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THE IDEAS DIAGRAM IN CREATIVE DESIGN

Laurenţiu Slătineanu.
slati@tcm.tuiasi.ro
Department of Machine Manufacturing Technology,
Faculty of Machine Manufacturing and Industrial Management,
The University "Gh. Asachi" of Iaşi
Iaşi, 700050, Romania

Margareta Coteaţă.
mcoteata@tcm.tuiasi.ro
Department of Machine Manufacturing Technology,
Faculty of Machine Manufacturing and Industrial Management,
The University "Gh. Asachi" of Iaşi
Iaşi, 700050, Romania

Oana Dodun.
oanad@tcm.tuiasi.ro
Department of Machine Manufacturing Technology,
Faculty of Machine Manufacturing and Industrial Management,
The University "Gh. Asachi" of Iaşi
Iaşi, 700050, Romania

Alexei Toca.
a_toca@mail.utm.md
Department of Machine Manufacturing Technology,
Faculty of Engineering and Management
in Machine Manufacturing,
The Technical University of Moldavia
Chişinău, Republic of Moldova

ABSTRACT

The activity of a designer engineer could sometimes involve the necessity to come with a certain solution in a short time; in such a situation, the engineer will not allocate much time to the design activity and will use the routine design instead; this means that he will use the solutions he already knows. However if there is enough time for the design activity, the engineer will use the creative design, trying to find new solutions to solve the design problem.

In the theory of management, there is a principle, according to which if in an important issue only one solution seems to exist, there is a high probability that this is not the best solution. Thus, to find a better solution, the designer first has to find many solutions for the problem to be solved; in the second stage, he must select the best solution by applying adequate selection criteria. In finding many solutions to solve the problem, the designer can apply the ideas diagram. This diagram could be considered as an application of the hierarchic principle from the axiomatic design on the first level.

Practically, the ideas diagram needs to decompose a known solution in its components; in a second stage, different variants could be searched for each variant. Afterwards, by the combination of all the variants for each component, known or new/improved solutions could be emphasized. Usually, the number of these solutions can be too high and distinct methods are applied to lower the number of the variants proposed to be analysed in detail.

Keywords: axiomatic design, creative design, ideas diagram commas.

1 INTRODUCTION

One knows that the activity of the designer engineer involves the materializing of some common stages. Sometimes, the designer engineer must design certain equipment in a short time; in such a situation, he must rapidly analyse the similar equipments already known and, step by step, he will select the adequate components, so as to fulfil his task. Such a design method is known as *a routine design* and usually it does not significantly include creative elements.

If there is enough time to solve the design task, the designer should try to find new or at least improved solutions for the equipment to be designed; this means that the designer will use *the creative design.*

On the other hand, within the theory of management, there is the principle which emphasizes that when for an important problem, only one solution seems to exist, there is a high probability that this is not the best solution [Ghinea, 1973].

The direct conclusion is that to find a better solution, the designer has first to find many solutions for the problem to be solved; in the second stage, he must select the best solution by applying adequate selection criteria.

There are different ways to find many solutions to solve a certain design problem. One of these solutions is the so-called *diagram of ideas.* This diagram could be considered as an application of the hierarchic principle from the axiomatic design on the first level.

The new computing and communication tools exerted a strong influence on the design activity; more and more, the design is studied in connection with the product life cycle [Tseng *et al.*, 2003].

It is a well-known fact that *the axiomatic design* was initiated and promoted in 1977 by the professor Nam P. Suh from MIT (Massachusetts Institute of Technology) [Suh, 1990 and 2005]; so far, the axiomatic design has been studied by many researchers and applied in different fields of engineering design.

Along the time, the axiomatic design has been compared to *the algorithmic design* [Drăghici and Banciu, 2007], to *the theory of inventive problem solving - TRIZ* [Yang and Zhang, 2000], to *the Robust Design – Taguchi* [Gould, 2000].

The axiomatic design is based on the acceptance of 2 axioms and 3 concepts; one of these concepts is the so called *hierarchic concept.* According to this concept, the design process develops from the highest level of abstractization to the level which provides multiple details. A graphical representation (a diagram) is used to emphasize different hierarchic abstractization levels; of course, the axiomatic design involves the zigzagging between the functional requirements in functional domain and design parameters in physical domain [Drăghici and Banciu, 2007, Yang and Zhang, 2000].

