SELECTION OF SOLID CARBIDE END MILL FOR MACHINING ALUMINUM 6082-T4 USING MCDM METHOD

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The selection of end mill for machining is a complex task because there are many manufacturers of end mills. In this paper, the selection of solid end mill for machining Al 6082-T4 is presented using multi-criteria decision making method, i.e. using the AHP method of the software package Expert Choice. Based on the four criteria (number of end mill teeth, cutting speed, feed per tooth and the price) there was a selection of the most appropriate end mill (the best alternative) of the considered six (solid carbide end mills made by the cutting tools manufacturers: Iscar, Seco and Young cutting tools).

Keywords: selection of end mill, multi-criteria decision making, AHP method, Expert Choice.

1. Introduction

Milling is the process of machining various non-rotational surfaces such as flat surfaces, grooves, profile surfaces, complex shaped surfaces and all other non-rotational shape surfaces. The main movement is rotational and it is performed by the cutting tool. It is defined by the cutting speed (V_c, m/min) i.e. the spindle speed (n, rev/min) on the machine. The feeding movement is translated and it is performed by the work-piece. It is defined by the feed per tooth (f_t, mm/tooth) i.e. the feed rate (V_p, mm/min) on the milling machine.

The latest trend in the milling is using cutting tools made of solid carbide. Selection of solid carbide end mill can be facilitated by using multi-criteria decision making method that helps the decision maker to choose the best solution based on the given criteria. The methodology of decision making has proven to be an irreplaceable help in the decision making process, as it significantly facilitates the selection process when ranking the alternatives.

The process of decision-making depends largely on the expert knowledge, applied methods and software tools. Today, there are many software packages that help in the decision-making process.

There are some papers about the selection of cutting tools using multi-criteria decision making method. Pantel in [1] investigated an insert selection for

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turning operation using various multiple attribute decision making methods such as an analytical hierarchy process (AHP), revised analytical hierarchy process and similar to an ideal solution. Shelar in [2] investigated selection of cutting tool insert for turning using analytical hierarchy process and weight product method. Madić in [3] investigated a selection of cutting inserts for turning aluminum alloys using multi-criteria decision making (MCDM).

2. Multi-criteria decision making

Multi-criteria decision making is one of the most used methods in the theory of decision-making with a wide application in solving real problems. It uses a set of mathematical methods and tools. Classical optimization methods use one, somewhat rarely several, goal function, which reduces the possibility to apply it in solving real problems where there are many goals. On the other hand, a large number of goals carry with its certain problems in decision-making, as a model for decision-making becomes more complex in the mathematical sense and therefore there is more difficult to solve. When deciding there is no ideal alternative that would be optimal with respect to all overall goal. These are two ways for multi-decision making. They are related to the various problems of decision making. The first way is to select the appropriate best alternative from a set of available alternatives. Another way is to select a set of good alternatives or grouping the alternatives. Methods of multi-criteria decision has found application in many scientific fields [4,5].

3. Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is one of the most popular methods of multi-criteria decision making. AHP method is devised and mathematically developed by Thomas L. Saaty [6,7]. The implementation process of AHP method involves four basic phases:

- Structuring of the problem,
- Data collection,
- Evaluating the relative weights,
- Identifying solutions to problems.

The AHP method is based on a hierarchical resolution of the problem. Hierarchically, the structure of the problem of decision making forms the basis for the comparison that should be in the next phases of problem solving. At the top of the hierarchy is the goal, while the criteria, sub-criteria, and alternatives are at lower levels, Figure 1.

