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DESIGN OF WORKING UNITS IN THE MANUFACTURING SYSTEM OF TOOL MACHINES REPAIR

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Abstract: The paper investigates the possibility of applying the concept of production on the principle of the group technology. To make that possible, it is necessary to have a stable production program as one of the most influential factors in the choice of spatial structure. The following factors have been observed: the process of grouping parts of machine tools in the overhaul by applying the classification system and subject approach in the construction of production structures. Empirical research has been related to the classification and categorisation of parts - production programs. In the second phase, the analysis of classification and operational similarity of parts in the machine tools overhaul process has been performed. The third phase has been related to the analysis of the representation of operational groups of individual machine tools in relation to the total number of formed operational groups in the machine tools overhaul production system. Research has shown that there are certain laws in the formation of operational groups, which can reliably assess the impact of analysed factors on the formation of permanent work units in terms of equipment allocation and workplaces (layout) regardless of the introduction of different types of machine tools in the overhaul process, and that has enabled the overhaul process efficiency increase in the overhaul system.
Keywords: group technology, work unit, overhaul, machine tool, layout

INTRODUCTION

Today, the problem of increasing the efficiency of the machine tool overhaul process is given extraordinary attention. The reasons for that should be sought in the fact that machine tools form the basis of the production process in the metal industry. Their overhaul represents an unjustified cost for both users and manufacturers. Therefore, ways are being sought to reduce these costs, i.e. to increase the efficiency of the machine tools overhaul process.

In this regard, an efficient overhaul, especially its subsystem for the production of parts of machine tools which are in the process of overhaul, requires an appropriate choice of spatial structure. The selected spatial structure directly determines the material flow system, which is reflected in the controllability of production, production cycles and the degree of utilization of means of production [3].

The choice of spatial structure is influenced by a number of factors, the most influential of which are the *production program* and *technology*, i.e. the product assortment and quantities, degree of constructional and technological similarity of products, shape, dimensions and tolerances, rate of product changes, market life cycle etc.[3].

On the basis of the above mentioned, the main goal of restructuring the existing spatial layout, in our case that is the machine tools overhaul production system, has been to explore the possibility of applying the concept of production on the principle of so-called Group technology - creation of work units (cells). This solution attempts to modify the traditional layout according to the process, by using all the advantages of line production [8]. To make it possible, it is necessary to have a stable production program, as mentioned earlier, as one of the most influential factors in the choice of spatial structure.

The basic *hypothesis* in this paper is derived from the stated and reads: *By applying the group technology, i.e. the classification system to the production program of the machine tools overhaul production system, it is possible to obtain a stable production program in the form of a finite number of operational groups.*

We will prove this hypothesis by the fact that the application of group technology, i.e. of the classification system on the production program of the machine tools overhaul production system, can lead to the formation of a finite number of operational groups regardless of the introduction of different types of machine tools in the overhaul process.

GROUP TECHNOLOGY

In order to take advantage of batch production and, in some production systems, of individual production, the idea of group technology appeared in the sixties of the 20th century. Group technology is a concept according to which work objects with similar characteristics are grouped into families (groups). The approach is based on integrating the work objects with similar characteristics, on the basis of a classification system that contains the criteria of categorisation into the groups of work objects with similar technological characteristics. A group of work objects obtained in the mentioned way on a certain work operation is called an *operational group*. It takes place with a certain flow of the production system once or a few times in the observed time period as a function of the type of flow and forms the basis for designing the group flow of the work process. The goal is to facilitate the processes of design - construction, development of technological processes and design of production structures.

Grouping procedures enable visible reduction of technological work, organisation of material flows, easier control of data flows and bases, directing the work of technologists, constructors, planners and flow controllers to the operational group as the basic unit of the system, thus achieving significant output effects.

The basis for setting up of a grouping system is the system of classification, i.e. of the categorisation of the work objects of the program in question into groups, where this term implies a system which sets out the conditions of classification. The classification process basically consists of the division of the basic set into subsets according to certain characteristics and is essentially a decision-making process aimed at shaping the subsets according to the requirements of the technological process.

The implementation of group technology requires the construction of a system of classification of parts, on the basis of which the grouping into families is performed. The classification is performed according to the technological-constructive characteristics of the elements and with the help of the classification system, whereby the necessary information is obtained by linking individual codes or their combinations to the individual parameters of the elements. Which parameters of the elements will be taken into account in the classification and how the classification system will be developed depends on the constructive characteristics of the elements and on the type of technologies by which the elements are formed.

The classification can be performed even a step further by organising the equipment and workplaces in production according to the family of parts. In this case, all the necessary equipment is grouped to produce a certain family of parts, thus achieving a proper line flow. When a family of similar parts is produced in a work unit, some equipment (machine) can be duplicated from one work unit to another and the capacity utilisation can therefore be reduced more than with the alternative or mixed flow. Nevertheless, the overall benefits of group technology are significant, provided that the optimal number of parts can be covered in each work unit.