2 ANALYSIS

2.1 DEFINITION OF THE IDEAS DIAGRAM

One of the methods able to offer many variants of equipment is *the method of the morphological matrices*. For the simplest case, when the equipment to be designed includes only two components, the method of morphological matrices implies the elaboration of a table in which, in the first vertical column, from bottom to top, different variants for the first component are specified and, on the last line, from left to right, the different variants for the second component are included. In such a case, the rest of the table spaces shall represent all the different combinations of the two components under consideration. Of course, some of these combinations should be original and/or superior to the known combinations and these new combinations could present a special interest to the creative designer [Belous, 1992].

If the considered equipment includes not only two components, but many such components, the method of morphological matrices has to use spatial representations or in case of more than 3 components, adequate ways to represent spaces with more than 3 dimensions.

But the method of morphological matrices seems to suggest a closed system, which is not able to consider the possibility that one or many new variants for the components should be identified after the moment when the classical morphological matrix was built. One can also appreciate that the method of the morphological matrix does not allow the direct intuition of the possible solutions. Within the first stage, only some alphanumerical symbols are included in the table spaces and this activity is highly abstract.

To diminish these inconvenient aspects, the so called *diagram of ideas* should be used. Of course, there are different variants of ideas diagram [Belous, 1992, Slătineanu and Duşa, 2002].

In the case analyzed in this paper, in principle, the ideas diagram is a graphical representation in which different components of the equipment are emphasized by means of some rectangles placed along a horizontal line. Under each such component, along a vertical line, different variants of the equipment components are emphasized also by the use of rectangles. If a component of the equipment is symbolized by the letter A, different variants of the component A receive the symbols A1, A2, A3 etc.

For components of the equipment to be designed, different proper structural subassemblies could be taken into consideration, but this condition is not restrictive. Thus, for example, the position of the subassembly (at the top, at the bottom, on the right side, on the left side etc.), the color, the dimensions, the shapes etc. could be also considered.

At the bottom end of each column of rectangles, rectangles including only the question mark should be placed, so as to suggest that a new variant could exist, but this variant is not known when the ideas diagram is elaborated. Such a rectangle including only the question mark could also be placed along the horizontal line in which different components (A, B, C etc.) of the equipment are mentioned, to suggest that other components could also exist, but these components are not known when the ideas diagram is elaborated. There is the opinion that the ideas diagram is more useful when in the rectangle destined to present a certain variant of a component, a simple draft of this variant is included [Belous, 1992]; in such a way, the combination of the variants to identify new and improved equipment solutions seems to be facilitated.

2.2 ELABORATING THE IDEAS DIAGRAM

To exemplify the way to build the ideas diagram, one can consider the case of designing a device for the study of the effects exerted by the abrasive granules on the surface layer of a proof sample (fig. 1). Basically, such a device has to include the pistol for sandblast cleaning and the proof sample. To emphasize the different conditions able to modify the impact effect of the abrasive granules on the proof sample material, it is necessary to modify the distance l between the pistol nose and the proof sample surface and also to modify the angle α of the direction along which the abrasive granules are directed to the proof sample. Of course, the equipment (the device) to be designed must take into consideration this initial design information.

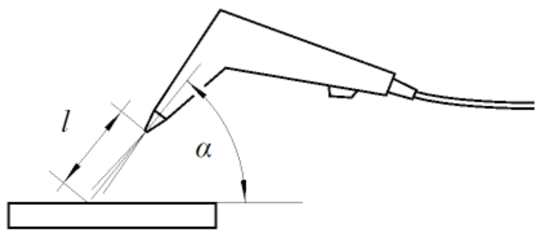

Figure 1. Initial conditions to design a device for the study of impact of abrasive particles with the proof sample surface.

Figure 2 shows the ideas diagram elaborated so as to find different variants of the equipment to be designed. As components of the device, the following components were considered: the subassembly for the changing of the distance *l* between the nose and the proof sample surface, the subassembly for the changing of the size of the angle *a* between the direction of the abrasive granules and the proof sample surface, the shape of the base piece used as support of the components, the priority of the first piece placed on the support piece (the subassembly for the modifying of the distance *l* or the subassembly for modifying the angle *a*). Of course, the other subassemblies could also be considered, but they were not used for the elaboration of the ideas diagram presented in figure 2, so as to avoid a too complicate graphical representation.

