Selecting an alternative to solve a problem from several available alternatives

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Abstract. When for a certain design problem many alternative solutions could be susceptible to be used, a selection activity should be developed. If in the case of simple problems, the identification of an applicable alternative could be made very fast, in the case of the complex problems, the identification of the most convenient alternative could constitute itself a difficult problem. Over the years, simpler or more complex methods were found and applied to help the problem solver in finding the most convenient applicable alternative. The selection of a certain alternative when many such alternatives seem to exist could be made using the double input matrix method and the method of the pairwise comparison matrix and distinct evaluation criteria. The results of applying the two selection methods in the case of necessity to establish a machining scheme for an electrical discharge machining process were presented in the paper.

1. Introduction

When there are several alternatives to solve a certain problem, it is necessary to take actions to select the most convenient of the available alternatives. If the problem is relatively simple and the number of alternatives is low, it is possible that the most convenient alternative will be quickly identified. This is the case of the so-called tactical problems, specific to the current activity. When the problem is more complex and involves the involvement of high material values and important human resources, we are dealing with a strategic problem and identifying the most convenient alternative can be difficult. In the last situation, we will have to use a method of optimal selection of the alternative to solve the problem we face.

The significance of the optimization concept takes into account the need to undertake an activity to select one or more alternatives considered as maximum convenient [1 - 4].

Optimization is a common activity in engineering activities of constructive or technological design, but also in actual practical activities. When the problem of establishing a certain machining process for obtaining a surface of a part is raised, the technology designer must resort to identifying the process alternatives usable in that case, and then select that process considered to be the most convenient in relation to criteria needed to be considered [5, 6].

Selecting a processing process from several processes that could lead to similar results is a matter of establishing a decision. To solve a problem of this nature, the so-called research field of decision analysis has been developed. In principle, such a field considers a group of methods that could be applied to select an optimal alternative from several available alternatives.

Taking into account the circumstances in which a decision must be made, it is possible to identify several groups of methods for the optimal selection of a particular alternative. Thus, in the case of
decisions characterized mainly by individual applicability and in conditions of certainty, methods can be found such as: global utility method, Technique for Order the Preference by Similarity to Ideal Solution, TOPSIS, group of methods ELECTRE I, II, II, IV, IS, TRI, weighted sum model (WSM), weighted product model (WPM), analytic hierarchy process (AHP), analytic network process (ANP), multi-attribute utility theory (MAUT), dominance-based rough set approach (DRSA), aggregated indices randomization method (AIRM), nonstructural fuzzy decision support system (NSFDSS), gray relational analysis (GRA), superiority and inferiority ranking method (SIR method), potentially all pairwise rankings of all alternatives (PAPRIKA), value analysis (VA), axiomatic design method, etc. If decisions are made at risk, it can be used the method of the waited value, the method of decision tree, etc. Finally, for decisions that must be adopted in conditions of uncertainty, the optimistic method, pessimistic method, temperate optimism method, equal probability method (proportionality method), regret minimization method, etc. can be used.

Over the years, the issue of selecting the most convenient option from several available alternatives has preoccupied many researchers. Thus, some of these researchers have conducted research on the use and better understanding of the principles of the pairwise comparison matrix method [7 - 10]. The objectives of the research presented in this paper aimed at the possibilities of using two distinct methods, with different levels of complexity, for the selection of the scheme of electrical discharge machining of cylindrical test pieces.

2. The problem of an optimal selection

During the research activities, it appeared at a certain moment the need to separate a cylindrical test piece, of relatively small dimensions (diameter of 6 mm and length of 10-15 mm) from a part made of a material characterized by special physical and mechanical properties. These test pieces were to be subsequently subjected to mechanical tests specific to the use of the part in question. Given the mechanical properties of the part material, it was decided to detach the test pieces by electrical discharge machining using a copper tubular tool electrode and the usual working movement of the work head of the machine, along a vertical direction, from top to bottom, towards the workpiece (part) fixed on the machine tool table, in a vise type device. The results were not really good, because due to the longer maintenance in the space between the two electrodes of the metallic particles detached from them, there were spurious lateral electrical discharges and the test piece thus obtained had a lateral surface with a certain taper. In these circumstances, there was a need to identify another technological solution, which would improve the accuracy of obtaining the lateral cylindrical surface of the test piece. Some of these machining schemes are those presented in figure 1.

Each of these proposed schemes has advantages and disadvantages and it has been proposed to use a method to facilitate the selection of the most convenient alternative, by taking into account the proper conditions available.

In figure 1, the first machining scheme was relatively simple, but it generated an unacceptable taper of the machined surface. The machining was performed by immersing the working area in the dielectric liquid.