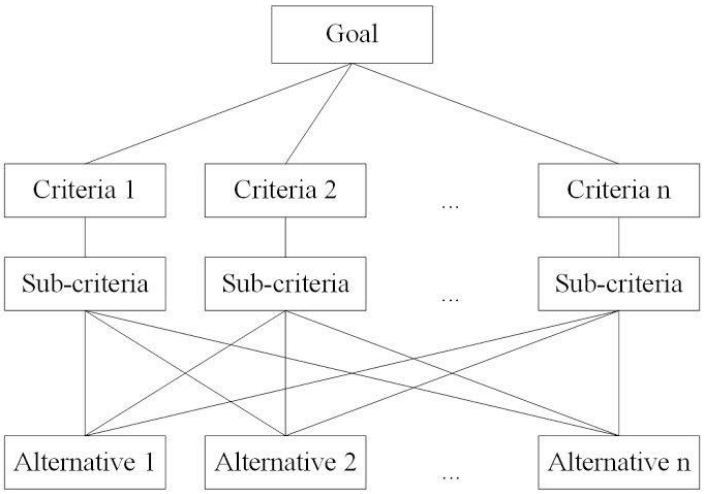


Fig. 1. AHP hierarchical tree

When solving a problem using the AHP method, it is necessary to use Saaty's scale for comparison criteria and attributes of alternatives, Table 1 [8,9].

Table 1

Saaty's scale

Numerical values	Definition	Explanation
1	Equal importance	Two activities contribute equally to the object.
3	Moderate importance	Experience and judgment slightly favor one activity over another.
5	Strong importance	Experience and judgment strongly favor one activity over another.
7	Very strong importance	An activity is a favor very strong over another, it is dominance demonstrated in practice
9	Extreme importance	The evidence favoring on activity over another is the highest possible order of affirmation.
2,4,6,8	Intermediate values	When the compromise is necessary.

4. The selection of solid carbide end mill using the AHP method

To help solving the practical problem by applying the AHP method such as selection of the solid carbide end mill for machining Al 6082-T4, a software Expert Choice has been used.

The Expert Choice software is used to solve the problem of multi-criteria decision-making by applying the AHP method and is one of the most efficient software packages with the ability to rank the alternatives and conduct the analysis of the charts for a visual presentation of the obtained solutions. It is adapted for application of the AHP method in real problems. It allows the structuring of the problems and comparison of alternatives and criteria for

according goal. After the defined criteria, it is necessary to determine their significance in relation to pre-defined alternatives. The comparison of criteria is based on Saaty's scale.

The aim of this paper is to select the best solid carbide end mill for machining Al 6082-T4. Solid carbide end mills are from three cutting tools manufacturers. Four criteria are used for selecting the solid carbide end mill (number of end mill teeth, cutting speed, feed per tooth and price). All end mills have the diameter of 16 mm. The model for decision making is shown in Table 2.

Table 2

Criteria and alternatives

Alternatives	Criteria			
Solid carbide end mill	Number of end mill teeth z_n	Cutting speed V_c (m/min)	Feed per tooth f_t (mm/tooth)	Price (EUR)
JS412 (SECO)	2	285	0.15	95
E5E49 (Young cutting tools)	3	210	0.096	100
JS413 (SECO)	3	275	0.15	105
ECA-B-3 (ISCAR)	3	234	0.05	138
EC-E-4L (ISCAR)	4	320	0.13	158
JS554 (SECO)	4	300	0.09	128

The process of defining the decision making problem in the Expert Choice software package consists of:

- Defining the goal,
- Defining the criteria,
- Defining the alternatives,
- Assigning weight criteria with respect to the goal,
- Comparison of alternatives in relation to the criteria,
- Synthesis in relation to the goal,
- Sensitivity analysis.

The goal, criteria and alternatives in software package Expert Choice is shown in Figure 2.