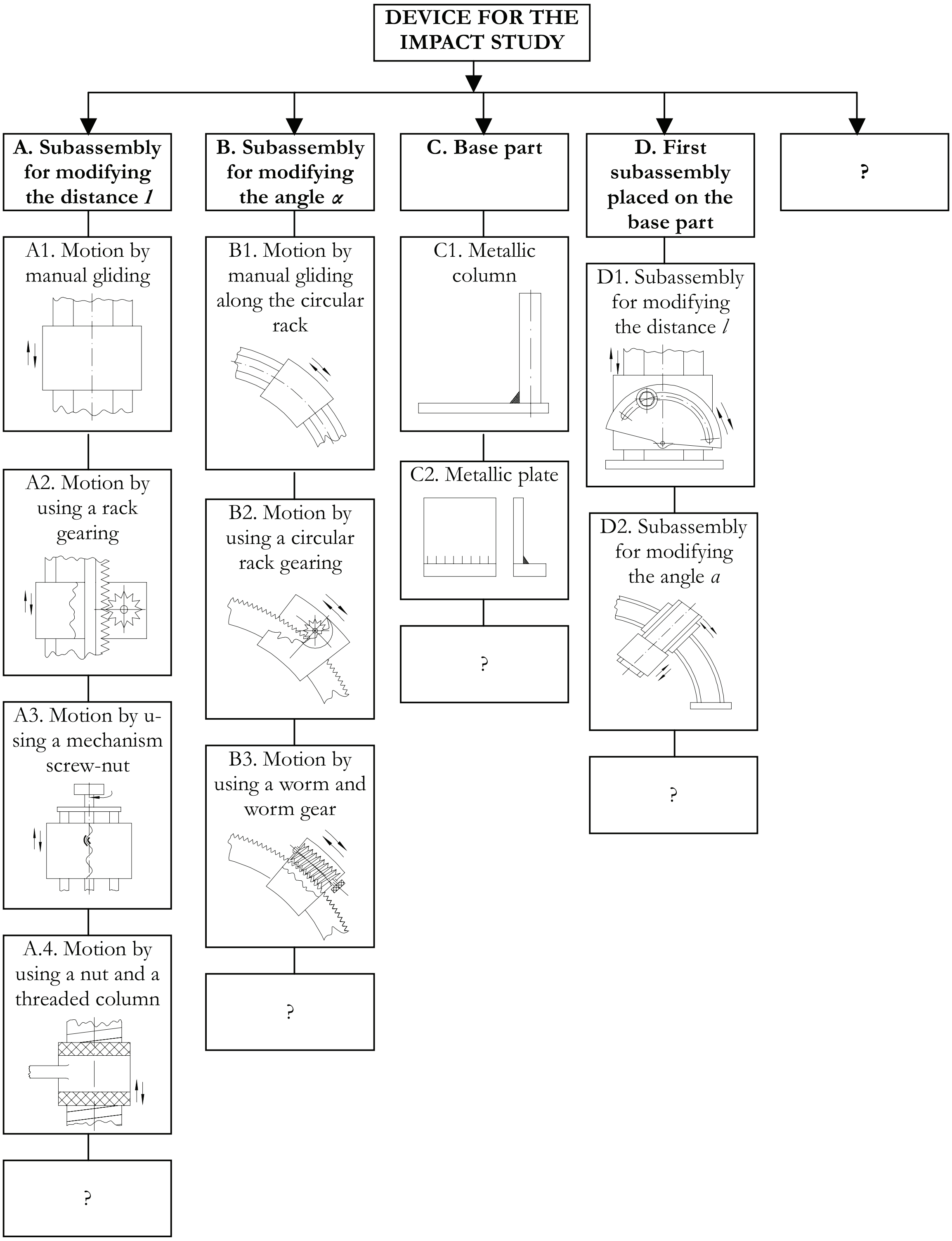

Figure 2. Ideas diagram elaborated in the case of the equipment for the experimental study of the impact effect of the abrasive granules with the surface of the proof sample.

2.3 EMPHASIZING THE POSSIBILE SOLUTIONS

The ideas diagram is one of the first stages used in the field of the creative design. After identifying different variants for each component of the equipment to be designed, the combinations of these components are to be analyzed. Different combinations can be emphasized by means of the alphanumerical symbols of the components. For example, A2B1C2D2 could be the symbol of the equipment for the impact study which includes a mechanism for the modification of the distance *l* by means of a rack gearing, a mechanism for modifying the angle *a*, based on the manual gliding along the circular rack, a metallic plate as base part and in which the first subassembly placed on the base part is the subassembly for modifying the angle *a*.

All the variants of the equipment for the impact study could be placed along a vertical column or they could be emphasized by using *a matrix* or the so-called *ordinate enumerating method*.