In the case of the processing scheme from figure 1, b it was necessary to resort to the aspiration of the dielectric liquid through the inside of the tubular tool electrode, other characteristics of this machining scheme being similar to those of the scheme shown in figure 1, a. Such a machining scheme could lead to a decrease in the conicity of the lateral surface, due to a faster evacuation (by aspiration) of the metallic particles suspended in the dielectric liquid.

The third machining scheme (figure 1, c) is based on the realization of the working movement by the workpiece from top to bottom, towards the tubular tool electrode fixed in a mandrel type device, located on the table of the electrical discharge machine. Since the evacuation of the detached metallic particles from the electrodes was performed under the action of gravity, it was expected that the taper of the outer surface of the test piece detached from the part would be lower.

In the case of the processing scheme from figure 1, d, compared to the scheme presented above, the aspiration of the dielectric liquid with metallic particles in suspension through the tubular tool electrode appears.
Since the machining schemes previously exposed used a non-rotating tool electrode, with the risk of copying possible deviations of the tool electrode in the outer surface of the test piece separated from the workpiece by electrical discharge machining, the fifth version of the machining scheme involved the rotational movement of the tubular tool electrode. An improvement in machining accuracy was expected, but also an increase in the complexity of the tool electrode positioning and clamping device.

The sixth machining scheme considered was based on the use of a cylindrical bar tool electrode, which performs a planetary movement around the axis of symmetry of the outer cylindrical surface of the test piece to be detached by electrical discharge machining from the plate type workpiece. In addition to the planetary motion, the tool electrode of course also performs the working movement from top to bottom specific to the normal use of the electrical discharge machine with massive electrode. The machining scheme became more complicated, the productivity decreased, but an improvement of the precision of the test piece surface obtained by electrical discharge machining was expected. In the previously mentioned aspects, only a few characteristics of each machining scheme considered were revealed very briefly. In reality, the comparison of such machining schemes makes necessary to identify and analyze other aspects, such as, for example, those related to the influence of tool electrode wear on machining accuracy, etc.

Without using methods to optimize the selection of an alternative when there are several alternatives and especially when the number of alternatives is large, it seems very difficult to select the most convenient alternative and here can be applied the various methods proposed by researchers to select the alternative, optimal or close to the optimal one. Furthermore, in order not to make the analysis too complex and to facilitate its understanding, only 5 alternatives for solving the problem and 4 criteria for their evaluation were considered.

3. Selecting a solution using the pairwise comparison matrix method

The pairwise comparison matrix method is also called the double entry matrix method, because both

![Diagram](image_url)

Figure 1. Machining schemes that could be used to detach a cylindrical test piece from a plate type workpiece.
along the first row and the first column, the identified alternatives for solving the approached problem are included. Next, in the places obtained at the intersection of a column with a line, marks resulting from the comparison of the pairs of alternatives defined by the line and the column in question are entered, granting evaluation marks of type 1, 0 and 0.5, for example. If the first alternative of the pair seems to be more advantageous, mark 1 will be entered in that column, while mark 0 will be entered in the column corresponding to the other alternative of the pair. When the two alternatives seem to be equal importantly, marks of 0.5 will be registered in both places. However, there is also the possibility of awarding marks varying between wider limits [7-10]. Along the diagonal whose position corresponds to the comparison of the same alternative, the symbol X will be inscribed.

**Table 1.** Table elaborated using the pairwise comparison matrix method when selecting a machining scheme.

| Alternative   | Alternative a | Alternative c | Alternative d | Alternative e | Alternative f |
|---------------|---------------|---------------|---------------|---------------|---------------|
| Alternative a | X             | 1             | 1             | 1             | 0.5           |
| Alternative c | 0             | X             | 1             | 1             | 0.5           |
| Alternative d | 0             | 0             | X             | 1             | 1.0           |
| Alternative e | 0             | 0             | 0             | X             | 0.5           |
| Alternative f | 0.5           | 0.5           | 0             | 0.5           | X             |
| Sum of marks  | 0.5           | 1.5           | 2             | 3.5           | 2.5           |
| Relative sum  | 0.05          | 0.15          | 0.2           | 0.35          | 0.25          |

New order: e-f-d-c-a since 0.35>0.25>0.2>0.15>0.05

After completing all the places in the tables with the results of the comparisons, a line follows in which the values of the sums of the marks awarded for each alternative are entered, along the column corresponding to that alternative. These sums already provide an image of the order of importance of the alternatives, an order established by comparing two by two of all the alternatives. In the penultimate line of the table, it can be entered the values of some relative sums, obtained by dividing the sum of the marks of each alternative to the number of comparisons. This $N_c$ number of comparisons is determined by means of a relation of form:

$$N_c = \frac{n(n-1)}{2}$$  \hspace{1cm} (1)

where $n$ is the number of alternatives considered. The last line of the table will include the new order of the alternatives, established by arranging them in descending order the relative sums of the marks obtained by each alternative.

