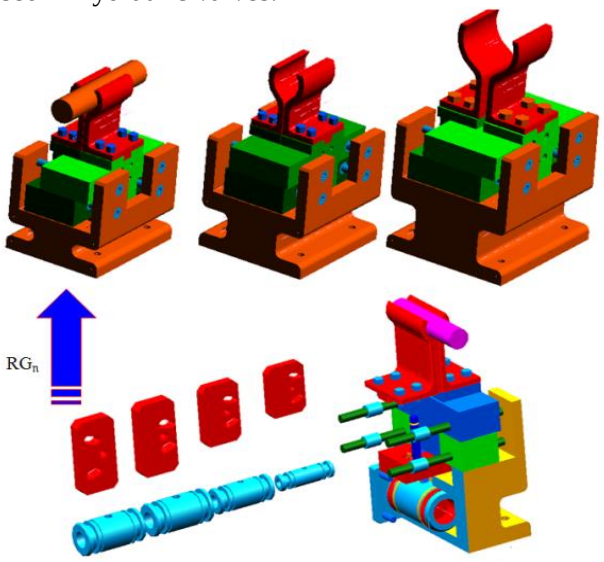

Fig. 5. Series of types of vice grippers (Gendarz, 2009)

The process of creating construction series of types involves ordering the set of needs Po_n^u and the set of designs to the form of a series of types $RK_n^u = Ts_n$. In this process, both characteristic features and qualitative characteristics undergo transformation.

Contrary to modular construction systems, series of types are characterized by the lack of construction solutions variability.

7. MODULAR CONSTRUCTION SYSTEMS

In the design and construction process of creating the ordered construction families for the wide spectrum of characteristics variability CCH_j (both qualitative and quantitative characteristics), it is seldom possible to obtain only one construction form $\prod^t$. Most commonly, we obtain several variants of construction forms $\prod^{p_t}$, which is characteristic for the modular construction systems (Gendarz, 2013).

A modular construction system SM_n is a set of diversified construction modules $\{mk_m^{rwe_j}; (j = 1, jz), (m = 1, mz)\}$ with the complex rules RG_n^{SM} of their selection.

$$SM_n\left[\left\{mk_m^{rwe_j}; (m = 1, mz), (j = 1, jz)\right\} \cup RG_n\right] \Rightarrow Ks_n^m\{ks_k^m; (k = 1, kz)\} \equiv RK_n^u \quad (8)$$

The reason why the geometric form varies in modular construction systems is the varying qualitative characteristics CCH_j^{ja}.

An example of the pneumatic cylinders modular system has been presented in Fig. 6.

Fig. 6. A modular system of hydraulic cylinders (Gendarz, 2009)

Modular constructions are characterized by the significant variability and flexibility of the construction solutions application.

8. CONCLUSIONS

The publication presents the structured method of creating the ordered construction families in the form of series of types and modular systems. The presented methodology has been practically verified using the example of construction families of hydraulic cylinders, gripper tongs and clutches. Series of types and modular

construction systems, created according to the presented methodology, prove the accuracy of this methodology. Currently, the presented methodology is being developed in the aspect of creating ordered construction families on the basis of the parameterized model construction and Theory of Construction Similarity (Gendarz 2009, Gendarz and Cielniak 2013).

In relation to the described problem, it is worth mentioning the achievements of the research group under the supervision of prof. dr hab. inż. Piotr Gendarz, a long standing employee of the Institute of Engineering Processes Automation and Integrated Manufacturing Systems at the Silesian University of Technology in Gliwice, in the area of creating ordered construction families based on the Theory of Construction Similarity, dimensions values aggregation using theory of automatic classification and parametric construction record. (Gendarz 2013).

REFERENCES

1. Beitz W., Pahl G., (1984). *Construction science*, pp. 21-98. WNT, (Warsaw) – in Polish.
2. Dietrych J., (1985). *System and construction*, pp. 33-113. WNT, (Warsaw), – in Polish.
3. Dietrych J., (1995). *Machines construction basis*, pp. 60-209. WNT, (Warsaw) – in Polish.
4.Gendarz P., Cielniak M., (2013). *Construction series of types. Application of constructional similatiy and costs model*, pp. 29-37. Publisher of Silesian University of Technology, (Gliwice) – in Polish.
5. Gendarz P., (2013). *Parametrical legacy of ordered families of machines designes*, pp. 25-94. Publisher of Silesian University of Technology, (Gliwice) – in Polish.
6. Gendarz P., (2009). *Flexible modular systems*, pp. 64-179. Publisher of Silesian University of Technology, (Gliwice) – in Polish.
7. Osinski Z., Wrobel J., (1995). *Construction Theory*, pp. 7-149. PWN, (Warsaw) – in Polish.
8. Tarnowski W., (1997). *Basis of technical design*, WNT, (Warsaw) – in Polish.

Received: June 15, 2014 / Accepted: December 10, 2014 / Paper available online: December 15, 2014 © International Journal of Modern Manufacturing Technologies.