Construction typification as the tool for optimizing the functioning of a robotized manufacturing system

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Abstract. Process of workcell designing is limited by different constructional requirements. They are related to technological parameters of manufactured element, to specifications of purchased elements of a workcell and to technical characteristics of a workcell scene. This shows the complexity of the design-constructional process itself. The results of such approach are individually designed workcell suitable to the specific location and specific production cycle. Changing this parameters one must rebuild the whole configuration of a workcell. Taking into consideration this it is important to elaborate the base of typical elements of a robot kinematic chain that could be used as the tool for building Virtual modelling of kinematic chains of industrial robots requires several preparatory phase. Firstly, it is important to create a database element, which will be models of industrial robot arms. These models could be described as functional primitives that represent elements between components of the kinematic pairs and structural members of industrial robots. A database with following elements is created: the base kinematic pairs, the base robot structural elements, the base of the robot work scenes. The first of these databases includes kinematic pairs being the key component of the manipulator actuator modules. Accordingly, as mentioned previously, it includes the first stage rotary pair of fifth stage. This type of kinematic pairs was chosen due to the fact that it occurs most frequently in the structures of industrial robots. Second base consists of structural robot elements therefore it allows for the conversion of schematic structures of kinematic chains in the structural elements of the arm of industrial robots. It contains, inter alia, the structural elements such as base, stiff members - simple or angular units. They allow converting recorded schematic three-dimensional elements. Last database is a database of scenes. It includes elements of both simple and complex: simple models of technological equipment, conveyors models, models of the obstacles and like that. Using these elements it could be formed various production spaces (robotized workcells), in which it is possible to virtually track the operation of an industrial robot arm modelled in the system.

1. Introduction
Typification is one of the stages of the normalization process. This process causes reducing costs, enabling mass production, functioning together devices from different manufacturers and replacement of worn parts. It facilitates also making commercial contracts. The whole normalization process includes: classification, typification and unification. Classification consists of searching similar constructions or constructional features and creating groups of similar objects. The example of classification is the group technology - manufacturing similar products in one production batch [1,2,3].
Typification is a process of limiting variety of constructions or their features (e.g. dimensions). This is realized by selecting a number of constructions or their features that however allow meeting demand in its whole range. The example of typification is the system of standardized dimensions (e.g. diameters of screw joints). Generally for small features the distance (in a similarity space) between typified objects is much smaller than for large ones (e.g. Renard sequence). As the results of typification one could obtain the series of types. Unification is the use the same elements and assemblies in different technical means. It concerns also features of produced elements. Generally speaking unification is then when only one element or assembly of the considered type is used for manufacturing. The example of unification is utilization of the same engine in different car models or one type of file format (e.g. Step). As it was stated unification is also considered with unification of construction features. For example in the Polish car CWS T1 (figure 1) was use the only type of screw joints (M10x1.5) and the sparking plug thread M18x1,5. So using one double-ended spanner it was possible to take the whole engine and car to pieces [4].

The presented discussion of normalization techniques in machine building shows its undeniable advantages. It is important to consider this approach in being elaborated and applied methodologies of technical means designing. Modern engineering informatics environments in the form of the system of the CAD/CAE/CAM [6, 7] class enable and facilitate such approach not only in designing of a particular technical means but also of complex technical systems. Particularly in the case of the last the possible profit not could be underestimated [8, 9].

2. Typification as the designing criterion
Typification process, as leading to types of series creation, should be included into methodology of designing, as it was mentioned previously. In the classical methodology [10] the designing process is treated as general, heuristics approach to the problem of new technical solutions searching. It is needed to systematize that process to show main directions of new technical solutions development to obtain an optimized construction. One approach to this issue could be pointed two groups of sub-processes leading to typified construction [11]. These two groups of sub-processes intermingled creating 9 optimizing requirements.

The first group relates to designing of typified constructional forms (figure 2). It is possible to determine three fundamental forms of a construction [12]. In other words, according to this assumption, construction is the result of synergetic assembly of three components called constructional forms. The first one is the geometric form. It describes construction as regards geometric relations and dimensions (scale). The typification process at the geometric form designing relate to simplification of variety of shapes and of dimensions of technical means. Sometimes the form is unified and dimensions create s series of types. The second constructional form relates to used material so it describes the micro- and nano-structure of technical means. Material typification is frequently replaced with material unification. In the designing process one drives towards eliminating material which are expensive, almost unworkable, not functional and not eco-friendly [13, 14, 15].

![Figure 1. Virtual model of a replica of the CWS T1 Torpedo [5].](image)
This phase includes also determining typical material dimensions like a hardening temperature. Finally the third process of constructional form designing and typifying is considered with assembling machine tools. Typification, at this phase, drives for limiting the variety of assembly procedures and dimensions (the example of an assembly dimension is the screw tightening torque [17].

![Figure 2. Typification processes in a designing methodology plan.](image)

The second group of typification operations is considered with previously determined sub-systems of a technical mean [11]. The first one concerns to the structural sub-system. It includes functional elements of a technical mean except the two next systems. During designing process of the structural subsystem of a technical mean three typification operations are conducted. They are related with typification of the structural subsystem under conditions concerning the three constructional forms (typification of the geometrical form of the structural subsystem, typification of the material form and typification of the assembly form). These typification operations lead to the typified structural sub-system as a technical solution for this one engineering task.

Realization of all three processes of designing designated sub-systems of a technical means allows conducting nine typification operations. As the result one could obtain both the typified constructional forms and sub-systems of a technical mean. The typification operation must include also mutual typification of particular processes (their influence on each other). The typified design is the result of mutual optimization of typified sub-systems and typified constructional forms.

3. **Typification of industrial robot constructions and work scenes**

One of areas of application the typification approach in the design process is elaborating constructions of industrial robots. Analyses show that there is a huge variety of designs of industrial robots (figure 3). In this situation each workcell has to be designed to the characteristics of an industrial robot and any exchange of a robot enforces its reconfiguration.

![Figure 3. Exemplar designs of industrial robots [16].](image)
In the conducted project it was assumed that it should be changed the philosophy of design. The challenge was to design robots to the previously designed workcell. Below is presented an exemplar workcell which should be robotized (figure 4). The workcell has been designed using typified machine tools and conveyors.

![Exemplar workcell](image)

**Figure 4.** Exemplar workcell.

The realization of such design process was based on utilization previously designed series of types of components of an industrial robot. It was selected next groups of typified elements: robot bases (with linear and rotational drives), robot drives (linear and rotational), robot arm parts (a series of types) and grippers. Using this components it is possible to assembly any robot configuration of any work space (of course in the limited range). The robots resulting from the assembly process are presented, in the simplified form, in the figure 5. The simplified form is utilized for the control procedure to analyze collisions and accessibility of a robot arm.

![Exemplar workcell with two typified robots](image)

**Figure 5.** Exemplar workcell with two typified robots (in the simplified form).

Utilization of typified components allows designing robots taking into consideration the requirements of existing workcells, which should be robotized or in which should be changed the robotized unit.

4. Conclusions

The presented analysis and practical example of typification process utilization allows stating that this approach is valuable and profitable and could be computer aided. One of identified problems is considered with data acquisition that is considered with widespread production computer systems [17].
The second problem is considered with realization specific optimization problems e.g. concerning the optimal vibrations characteristic [18,19,20].

The next investigations will be considered with determining rules allowing creating the minimal families of construction at required level of dimensional variety. The modern CAD/CAE environments let to elaborated such typified construction in shorter time and to test them in a virtual environment what causes decreasing of designing costs.

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