The practical application of group technology has two basic steps:

≡ identifying and defining the family of parts - *operational groups* and
≡ organisation of production equipment and jobs into appropriate *work units* (cells).

WORK UNITS

Machines (classical or numerically controlled) are grouped in a work unit in accordance with the production process of a group of technologically similar work objects. The internal structure of a work unit (cell) is similar to the division on the basis of the type of processing, which has the flexibility of such a structure, but with a spatial arrangement which best suits the flow of production process materials for a defined product group. Due to that, the production system, consisting of work units, possesses the line efficiency and partially the flexibility of systems structured according to the type of processing. This structure also contributes to the humanisation of work, as it allows the workers an insight into the entire production process, or the end result and purpose of their work. Therefore, the workers can perform a part of the organizational work, and that reflects in the increasing of motivation and achieving of better work results.

Structuring of a system into work units results in the division into smaller subsystems, and that significantly simplifies the material flow system, as well as the production planning and control. Therefore, they are particularly suitable for the application of the group technology concept and production automation.

Work units can be completely independent, implying that they can fully process a group of similar products from start to finish. Then there will be no flow of material among the work units in the system, but it will take place mostly only with the warehouses.

If for a given group of products and production quantities the load of some, especially expensive means of production is small, it is not profitable for economic reasons to provide such capacities, but they should, if possible, be shared with another work unit. Work units that share the means of production with other work units are called partially independent and cause a mutual flow of materials.

The basic characteristics of production in work units are [8]:

≡ shorter transport routes and less material handling than with layouts based on the process,
≡ shorter ordering time,
≡ reduced retention time of individual parts in the process by up to 80% compared to classic workshop production (smaller quantity of unfinished production),
≡ reduced amount of material in intermediate warehouses in relation to the schedule based on the processing process,
≡ better motivation of workers leads to increased productivity,
≡ simplified planning and production control,
≡ preparation time is reduced so that the batch replacement costs are lower (shorter preparatory-ending time).
≡ shorter waiting time of parts to be processed in relation to the production based on the processing process,
≡ reduced amount of scrap,
≡ better utilization of work surfaces leads to reduced investment costs for the building (up to 20%),
≡ more favourable use of equipment than in line production,
≡ relatively high productivity,
≡ large investments.

METHODOLOGY

In this paper, the emphasis is placed on a research in terms of identifying and defining the family of parts - operational groups and the laws of formation of operational groups by introducing different types of machine tools into the overhaul process. For that purpose, the classification system KS-IIS-08 and the automated procedure for shaping production structures - APOPS-08 developed at the Institute for Industrial Systems of the Faculty of Technical Sciences in

Novi Sad have been used to classify the replaced parts in the process of overhauling the following machine tools:

1. Radial drill „RABOMA" 12U-1500,
2. Horizontal drilling and milling machine „TOS" HB-80,
3. Short-run planer „PRVOMAJSKA" KB-500,
4. Universal milling machine „PRVOMAJSKA" UG-1,
5. Milling machine for hobbing „TOS" FO-6,
6. Universal production lathe „POTISJE" PA-30.

The replaced parts of these machine tools also make up the *production program* by the assortment (p_j) and quantities (q_j) of the machine tools overhaul production system.

The analysis of the production program consisting of the replaced parts of the mentioned machine tools will be performed using:

1. Coefficient of operational similarity and
2. Coefficient of representation of operational groups.

Ad. 1) The *coefficient of operational similarity* ($K_{op.sl.}$) is a measure of unification of parts during the overhaul of machine tools according to predetermined characteristics and is given in the following form:

$$K_{op.sl.} = \frac{\text{number of operational groups}}{\text{number of different parts}} \cdot 100[\%]. \quad (1)$$

The size of the coefficient of operational similarity is influenced by predefined characteristics according to which the parts are grouped into certain operational groups. The coefficient of operational similarity directly affects the degree of flow seriality and the choice of the type of material flow in the machine tools overhaul production system by increasing the units of work objects with similar characteristics in the production program.

Ad. 2) The *coefficient of representation of operational groups* (K_{zog}) is a measure of the representation of operational groups of a machine tool in overhaul in relation to the total number of formed operational groups in the machine tools overhaul production system and is given in the following form:

$$K_{zog} = \frac{\text{number of operational groups of a machine tool}}{\text{total number of operational groups}} \cdot 100[\%] \quad (2)$$

RESULTS AND DISCUSSION

In the text that follows, there is a presentation of the results of empirical research in terms of:

1. Analysis of production programs,
2. Analysis of operational similarity and
3. Analysis of the representation of operational groups.

Ad. 1) The production program is given in Table 1 in the form of assortment (p_j) and total quantity (q_j). The table shows a large number of different parts, and thus a large number of individual material flows through the machine tool overhaul production system.

Ad. 2) Coefficients of operational similarity for individual machine tools in overhaul are given in Table 2. Through the coefficients of operational similarity, the table shows how much the number of material flows in the production system will be reduced by forming operational groups in relation to individual flows. That percentage of overhaul of one machine tool ranges from 75% to 85,2%. However, by increasing the number of machine tools that are in the process of overhaul, the number of material flows in the production system decreases by 94,3%.