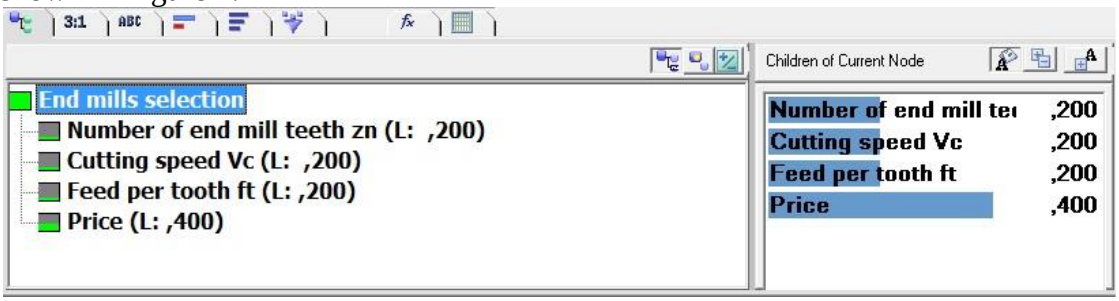


Fig. 2. Goal, criteria and alternatives in software package Expert Choice

The hierarchical tree of the structure of decision making problems, with the software package Expert Choice is shown in Figure 3. The goal is left while criteria and alternatives are at lower levels of the hierarchical structure.

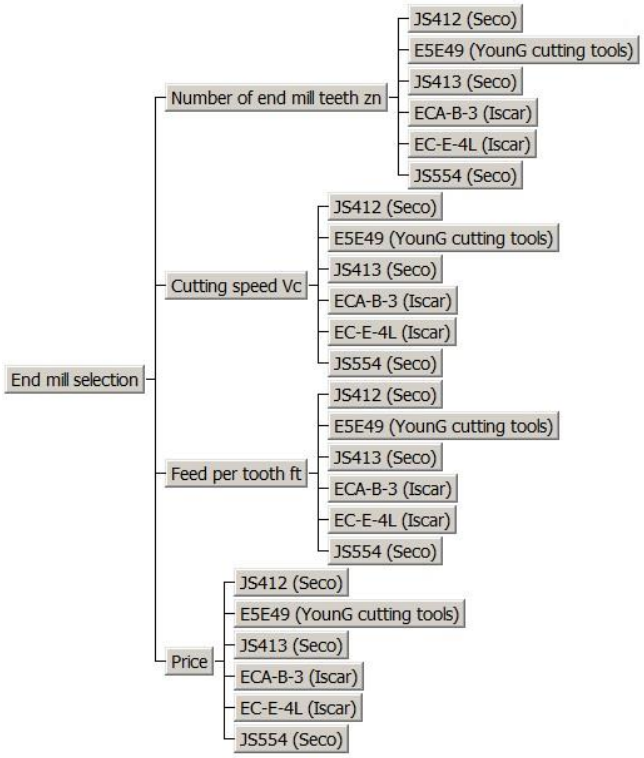


Fig. 3. Hierarchical tree of the decision problem in software Expert Choice

After defining the goal, it is necessary to compare the criteria and alternatives according to attributes. The criteria are compared with each other with respect to the significance in relation to the goal. The pair-wise comparison is based on Saaty's scale. Comparison of criteria in relation to the goal is shown in Figure 4.

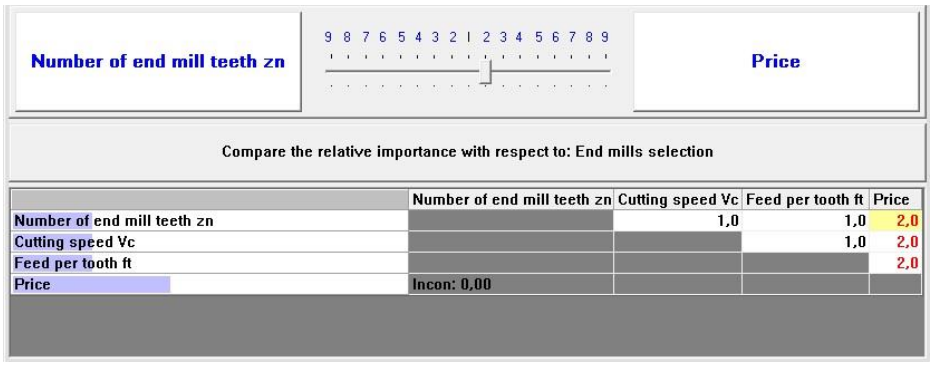
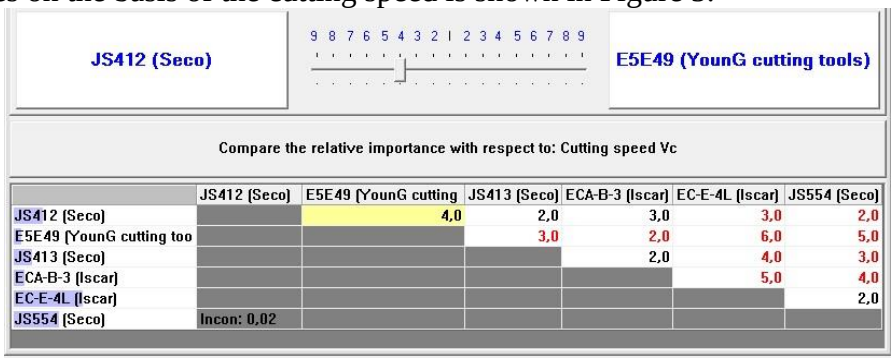


