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IDENTIFYING POSSIBLE SOLUTIONS FOR A POLYFUNCTIONAL MINIMACHINE TOOL BY MEANS OF IDEAS DIAGRAM METHOD

Laurențiu SLĂTINEANU[1], Oana DODUN[2,*], Margareta COTEAȚĂ[3], Gheorghe NAGÎȚ[4], Marius Ionuț RÎPANU[5], Irina BEȘLIU[6]

[1, 2, 4)] Professor, PhD, Department of Machine Manufacturing Technology, "Gheorghe Asachi" Technical University of Iași, Romania
[3, 5)] Lecturer, PhD, Department of Machine Manufacturing Technology, "Gheorghe Asachi" Technical University of Iași, Romania
[6)] Lecturer, PhD, Department of Mechanics and Technologies, "Ștefan cel Mare" University of Suceava, Romania

Abstract: *There are situations when the problem of using various machining processes is formulated and there is not a mechanical workshop in which the necessary machine tools exist. In such a case, a polyfunctional minimachine tool could be appreciated as useful, in order to achieve many distinct machining processes. An analysis of the existing solutions for polyfunctional machine tools and of the researches developed about various constructive solutions of polyfunctional machine tools, respectively, was achieved. The ideas diagram method is one of the methods susceptible to be applied in order to facilitate an increase of the use of the technical creativity. In order to identify improved versions of a polyfunctional minimachine tool, the principles specific to the ideas diagram method were discussed and applied. Thus, some constructive aspects concerning a polyfunctional minimachine tool were defined. If the ideas diagram method facilitates identifying of various versions of the desired solution, it must be applied in association with adequate methods of highlighting all the possible solutions, methods for diminishing the number of solutions to be analyzed in detail and a method able to carry out the most convenient solution. Such considerations were applied in order to find possible solutions for a polyfunctional minimachine tool.*

Key words: *polyfunctional minimachine tool, ideas diagram method, frame, machining units, solution selection*.

1. INTRODUCTION

In accordance with the concept accepted in machine building field, *the machine tool* is a work machine able to be used in order to generate various types of surfaces by a cutting process and meeting certain requests concerning the material removal rate, machining accuracy and surface quality. There is a large variety of machine tools, able to materialize processes of turning, milling, drilling, grinding, lapping, honing etc. If initially these machine tools took into consideration the so-called *classical machining methods*, nowadays there are machine tools for achieving machining processes by means of the so-called *nonconventional machining methods* and there are machine tools able to use processes of electrical discharge machining, electrochemical machining, ultrasonic machining, laser beam machining etc. In order to introduce a difference between the machine tools used in materializing processes of machining by classical machining methods and by nonconventional machining methods, certain specialists prefer to use, in the last case (for nonconventional machining processes) the concept of equipment for machining by a certain nonconventional machining method.

A polyfunctional machine tool could be defined as a machine tool on which various machining processes could be materialized. This could mean that distinct machining processes, like turning, milling, drilling etc. could be achieved on such a machine tool.

One could mention that other concepts are also used when the problem of existence of a machine tool able to materialize various machining processes is approached. Thus, one can meet the use of concept of *multifunctional machine tools* [3, 9, 10, 14, 18], *polyfunctional machine tools* [3, 7], *multi-purpose machine tools* [1], *special machine tools* [12] or *multimachine* [4].

One the other hand, one could formulate the problem of achieving small polyfunctional machine tools; such polyfunctional machine tools could find application fields of real interest. For example, polyfunctional minimachine tools could be used in fine mechanics, in bricolage activities, in small mechanical workshops etc.

Over the years, there were invested real efforts in searching and using polyfunctional machine tools. In Romania, G. Brabie et al. [3] published in 1980 their research results concerning some economical characteristics of achieving the so-called polyfunctional machine-tools. Within a monograph referring to the special machine tools published in 1982, the authors (V. Moraru, B.

[*] Corresponding author: Technical University "Gheorghe Asachi" of Iași, Department of Machine Manufacturing Technology, Blvd. D. Mangeron, 39A, 700050 Iași, Romania
Tel.: +40 747 144 604;
Fax: +40 232 217 290.
E-mail addresses: *slati@tcm.tuiasi.ro* (L. Slătineanu), *oanad@tcm.tuiasi.ro* (O. Dodun), *mcoteata@tcm.tuiasi.ro* (M. Coteață), *nagit@tcm.tuiasi.ro* (G. Nagîț), *ripanumariusionut@gmail.com* (M.I. Rîpanu), *irina.besliu@yahoo.com* (I. Bești).