It can be seen that the method described here does not use criteria when comparing two alternatives, which leads to a less objective evaluation, but the advantage of the method is the shorter duration of its application. Table 1 shows the results of applying the method in the case of the 5 versions of machining schemes previously identified. The most convenient alternative established by applying the method is the alternative e, which is assigned the highest value of the relative sum.

4. **Selecting a solution using a matrix of comparing pairs of alternatives and distinct evaluation criteria**

A method that uses a comparison of existing pairs of alternatives using distinct criteria will be addressed in this chapter. A version of this method was promoted by Professor Belous (from the “Gheorghe Asachi” Technical University of Iași, Romania) [11] and called the technique of the imposed decision. In principle, this method can be included in the broader group of value engineering methods [12].
To illustrate how to use this method, the information contained in table 2 was used. A first part of the table was intended to compare the selection criteria used two by two and respectively to establish weights given to each of the criteria.

### Table 2. Table elaborated using a matrix of comparing pairs of alternatives and distinct evaluation criteria.

| Criterion | Results of comparisons | Sum | Weighting coefficient |
|-----------|------------------------|-----|-----------------------|
| Column 1   |                        |     |                       |
| A | 1 | 1 | 0.5 | 2.5 | 0.41 |
| B | 0 |   | 0   | 0.5 | 0.08 |
| C | 0 | 1 | 1   | 2.0 | 0.33 |
| D | 0.5 | 0.5 | 0   | 1.0 | 0.16 |

#### 2. Calculation of the importance coefficient for each alternative using the criterion of achievable accuracy

| Alternative | Results of comparisons | Sum | Importance coefficient |
|-------------|------------------------|-----|-----------------------|
| a | 0 | 0 | 0   | 0 | 0.0 |
| c | 0 | 0 | 0   | 1 | 0.1 |
| d | 1 | 1 | 0   | 1 | 0.2 |
| e | 1 | 1 | 1   | 0.5 | 0.35 |
| f | 1 | 1 | 0.5 | 3.5 | 0.35 |

#### 3. Calculation of the importance coefficient for each alternative using the criterion of the expected rate of material removal

| Alternative | Results of comparisons | Sum | Importance coefficient |
|-------------|------------------------|-----|-----------------------|
| a | 0 | 0 | 0.5 | 0.5 | 0.05 |
| c | 1 | 1 | 1   | 2 | 0.2 |
| d | 1 | 1 | 0   | 3 | 0.3 |
| e | 1 | 1 | 1   | 4 | 0.4 |
| f | 0.5 | 0 | 0   | 0.5 | 0.05 |

#### 3. Calculation of the importance coefficient for each alternative using the criterion of the constructive simplicity of the devices necessary for the materialization of the alternative of the machining scheme

| Alternative | Results of comparisons | Sum | Importance coefficient |
|-------------|------------------------|-----|-----------------------|
| a | 1 | 1 | 1   | 4 | 0.4 |
| c | 0 | 1 | 1   | 3 | 0.3 |
| d | 0 | 0 | 1   | 2 | 0.2 |
| e | 0 | 0 | 0   | 1 | 0.1 |
| f | 0 | 0 | 0   | 0 | 0.0 |

#### 4. Calculation of the importance coefficient for each alternative using the criterion of the risk of copying the deviation of the shape of the tool electrode in the machined surface

| Alternative | Results of comparisons | Sum | Importance coefficient |
|-------------|------------------------|-----|-----------------------|
| a | 0.5 | 0.5 | 0 | 1.0 | 0.1 |
| c | 0.5 | 0.5 | 0 | 1.0 | 0.1 |
| d | 0.5 | 0.5 | 0 | 1.0 | 0.1 |
| e | 1 | 1 | 1   | 0.5 | 3.5 | 0.35 |
| f | 1 | 1 | 0.5 | 3.5 | 0.35 |

Calculation of the value numbers associated with each alternative

| Alternative | Value Numbers |
|-------------|---------------|
| a | 0.41·0.08·0.05·0.33·0.4·0.16·0.1 = 0.152 |
| c | 0.41·0.1·0.08·0.2·0.33·0.5·0.16·0.1 = 0.172 |
| d | 0.41·0.2·0.08·0.3·0.33·0.2·0.16·0.1 = 0.188 |
| e | 0.41·0.35·0.08·0.4·0.3·0.1·0.16·0.35 = 0.7125 |
| f | 0.41·0.35·0.08·0.05·0.33·0·0.16·0.35 = 0.2035 |