Fig. 4. Pair-wise comparison of criteria

The next step is to compare alternatives in relation to each individual criterion (first based on the number of end mill teeth, followed the cutting speed, feed per tooth and price at the end). For example, pair-wise comparison of alternatives on the basis of the cutting speed is shown in Figure 5.



	JS412 (Seco)	E5E49 (YounG cutting	JS413 (Seco)	ECA-B-3 (Iscar)	EC-E-4L (Iscar)	JS554 (Seco)
JS412 (Seco)		4,0	2,0	3,0	3,0	2,0
E5E49 (YounG cutting too			3,0	2,0	6,0	5,0
JS413 (Seco)				2,0	4,0	3,0
ECA-B-3 (Iscar)					5,0	4,0
EC-E-4L (Iscar)						2,0
JS554 (Seco)	Incon: 0,02					

Fig. 5. Pair-wise comparison of alternatives

The Expert Choice software package calculates the weights by AHP methodology. Figure 6 shows the ranking of alternatives after performing synthesis. The total value of the coefficient of inconsistency should be less than 10%, on the basis of which we can say that the model is well structured [10]. In the case that the coefficient of inconsistency is greater than the required value, it is necessary to correct the comparison values of certain criteria. The correction of comparison values of certain criteria is done randomly. Changing the values of the comparison criteria affects the value of the inconsistency coefficient.

Fig. 6. Synthesis with respect to goal

The software package Expert Choice has suggested end mill JS412 (Seco) as the first choice, end mill EC-E-4L (Iscar) as a second choice, then the end mill JS554 (Seco), JS413 (Seco), E5E49 (Young cutting tolls) and end mill ECA -B-3 (Iscar) as the last choice.

The Expert Choice software package enables graphic representation of results based on defined criteria. The graphics may be over [10,11,12]:

- Performance sensitivity graph,
- Gradient sensitivity graph,
- Dynamic sensitivity graph,

- Head-to-head graph,
- Two dimensional graph.

The performance sensitivity graph is shown on Figure 7. The criteria of significance are presented using the bars (vertical bollards) while the alternatives are shown using broken lines. The meeting point of broken lines of the alternative with the vertical line of the criteria shows the priority of the alternative for the given criterion, which can be read on the right vertical axis (Alt%). The left axis (Obj%) shows the priority of criteria for the given goal. The total priority of each alternative is represented by a vertical line overall.