Plahteanu, S. Velicu, T. Aurite) took into consideration some categories of multifunctional machine tools [12]. The general problem of polyfunctional machine tools was approached by D. Ghelase, in a paper published in 1995 [7].

Ample researches concerning the multifunctional machine tools were developed by teams including researchers from the Mechanical Engineering and Research Institute of Bucharest and from the Department of Machine Manufacturing Systems from Politehnica University of Bucharest. Thus, in papers published by L. Păun, V. Avramescu, R. Grejdanescu, H. Teodorescu, C. Dogariu, S.T. Crăciunoiu, S. Popescu, E. Străjescu, C. Bîșu, N. Predincea etc., there were approached aspects concerning the use of composite materials, problems of achieving computer numerical controlled machining movements, dynamic behaviour or other detail aspects valid in the case of polyfunctional machine tools [9, 13, 14, 15].

The problem of polyfunctional machine tools could be discussed also in connection with the so-called *modular machine tools* or *reconfigurable machine tools*. A modular machine tool could be achieved by taking into consideration distinct modules, which are assembled in accordance with the practical necessities [8]. A reconfigurable machine tool is a machine whose subassemblies could be associated in various ways, also in accordance with the customer requests [6].

The problem of design and use polyfunctional machine tools was also a research object for researchers working in other countries. Thus, Guergov investigated the possibility to generate a 3D simulation model in the case of reconfigurable multifunctional machine tool [10].

In 2008, the Japanese researcher T. Moriwaki published some considerations concerning the design principles, kinematic configurations, control, programming, and assessment of multifunctional machine tools [11].

A problem appeared in the last decades was that of design and use of polyfunctional minimachine tools. Such machine tools could find applications in situations how are the followings: a) In the case of isolated dwellings, when the necessity of modifying or repairing a certain part appears and when the requests concerning the productivity and the machining accuracy are not too high. In such a case, the polyfunctional minimachine tool has to be used by persons which have some knowledge and abilities in the mechanical field, but these knowledge and abilities are not ample; b) In the case of small workshops existing usually within enterprises whose main activity object is not manufacturing of mechanical assemblies, but to a high extent they use various mechanical structures and equipment (for example, textile enterprises, chemical enterprises, wood processing enterprises, food processing enterprises etc.). In such situations, it is possible to appear necessity of repairing or fast manufacturing of simple parts and these parts could be achieved on a polyfunctional minimachine tool. The use of this equipment could need a worker having relatively ample knowledge and abilities in the field of machining processes; c) In a certain connection with the situation presented in the paragraph a) could be the necessity of using a polyfunctional minimachine tool within the bricolage activities. It is expected that in the future, as the people age increase or the people have more free time, the necessity of using polyfunctional minimachine tool increase also; d) Within professional training of the schoolboys or their early familiarization with the manufacturing equipment and processes, a polyfunctional minimachine tool could be also necessary. One must mention that especially in the case of schoolboys and from the ecological point of view, a pedal powered polyfunctional minimachine could present a certain interest, inclusively if the problem of stimulating the schoolboys' technical creativity is formulated; e) In the case of a more complex polyfunctional minimachine tool, eventually equipped with computer numerical controlled subsystems, the familiarizing with the various problems specific to computer numerical control could be approached and exemplified. One may mention that in such a case, essential problems concerning the machining processes must be know and this means that a previous professional training of the future workers or other categories of specialist could be necessary.

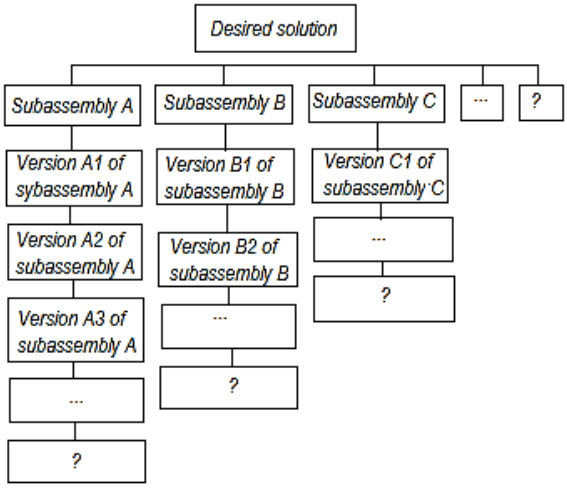

Fig. 1. Ideas diagram.