2.4 DIMINISHING THE NUMBER OF THE SOLUTIONS TO BE ANALYSED IN DETAIL

Sometimes, the number of the combinations could be very high; in such a case it could take someone a great amount of time to examine all the variants and, for this reason, methods to restraint the number of variants to be analyzed in detail could be used.

In the case of the device for the impact study, the number of the variants can be determined as the product of the numbers of variants for each subassembly:

$$N_v = 4 \cdot 3 \cdot 2 \cdot 2 = 48 \qquad (1)$$

It is difficult to analyze in detail all the 48 solutions possible from a theoretical point of view. One can try to diminish the number of the solutions to be analyzed in detail.

Thus, one can notice that the use of the plate as support piece (the variant C2) could be considered an expensive solution; this variant could not be taken into account. Therefore, in table 1, all the combinations including the symbol C2 were strikethrough.

Table 1. Solutions for the equipment for the study of the impact phenomenon.

Alphanumerical symbolized variants		
A1B1C1D1	A1B2C1D1	*A1B3C1D1*
A1B1C1D2	A1B2C1D2	*A1B3C1D2*
~~A1B1C2D1~~	~~A1B2C2D1~~	~~A1B3C2D1~~
~~A1B1C2D2~~	~~A1B2C2D2~~	~~A1B3C2D2~~
A2B1C1D1	A2B2C1D1	*A2B3C1D1*
A2B1C1D2	A2B2C1D2	*A2B3C1D2*
~~A2B1C2D1~~	~~A2B2C2D1~~	~~A2B3C2D1~~
~~A2B1C2D2~~	~~A2B2C2D2~~	~~A2B3C2D2~~
A3B1C1D1	A3B2C1D1	*A3B3C1D1*
A3B1C1D2	A3B2C1D2	*A3B3C1D2*
~~A3B1C2D1~~	~~A3B2C2D1~~	~~A3B3C2D1~~
~~A3B1C2D2~~	~~A3B2C2D2~~	~~A3B3C2D2~~
A4B1C1D1	**A4B2C1D1**	**A4B3C1D1**
~~A4B1C1D2~~	~~A4B2C1D2~~	~~A4B3C1D2~~
~~A4B1C2D1~~	~~A4B2C2D1~~	~~A4B3C2D1~~
~~A4B1C2D2~~	~~A4B2C2D2~~	~~A4B3C2D2~~

One can also notice that the use of the variant A4. (Motion by using a nut and a threaded column) is in contradiction with variant 2 of the subassembly D (D2. Subassembly for modifying the angle *a*); if a threaded column is preferred to modify the distance *l* between the nose and the proof sample surface, there is no possibility to place on the first position the subassembly for changing the angle *a* on the support part). This means that all the variants which contain the symbols A4 and D2 must also be eliminated; these variants were double strikethrough in table 1.

From the manufacturing point of view, the worm and the wheel are not generally easy to be performed; for this reason, one can remove the solutions including the worm and worm gear (the variant B3). The variants left from the previous selection and containing the symbol B3 were emphasized in table 1 by Italics.

On the other hand, some difficulties of manual operation when using the variant A4 can determine, at least initially, to disconsider this variant. This means that the combinations containing the symbol A4 could not be taken into consideration; these combinations were emphasized in table 1 in bold.

By the removal of the above mentioned combinations, one can notice that only 8 combinations remain (A1B1C1D1, A1B2C1D1, A1B1C1D2, A1B2C1D2, A3B1C1D1, A3B2C1D1, A3B1C1D2, and A3B2C1D2).

Each variant (combination of all the components) is afterwards examined and different symbols can be used to grade them (*known* solution, *inferior* solution, *impossible* combination, *interesting* combination etc.). The concept of "interesting combination" could be used to emphasize those combinations which seem to present some advantages in comparison with the variants known up to the moment when the creative design is used.

In this way, the number of the variants to be analyzed in detail could be, for example, of 5-10. Only for these variants could one apply a method to find the best solution. For example, with this aim in view, *the methods of the value analysis* can be used.

Other interesting method for diminishing the number of the combinations resulted by the use of the ideas diagram is *the sequential selective method* [Belous, 1992, Slătineanu and Dușa, 2002].

In accordance with this method, initially only the combinations of the first two components (A and B, for example) are analyzed and evaluated.

From these combinations (type AiBj), only the combinations which seem to be interesting will be extracted and used in the next stage.