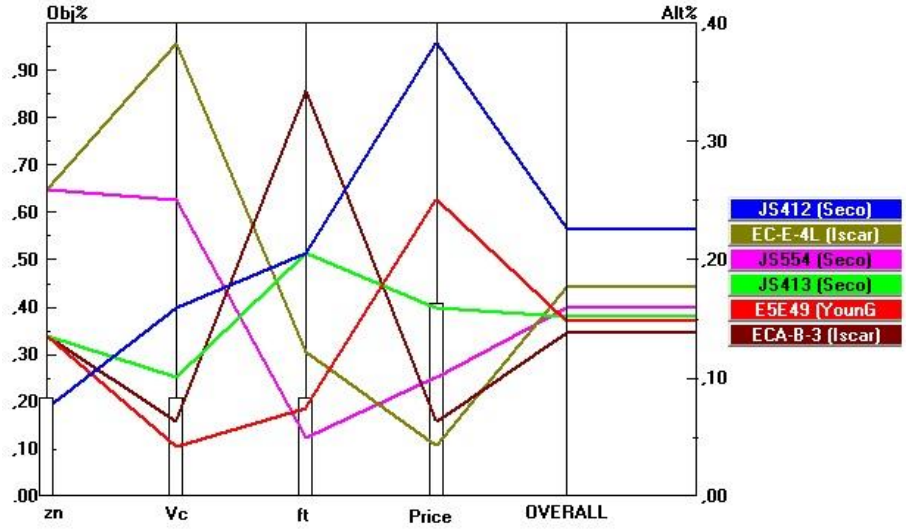


Fig. 7. Performance sensitivity graph

The gradient sensitivity graph enables analyzing the impact of each criterion separately on the given goal, Figure 8.

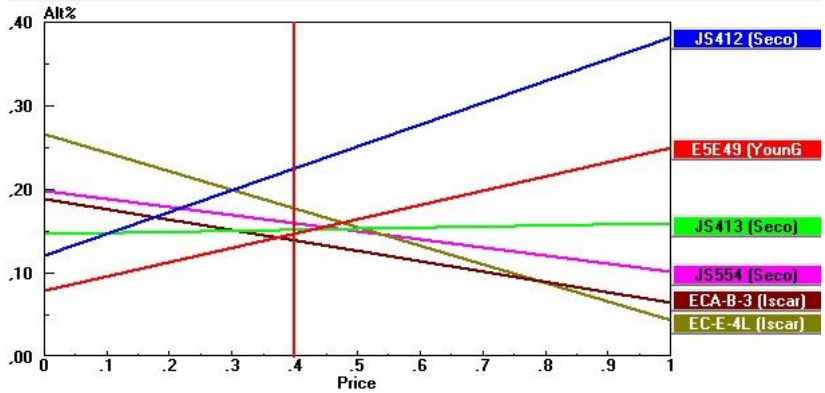


Fig. 8. Gradient sensitivity graph

The dynamic sensitivity graph represents a set of horizontal rectangles and provides an analysis of the impact of changes in the priorities of alternative by

increasing or decreasing the weight criteria. When you change one criterion, other weights change in proportion to the initially given weight criteria. Figure 9 shows the diagram of the dynamic sensitivity graph, where the portions of effects of all the criteria are on the left side (number of end mill teeth, cutting speed, feed per tooth and the price) while the right side of the diagram shows the alternatives according to their priority.

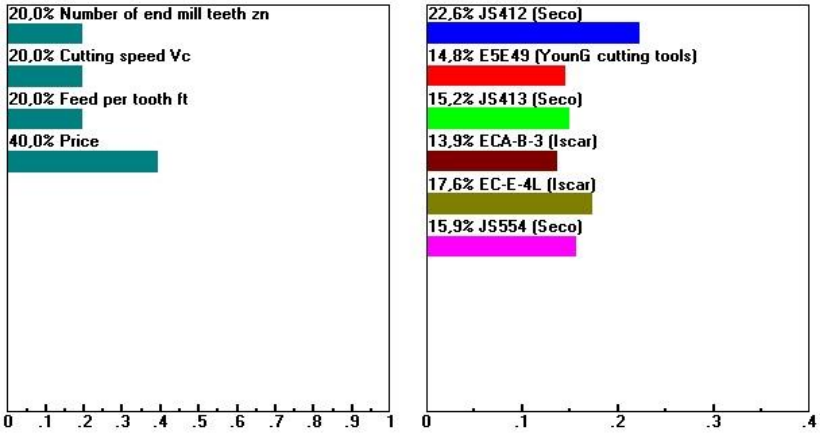


Fig. 9. Dynamic sensitivity graph

The head-to-head graph, Figure 10, is used to direct comparison of alternatives. Information on what criteria are better displayed as horizontal rectangles. The total decision which alternative is best displayed using the last horizontal rectangle (overall).