The above mentioned arguments showed that a single polyfunctional minimachine tool could not satisfy the requests for all situations and, for this reason, a general approaching of distinct destinations of the polyfunctional minimachine tools has to be taken into consideration.

The main objective of the research presented in this paper was to analyze some situations when a polyfunctional minimachine tool could be necessary and to investigate some essential problems concerning the structure of such a machine tool. A useful instrument in defining the structure of the polyfunctional minimachine tool could be the so-called *ideas diagram method*, as this method is used as a method of stimulation of the technical creativity [2, 5, 17].

2. PREMISES FOR USING THE IDEAS DIAGRAM METHOD IN IDENTIFYING A SOLUTION FOR A POLYFUNCTIONAL MINIMACHINE TOOL

The technical creativity could be defined as a human capacity to find new or improved solutions for solving technical problems.

There is a high number of factors able to exert influence on the technical creativity; some of these factors are specific to human being, while other factors are largely

connected with the human society, who could decisively influence the manifestation of the creativity in general or of the technical creativity, in particular.

Knowing the importance of the technical creativity, there was normal that researchers search and find methods and instruments able to increase or to stimulate the use of the technical creativity.

There are many possibilities to classify the methods which aim to contribute to the stimulation of the technical creativity. If the role of the intuition within the process of searching and identifying new or improved solutions for a technical problem is taken into consideration, it may notice two essential groups:

a) *Intuitive methods*, when the intuition is appreciated as the essential factor and the methods included in this group must offer possibilities of full manifestation of intuition. This group could be divided in *methods based on the changing the position of problem examination* (trial and error method, advocate's method, method of uninitiated persons, input-output method, method of provoked dream, teratology scenario method, method of intersecting the real with the imaginary etc.), methods aiming *the revelation of correlations between the proposed objectives and words or images logically al randomly selected* (association method, method of inventory of attributes, method of using the catalogue, method of forced crossbreeding, method of using words randomly selected – method of using the Kent-Rozanoff list, method of puns, method of random couples, method of focal objects, method of projection etc.), *methods supposing the application of quantitative of qualitative changes* (combination, division, modifying by replacing, shape change, change by re-dimensioning, modifying by removing, modifying by re-arranging, Osborn's interrogative lists etc.), and *complex intuitive methods*, based on the use of many simpler methods from the ones above mentioned (method of lateral thinking, method of associations chains, brainstorming, synectics, Philips 66 method, Delphi method, Frisco method etc.);

b) *Systematic* or *logical or algorithmic methods*, when by applying usually rigorously established stages, it is expected to obtain the desired new or improved technical solutions. Methods like morphological matrixes method, method of generalized object of the technical creativity, TRIZ method or Altshuller's algorithm, axiomatic design method, method of heuristic approaches, general heuristic method, general algorithm of inventing etc. could be included in the larger group of systematic methods aiming the stimulation of technical creativity.

The researchers appreciate that sometimes there is not possible a strict differentiation between intuitive methods and logical methods, since usually it is difficult to completely neglect the role of the intuition or of the logic approach within a certain method.

As above mentioned, at least in some of its stages, the ideas diagram method has a more logical character, being based on a systematic/logical analysis of the existing technical solutions.

Essentially, when the ideas diagram method has to be applied, a certain graphical representation is elaborated, but this graphical representation is firstly the result of analysis of one or more existing solutions, able to highlight the main components necessary when the problem of the creativity stimulation is formulated. Subsequently, along a horizontal line (Fig. 1), the main distinct subassemblies of a possible solution are showed. It may be specified that not only the main subassemblies of the possible solution could be taken into consideration along this horizontal line, but also every possibility to classify or differentiate distinct versions of the solution. Thus, one could consider the positions of the distinct subassemblies (up, down, on the right or on the left side, in front or in back etc.), various materials, distinct colours etc. Under each subassembly *Ai*, distinct versions *Aij* of the subassembly could be considered; these versions could be the results of an attentive examination of the ways in which the subassembly could be materialized.

Usually, the simple use of the ideas diagram is not enough to finally establish a new or improved technical solution and other stages or even methods must be approached. Thus, he possible next stage necessary to be approached after the elaboration of ideas diagram could refer to establishing the combinations obtained by taking into consideration a single version of each subassembly. If the numbers of versions corresponding to each subassembly are high, the necessity of analyzing a high number of combinations could appear. Thus, for example, if there are n_A versions for the subassembly *A*, n_B versions for the subassembly *B* and so one, the total number N_t of combinations susceptible to be examined is given by the product of versions numbers corresponding to each subassembly:

$$N_t = n_A \cdot n_B \cdot n_C \cdot ... \quad (1)$$

In this way, it is possible to reach very high values for the number N_t and in order to arrive to a reasonable number of solutions that has to be examined in detail various methods of diminishing this number could be applied. Finally, a more detailed method of analysis could be used in order to detach the most convenient solution/solutions able to meet the proposed objectives for the desired solution.