Table 1. Replaced machine tool parts - Production program

Ord. no.	NAME OF THE MACHINE TOOL	Production program	
		Assortment (p_j) [pcs]	Quantity (q_j) [pcs]
1	Radial drill „RABOMA" 12U-1500	189	615
2	Horizontal drilling and milling machine „TOS" HB-80	125	477
3	Short-run planer „PRVOMAJSKA" KB-500	145	261
4	Universal milling machine „PRVOMAJSKA" UG-1	80	212
5	Milling machine for hobbing „TOS" FO-6	92	121
6	Universal-production lathe „POTISJE" PA-30	109	139

Ad. 3) By applying the classification system KS-IIS-08 and the automated procedure for shaping production structures - APOPS-08 to the parts, i.e. the production program for the mentioned machine tools, a total of 42 operational groups has been formed.

The representation of the operational groups of individual machine tools in the total number of operational groups is given, through the coefficient of representation of operational groups (K_{zog}), in Table 2.

Table 2. Values of coefficients of similarity and coefficients of representation of operational groups

Ord. no.	NAME OF THE MACHINE TOOL	Number op. group	$K_{op.sl.}$ [%]	K_{zog} [%]
1	Radial drill „RABOMA" 12U-1500	28	85,2	66,6
2	Horizontal drilling and milling machine „TOS" HB-80	27	78,4	64,3
3	Short-run planer „PRVOMAJSKA" KB-500	24	83,4	57,1
4	Universal milling machine „PRVOMAJSKA" UG-1	19	76,3	45,2
5	Milling machine for hobbing „TOS" FO-6	23	75	54,8
6	Universal-production lathe „POTISJE" PA-30	33	79,8	52,4

Analysis of the representation of operational groups indicates that the representation of operational groups of individual machine tools in the total number of formed operational groups ranges from 45,2 to 66,6%, which indicates a certain consistency of the formed operational groups.

The increase of newly formed operational groups of individual machine tools in relation to the number of formed operational groups of radial drill „RABOMA" 12U-1500 is shown in Figure 1.

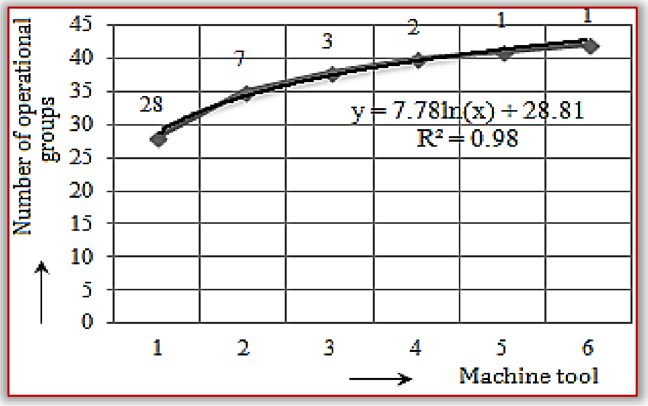

Figure 1. Diagram of growth of operational groups

The representation of parts in newly formed operational groups is:

≡ 12% on the horizontal drilling and milling machine „TOS" HB-80,
≡ 2,8% on the short-run planer „PRVOMAJSKA" KB-500,
≡ 3,8% on the universal milling machine „PRVOMAJSKA" UG-1,
≡ 1,1% on the milling machine for hobbing „TOS" FO-6,
≡ 14,7% on the universal-production lathe „POTISJE" PA-30.

From the diagram in Figure 1, we notice the regularity of the growth of operational groups. This regularity leads to the conclusion that there is no significant increase in operational groups, clearly indicating that the established work units in the machine tools overhaul production system based on group technology will not change regardless of the introduction of different types of machine tools in the overhaul process.

On the basis of the mentioned, it can be concluded that the hypothesis of the subject paper has been proven.

CONCLUSION

The research presented in this paper and the obtained results lead to the following conclusions:

≡ The presented grouping procedure and the applied classification system are an objective basis for:
  ✓ development of a flexible machine tools overhaul production system with an increased degree of efficiency based on work units;
  ✓ defining of the scope and structure of overhaul works for certain types and families of machine tools;
  ✓ constructive unification of parts in the process of deffectation;
  ✓ unification of surfaces of parts, materials and semi-finished products.
≡ The developed grouping procedure and the applied classification system are applicable in real machine tools overhaul production systems with the:
  ✓ definition of the machine tools overhaul corpus,
  ✓ definition of the overhaul for certain types and families of machine tools,
  ✓ definition of production and material norms,
  ✓ introduction of a classification-identification system,
  ✓ introduction of an appropriate information system based on computer data processing,
  ✓ introduction of the necessary technological discipline.
≡ Overhaul of capital equipment, such as machine tools, performed in the presented manner, will provide better efficiency in comparison to the previous method of execution.

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