New order: e-f-d-c-a since 0.7125 > 0.2035 > 0.188 > 0.172 > 0.152
In the case of the five alternatives proposed for establishing the machining scheme usable for separating cylindrical test pieces by electrical discharge machining from a plate-type workpiece, it could be as differentiating criteria: the achievable accuracy, expected rate of material removal, constructive simplicity of the devices necessary for the materialization of the proposed machining scheme, the risk of copying the deviation of the shape of the tool electrode in the machined surface, the machining cost (including the level of complexity of the device), efficiency of the removal of detached metal particles from electrodes in the machining area, the risk of accumulation of gas bubbles (from the gases released as a result of the electrical discharge machining process) between the tool electrode and the workpiece (these bubbles would have a low electrical conductivity, which could change the nature of discharges electrical and a possible more pronounced deterioration of the processed surface), etc.

As can be seen, the number of criteria that could be taken into account when comparing alternatives can be quite large, but in the case of this paper only the first four criteria were used, to which the symbols A, B, C, and D were assigned.

Specifically, in the first part of table 2, the criteria for evaluating the alternatives of machining schemes were compared and received weighting coefficients. As in the case of the method pairwise comparison matrix, the criteria considered were compared two by two, assigning marks of 1-0, when the first criterion was assessed as more important, 0-1 when more important was assessed as being the second criterion and respectively 0.5-0.5 when the two compared criteria were appreciated as being of equal importance. In the penultimate column of this first part of table 1 were entered the sums of marks given to each criterion, and in the last column was entered the value of the weighting of the criterion, by relating the sum of marks to the number of comparisons made (there are four criteria, number of comparisons will be 4 x 3/2 = 6 comparisons).

Similar working principles were applied in the following four components of table 2, when the five alternatives were compared in pairs and using each of the four criteria considered. In this way it became possible to establish a coefficient of the importance of each alternative by taking into account each evaluation criterion.

In the last part of table 2 there were calculated the value numbers of each alternative, by summing the products of the importance coefficients of each alternative determined in the case of a certain evaluation criterion with the value of the weighting coefficient of the respective criterion. The calculation relation of the value numbers has the aspect:

\[ N_{vj} = \sum_{i=1}^{n} C_{wi} C_{ji} \]  

where \( C_{wi} \) is the weighting coefficient of each criterion \( i \), and \( C_{ji} \) is the value of the importance coefficient of alternative \( j \) when using criterion \( i \).

By applying the matrix method of comparing pairs of alternatives and distinct evaluation criteria, it can be seen that the most convenient machining scheme alternative among the five alternatives considered is the alternative e, since in this case the highest value of the value number \( N_{ve} \) was obtained. As expected, the least convenient alternative is alternative a, this being in fact the one that later allowed to outline the problem of selecting a solution alternative when several such alternatives are available.

5. Discussion

If we compare the time required to select the most convenient alternative from the five available alternatives, we find that the use of the matrix method of comparing pairs of alternatives and distinct evaluation criteria requires a much longer duration than that of the pairwise comparison matrix method. We will note, however, that by considering several evaluation criteria, it is expected that the matrix method of comparing pairs of alternatives and distinct evaluation criteria can provide a more objective ordering of the alternatives considered and therefore, when available, long enough, it is preferable to use the latter method.

We will find further that the use of the second method (method that uses the pairwise comparison matrix and distinct evaluation criteria), through the more detailed analysis it involves, can lead to
useful suggestions for further improvement including the selected alternative, even by taking into account those criteria for which it was not well rated.

6. Conclusions
When it is necessary to select an alternative from a low number of available alternatives, the selection is relatively easy to make. If the number of available alternatives is large, there is a need to use a method that allows the justified choice of the most convenient alternative. In the literature there are mentioned many methods that can be used in this regard. In the present paper, the problem of selecting a machining scheme that would allow the detachment by electrical discharge machining of a cylindrical test piece from a plate-type workpiece was considered, identifying several such possible schemes. It was thus found that applying the pairwise comparison matrix method is possible to select the most convenient in a relatively short time, but the use of a pairwise matrix comparison and distinct evaluation criteria allows a more objective selection of the most convenient alternative from the considered alternatives. It was also appreciated that a more detailed method may facilitate the emergence of suggestions for improving one or more of the alternatives analyzed. In the future, the identification and analysis of other methods designed to facilitate the selection of the most convenient alternative will be pursued when several available alternatives are available.

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