The application of the ideas diagram method and of the subsequent stages could need a high time consumption and, in order to faster identify a useful solution, some simplifications of the above mentioned succession of stages could be applied.

2. USE OF IDEAS DIAGRAM METHOD FOR IDENTIFYING DISTINCT SOLUTIONS FOR A POLYFUNCTIONAL MINIMACHINE TOOL

Taking into consideration the problem of identifying a convenient solution for a polyfunctional minimachine tool in the conditions specified in the first section of this paper, one considered that at least some useful suggestions could be obtained by using the ideas diagram method in analyzing and developing a principle structure for the polyfunctional minimachine tool.

One noticed that a first analysis offered a large variety of points of view concerning the subassemblies susceptible to be considered or the criteria able to generate distinct versions of polyfunctional minimachine tools

In this way, a version of the graphical representation corresponding to the use of ideas diagram method was gradually elaborated (Fig. 2).

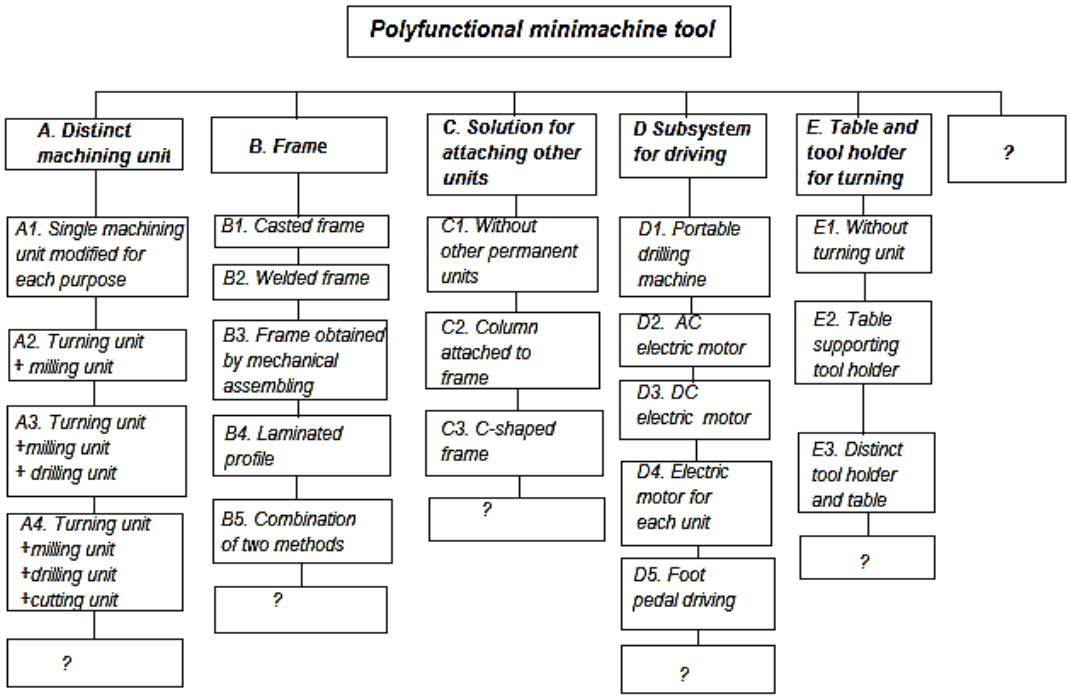

Fig. 2. Ideas diagram proposed in the case of a polyfunctional minimachine tool.

As a first subassembly or rather a first point of view of analysis, one could take into consideration the distinct machining units which could be incorporated in the desired polyfunctional minimachine tool. One could find thus the following versions: 1) There is the possibility to use a single unit for adequate answering each of the possible necessities of machining; for example, the same unit has to be adaptable for materializing processes of turning or milling or drilling etc.; 2) A second version could take into consideration two machining units, one for turning and the second for milling; one considered, in this case, that a distinct drilling unit is not strictly necessary, since there are portable drilling minimachines, which could be easily found and used when the problems of drilling could appear; 3) By developing the above mentioned considerations, another polyfunctional minimachine tool could include three distinct machining units, able to materialize, for example, processes of turning, milling, drilling or, extending this aspect, four machining units, when a supplementary unit for cutting or grinding etc. could be taken into consideration.