For example, one can suppose that only the solutions A1B3, A2B1 and A3B1 present certain advantages. In the next stage, the variants of the component C will be added to the three combinations selected before (A1B3, A2B1and A3B1). From these new combinations (containing three components (A, B and C), only those combinations characterized by interesting aspects are selected and used in the next stage. This work modality is repeated until all the components of the equipment to be designed are considered.

But not only the sequential selective method can be used o diminish the number of the combinations to be analyzed in detail. Other such methods which can be used to reach the same objective (diminishing the number of the variants to be in detail analyzed) are *the method of dividing in sub-morphologies, the simple randomization, the selection by weighted randomization, the selection by random feed, the selection by similitude* etc.

Diminishing the number of the equipment variants resulted as consequence of the application of the method of the ideas diagram is not usually a simple problem, since certain solutions which may seem to be unacceptable, can afterwards prove validity and even superiority in comparison

Table 2. Comparison of the combinations remained after the removal of the solutions which seem to be not convenient.

	A1B1C1D1	A1B2C1D1	A1B1C1D2	A1B2C1D2	A3B1C1D1	A3B2C1D1	A3B1C1D2	A3B2C1D2
A1B1C1D1	X	0	0	0	1	0	1	1
A1B2C1D1	1	X	1	0	1	1	1	1
A1B1C1D2	1	0	X	0	1	1	1	1
A1B2C1D2	1	1	1	X	1	1	1	1
A3B1C1D1	0	0	0	0	X	1	0	1
A3B2C1D1	1	0	0	0	0	X	0	1
A3B1C1D2	0	0	0	0	1	1	X	1
A3B2C1D2	0	0	0	0	0	0	1	X
Sum of marks	3	1	2	0	5	5	5	7

with the solutions (combinations) left after the first analysis. Such situations emphasize the necessity to thoroughly examine the solutions proposed to be eliminated, so as not to exclude the variants which can "hide" useful/interesting characteristics.

2.5 SELECTION OF THE MOST CONVENIENT VARIANTS FOR THE EQUIPMENT TO BE DESIGNED

If a reasonable number of variants to be analyzed in detail are established, one can find and use a method to select the most convenient variant for the equipment to be designed, from the available variants.

With this aim in view, some distinct methods could be used (for example*, the Electre method*, different *methods of value analysis* etc.).

For the considered equipment to be designed (device for the study of the impact effect of the abrasive granules on the proof sample material), a simplified method of value analysis was applied; this method is named *the method of the matrix with double entries*.

The method needs to use a table in which on the first column and the first line, the previously selected variants (this means those variants resulted as consequence of the application of a method for diminishing the number of the solutions elaborated on the basis of the ideas diagram) are considered (table 2).

In each of the other spaces of the table, a grade (an appreciation) resulted from the comparison of the solution corresponding to a certain column with the solution corresponding to a certain horizontal line is included. For example, if the solution corresponding to the third column is appreciated as more convenient than the solution corresponding to the fourth horizontal line, in the space of the intersection of the third column with the fourth horizontal line, the grade 1 is placed. If the situation is reverse (the solution corresponding to the third column is considered as less convenient than the solution corresponding to the fourth horizontal line), this means that the grade placed in the above mentioned space must be 0 (zero). If the two analyzed solutions are considered equivalent or approximately equivalent, the mark 0.5 could be used.

In an additional horizontal line placed at the bottom of the table, a grade resulted as the sum of the grades included in the same column, consequently valid for a certain solution of the equipment to be designed, can be inscribed.

Analyzing these grades from the last horizontal line of the table, one can conclude which the most convenient solution is or which the most convenient solutions for the equipment to be designed are.

In the case of the device for the study of the impact effect of the abrasive granules on the proof sample material, such convenient solutions seem to be A3B2C1D2, A3B1C1D2, A3B2C1D and A3B1C1D1.

At this moment, the designer engineer has a more adequate image concerning the equipment to be designed; this means that the designer can elaborate one or more drafts for the equipment under consideration.

Two examples of such drafts are presented in figures 3 and 4. Of course, afterwards one needs to observe the other stages specific to the design of a mechanical equipment (selection of the materials which will be used for each component of the equipment, preliminary design, verifying or establishing the dimensions and/or the shape of each machine element by taking into consideration the service conditions etc. [Norton, 1996]).