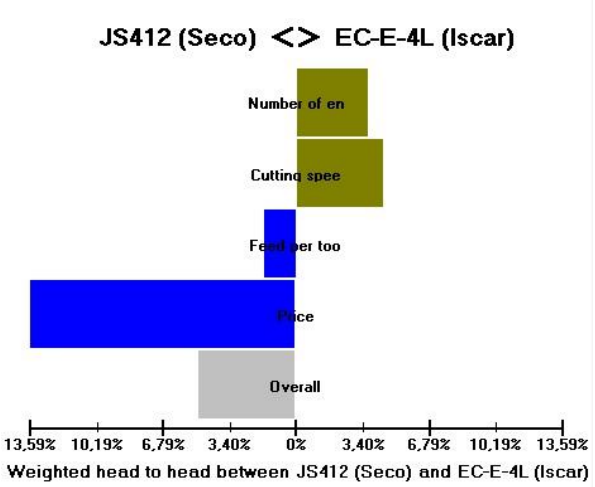


Fig. 10. Head-to-head graph

The two dimensional graph, Figure 11, shows the alternatives, priorities with respect to two objectives at a time. The area of the two dimensional plot is divided into quadrants. The most favorable alternatives with respect to the

objectives on the two axes will be shown in the upper right quadrant. The least favorable alternatives will be shown in the lower left quadrant. Alternatives located in the upper left and lower right quadrants indicate key tradeoffs where there is conflict between the two selected objectives [13].

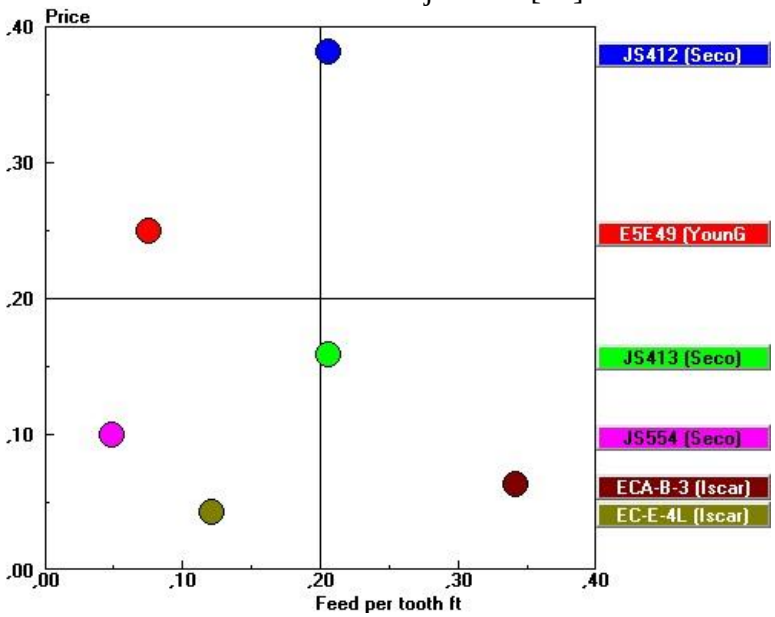


Fig. 11. Two dimensional graph

5. Conclusion

Today there are many different softwares for implementing the AHP method. The widespread use is certainly due to its ease of applicability and the structure of AHP method. AHP method is an effective management tool. It can handle many alternatives at the one time and so permit comparisons to be made. Other popular methods, such as the Dimensional Analysis and Relative Merit Method, can only handle two alternatives. The assumption of criteria may sometimes a limitation of AHP method. The decision maker must answer a much large number of questions, which of two alternatives influences the given criterion. For selection solid carbide end mill for milling Al 6082-T4 used AHP method implemented in software Expert Choice. Software Expert Choice, based on the criteria (number of teeth, cutting speed, feed per tooth and price) suggested solid carbide end mill JS412 (Seco) as the first choice, end mill EC-E-4L (Iscar) as a second choice, then the end mill JS554 (Seco), JS413 (Seco), E5E49 (Young cutting tool) and end mill ECA-B-3 (Iscar) as the last choice. The Software Expert Choice can be used for the selection of cutting tools in various machining process and for machining different materials.

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