Another subassembly of the polyfunctional minimachine tool that could be analyzed in order to highlight distinct versions of final solution is the principle version of the machine tool bed. A succinct analysis highlighted the following principle versions of the bed corresponding to the polyfunctional minimachine tool: a) Casted bed, the casting facilitating the direct obtaining of bed complex shapes, but needing the insurance of a possibility of obtaining casting parts; b) Bed obtained by welding parts obtained previously by more accessible machining methods; c) Bed obtained by mechanical assembling of parts previously obtained by other machining methods; d) A laminated profile could be used, if such a profile could be identified so that the requests specific to the polyfunctional minimachine tool are met; e) Another solution could be a combination of the versions above mentioned; in fact, various combinations could be now considered (using machined parts, casted parts, welded subassemblies, subassemblies obtained by mechanical assembling etc.).

If the way in which other units could be added to the polyfunctional machine tool is analyzed, some of the possible solutions could be: a) Without a proper solution for attaching other machining units; this means that all the machining units will be attached in the same place; b) A column could be attached to the polyfunctional minimachine tool bed, in order to be used when milling or drilling or cutting units has to be attached; c) A C-shaped frame could facilitate the simultaneous existing of various machining units, which could be used successively.

An important problem concerning the solution of a polyfunctional minimachine tool could be the driving subsystem. One could take into consideration: a) A portable drilling machine, which could be moved ant attached to the machining unit when there is the necessity to materialize a certain machining process; b) A unique alternative current electric motor could be an accessible solution, but problem of changing the number of revolution per minute of the main shaft could appear; c) A unique direct current electric motor could facilitate the change of the main shaft rotation speed, but a rectifier-transformer subsystem is necessary; d) A solution in which a foot pedal driving subsystem could be also acceptable in certain situations, especially from the ecological point of view, but other problems concerning the machining conditions have to be solved in such a case.

If a turning unit must be included in the polyfunctional minimachine tool, the problem of separation between the tool holder and machine tool table could be analyzed: a) Thus, the first case could be that when a turning units is not included and the problem of separa-

tion between tool holder and minimachine tool table practically could not be considered; b) A version could take into consideration the use of a unique minimachine tool table, on which the tool holder could be placed; c) A more complex version could use distinct subassemblies corresponding to the tool holder and minimachine tool table.

As above mentioned, aiming only to illustrate the possibilities of generating an ideas diagram, few subsystems of the desired polyfunctional minimachine tool were taken into consideration (Fig. 2). If a more complex approaching analysis has to be developed, other subassemblies or criteria of obtaining distinct versions of the polyfunctional minimachine tool could be used (for example, the presence and the position of the lead screw, the possibility of using constructive modular solutions etc.). Once the ideas diagram elaborated, one could estimate the total number of possible versions for the polyfunctional minimachine tool. Taking into consideration only the 4 versions for the subassembly *A*, 5 versions for the subassembly *B*, 3 versions for the subassembly *C*, 5 versions for the subassembly *D* and 3 versions for the subassembly *E*, the total number of possible solutions of polyfunctional machine tool could be:

$$N_t = 4 \cdot 5 \cdot 3 \cdot 5 \cdot 3 = 900 \text{ versions.} \quad (2)$$

It is clear that a detailed analysis of 900 versions of the polyfunctional minimachine tool is not possible and some methods could be used in order to obtain a decrease of the solutions which has to be analyzed in detail. Such methods could be the method of global evaluation, sequential selective method, method of dividing in submorphologies, method of simple randomizing, method of weighted randomizing, selecting by random feed, selection by taking into consideration the similarities etc. [2, 17].

In order to facilitate a succinct analysis of the identified versions, each version will be symbolized by using a code including the version for each considered subassembly. For example, the code *A*2*B*3*C*2*D*1*E*2 could correspond to a polyfunctional minimachine tool (Fig. 3) that includes only units for turning and milling (*A*2), a frame obtained by mechanical assembling (*B*3), a column attached to the frame (*C*2), portable drilling machine used in order to drive each machining unite (*D*1) and a table able to support the tool holder (*E*2).

Another version of polyfunctional minimachine tool, which could be driven by means of a foot pedal, is presented in Fig. 4. The code attached to this version is *A*2*B*3*C*2*D*5*E*2, in which *D*5 corresponds to pedal foot driving.