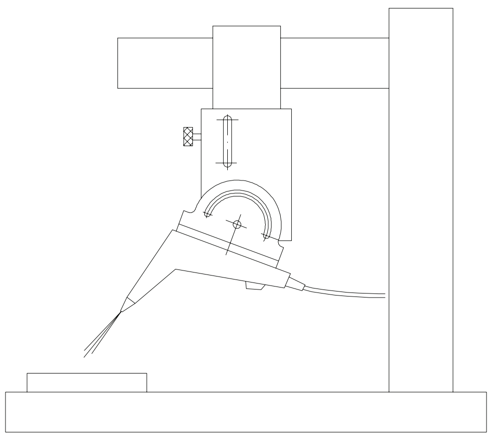

Figure 3. Device for the study of the impact effect at which the subassembly for the modifying the distance *l* is placed on the base part.

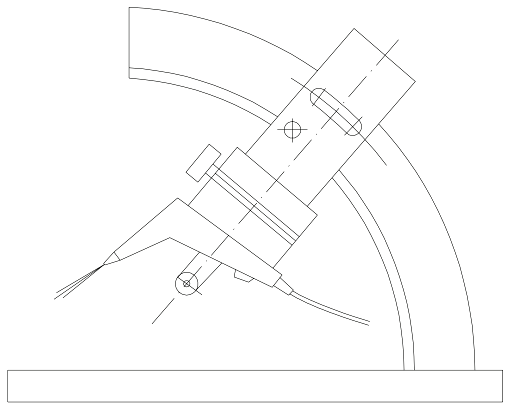

Figure 4. Device for the study of the impact effect at which the subassembly for the modifying the angle α is placed on the base part.

3 CONCLUSION

In a certain stage, the axiomatic design needs to use diagrams to reveal the hierarchy of the different requirements belonging to the functional or physical domains, for example. But such hierarchical diagrams could also be used to emphasize the components of the equipment to be designed and the variants of these components; thus, the so-called ideas diagram can be elaborated.

Such an ideas diagram was designed for the case of the equipment destined to allow the study of the impact effect of the abrasive granules directed to the proof sample material.

By the combination of the variants corresponding to each of the equipment components, many distinct equipment variants can also be generated, but not all these variants of the equipment to be designed are functional or convenient from different points of view. In order to diminish the number of the variants to be analysed in detail, there are different methods; in the case of the equipment considered, some combinations which seemed to be inconvenient were eliminated.

A further selection of the variants selected in this way can be made by using the optimization methods. The method of the matrix with double entries was applied in the case of the equipment under consideration.

Two variants resulted as a consequence of the application of the succession of design stages starting with the use of the ideas diagram, were taken into consideration and two drafts corresponding to these variants were elaborated.

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5 REFERENCES

[1] Belous V., *Inventics* (in Romanian), Iaşi: Editura Asachi, 1992.

[2] Drăghici G., Banciu F., "Parallelism between Algorithmic (Systematic) Design and Axiomatic Design", *Annals of the Oradea University. Fascicle of Management and Technological Engineering*, Vol. VI (XVI), pp. 1457-1468, 2007.

[3] Ghinea M., Optimization of the decisions making process (in Romanian), *Buletin de informare tehnico-economică*, No. 2, 1973.

[4] Gould L. S. Building Better Vehicles via Axiomatic Design. June, 2000. Available at: *http://www.autofieldguide.com/articles/060001.html.* Accessed: 20.11.2008

[5] * * * Ideas Diagram Software. 2005. Available at: *http://webcampus.drexelmed.edu/pil/SMART_Ideas_Software_Version_5_User's_Guide.pdf.* Accessed: 1 November 2008.

[6] Norton R.L., *Machine Design. An Integrated Approach*, Upper Saddle River: Prentice-Hall, 1996. ISBN 0-13-555475-6.

[7] Slătineanu L., Duşa P., *Management of the technological innovation* (in Romanian), Iaşi: Tehnopress, 2002. ISBN 973-8048-56-7.

[8] Suh N.P., *Complexity: theory and application*, New York: Oxford University Press, 2005. ISBN 13978-0-19-517876-0, ISBN 0-19-517876-9

[9] Suh N.P., *The Principles of Design*, New York: Oxford University Press, 1990. ISBN 0-19-504345-6

[10] Tseng M.M., Kjellberg T. and Lu S. C.-Y., "Design in the New e-Commerce Era", *Annals of the CIRP*, Vol. 52, No. 2, pp. 509-519, 2003.

[11] Yang K., Zhang H., "A Comparison of TRIZ and Axiomatic Design", *Proceedings of ICAD2000. First International Conference on Axiomatic Design,* Cambridge, June 21-23, 2000.