One has to mention that when using the pedal foot driving the question if a simple turning process with a low intensity of the cutting process could be achieved by means of such a way of driving. In order to verify the power necessary to materialize a turning process characterized by a depth of cut a_p = 1 mm, cutting feed f=0.1 mm/rev and a cutting speed v = 30 m/min, the following relation [16] could be used:

$$N = \frac{C_4 a_p^{x_1} f^{y_1} HB^{n_1} v}{60000}, \quad (3)$$

where F_z is the main component of cutting force, v is the cutting speed, HB – the hardness of workpiece material C_4 – a constant supposed as having the value C_4 = 279 in case of using a normal turning tool and the hardness of the workpiece material being HB = 170 and x_1, y_1, n_1 – exponents experimentally determined.

By using the equation (3), and taking into consideration the values x_1 = 1, y_1 = 0.75, n_1 = 0.35, one could obtain N = 0.249 kW and one considered that such a power could be obtained by means of foot pedal driving.

Before the succinct analysis of the versions appeared as a consequence of using the ideas diagram method, a solution to highlight all the possible versions could be taken into consideration. Thus, on could consider the lexicographic method or the matrix method etc.

When analyzing the identified possible versions of the polyfunctional minimachine tool, the following situations could be met:

- *impossible solutions*, when these proposed solutions could not exist, due to flagrant violation of physical or general scientific principles of functioning;
- *known solutions*, when practically there are solutions used just in the initial stages of applying the ideas diagram method. It is clear that these solutions will not be taken into consideration if improved solutions have to be identified;
- *solutions which present lower characteristics* when they are compared with the known solutions. These solutions will be also eliminated in developing the subsequent analysis;
- *interesting solutions*, this meaning that some interesting aspects, from various points of view could exist and only these solutions will be later analyzed in detail.

When by applying a method of diminishing the total

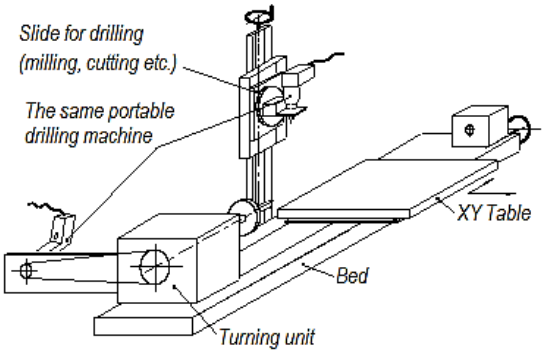

Fig. 3. Version of polyfunctional minimachine tool.

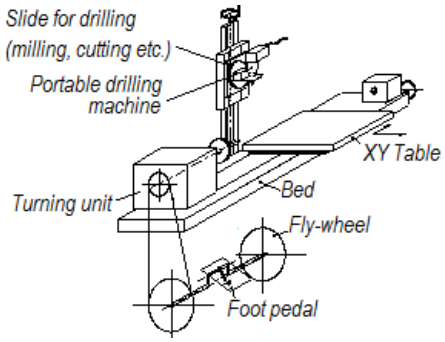

Fig. 4. Version of polyfunctional minimachine tool acted by foot pedal.

number of possible solution only a reasonable number of solutions were considered as presenting interest, another method (for example, the method of value analysis) could be applied in order to select the most convenient solution or solutions.

Professor Belous recommended [2] that the elimination of the impossible solutions or of inferior solutions has to be very attentively made, in order not to neglect aspects of real interest and where the technical creativity could be efficiently used.

5. CONCLUSIONS

The problem of design and using a polyfunctional minimachine tool preoccupied the specialists and researchers, since there are situations when such a machine too could be necessary. The literature review highlighted the existence of researches in such a direction just in the first half of the previous century. At present, there are situations when a polyfunctional minimachine tool could be the solution able to solve the problem of manufacturing or repairing not very complex parts.

In order to define the principle scheme and the structure of such a machining equipment, various methods able to contribute to a more efficient use of technical creativity could be used and the method of ideas diagram is one of them. Some principles of applying the ideas diagram methods were taken into consideration and an application was developed in the case of a polyfunctional minimachine tool. As a first stage in applying the ideas diagram method, some main components of the polyfunctional minimachine tool were considered and versions for these components were identified. By combining various versions of the polyfunctional minimachine tool components, a high number of solutions could exist, but using adequate selection criteria, some more convenient versions of polyfunctional minimachine tools could be established. In future, there is the intention to develop the elements specific to the machine tool design and manufacture such a polyfunctional minimachine tool.

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