SELECTION OF DRILL FOR DRILLING WITH HIGH PRESSURE COOLANT USING ENTROPY AND COPRAS MCDM METHOD

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The selection of drill for drilling holes in a concrete material is a very important task. In this paper the selection of solid carbide drills for drilling holes in aluminum alloys with high pressure coolant using the multi-criteria decision making methodology is presented. The multi-criteria decision making method is applied using CORPAS method, while for determining the weight coefficients the entropy method is used. Based on the four criteria (cutting speed, feed per revolution, pressure coolant and machining time) four alternatives were ranked, carbide drills from different manufacturers (Iscar, Sandvik, Seco and Kennametal).

Keywords: Entropy, COPRAS, multi-criteria decision making, solid carbide drill.

1. Introduction

Drilling is a machining process for creating holes in a solid material. The main rotary motion in drilling is the running of a tool (drill). Secondary translational movement is carried out by a tool or workpiece. The main movement is defined by cutting speed or number of revolutions at the machine tool, and supported by the movement of feed rate [1].

The most important factor affecting the process of drilling is the temperature that occurs in the cutting zone. Increased temperatures in the cutting zone may lead to rapid tool wear and the formation of chips. [1]. In order to reduce wear and increase life of cutting tool coolants are used. Drilling with high pressure coolant (20-150 bars) is commonly -used in cases where the depth is three times larger than the diameter of the drill [2].

The selection of solid carbide drill for drilling with high pressure coolant can be made easier using a multi-criteria decision making methods. The methodology of multiple criteria decision making is based on the structuring problems and making decisions. Multi-criteria decision making methods help the decision makers to choose the best solution based on the given criteria. Decision-making consists of the following steps: defining a problem, determining the goal, determining the criteria and alternatives, ranking the alternatives based on the given criteria and decision making [3].

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In this paper, for solving the problem of selection solid carbide drills with high pressure coolant the entropy method is applied for determining weight coefficients and COPRAS method for determining the best alternative based on the given criteria.

2. Entropy method

Before applying the entropy method for determining weight coefficients is necessary to define alternatives and criteria for the selection of solid carbide drill for drilling with high pressure coolant. Table 1 presents four alternatives, solid carbide drills from different manufacturers (Iscar, Sandvik, Seco, Kennametal) and four criteria, cutting speed, feed per revolution, pressure coolant and machining time. The goal is to choose a drill for drilling holes with high pressure coolant, which has a maximum cutting speed, feed per revolution, pressure coolant and minimal machining time.

Table 1

Alternatives and criteria

Alternative	Criteria			
Solid carbide drills	C_1-max	C_2-max	C_3-max	C_4-min
	Cutting speed (m/min)	Feed per rev. (mm/rev)	Pressure coolant (bar)	Machining time (s)
A_1 SCD-ACG5 (Iscar)	140	0.45	45	6.9
A_2 R840 (Sandvik)	122	0.406	40	7.7
A_3 SD205A (Seco)	140	0.48	40	6.7
A_4 B285(Kennametal)	120	0.38	40	8

Determining the weight coefficients based on the defined criteria using the entropy method is performed by applying in four steps:

Step 1: Determining the elements of of normalized decision matrix, while the equation (1) [2, 4]:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, i = 1,...,m, j = 1,...,n \qquad (1)$$

Where: x_{ij} is the performance of the i-th alternative in relation to the j-th criteria, m is a number of alternatives and n is a number of criteria. Based on the equation (1) normalized decision making matrix is shown in Table 2

Table 2

Normalized decision making matrix

Alternative	C_1	C_2	C_3	C_4
A_1	0.268199	0.262238	0.272727	0.235495
A_2	0.233716	0.236597	0.242424	0.262799
A_3	0.268199	0.27972	0.242424	0.228669
A_4	0.229885	0.221445	0.242424	0.273038

Step 2: Quantity of information contained in the normalized decision matrix and broadcast by criteria can be measured as the value of entropy e_j using the equation (2) [2]:

$$e_j = -k \sum_{i=1}^{m} \left(r_{ij} \cdot \ln r_{ij} \right) \tag{2}$$

Where: $k = 1/\ln m$ is a constant which ensures that the value of the entropy moves within the interval $0 \le e_j \le 1$, and m is the number of alternatives. For selection of solid carbide drill with high pressure coolant $m=4$ and constant $k=0.721$, the value of the entropy of normalized decision making matrix is shown in Table 3.

Table 3

Value of entropy

Value of entropy	C_1	C_2	C_3	C_4
e_j	0.998076	0.997073	0.999025	0.521365

Step 3: Determining the degree of deviation d_j from the average level of the information contained in the values which are the alternatives described using the equation (3) [2]:

$$d_j = 1 - e_j, \, j = 1,...,n \tag{3}$$

If the value of d_j for a given criterion is higher, the importance of criteria j for a given decision problem is bigger. The degree of deviation for the selection of solid carbide drill is shown in Table 4.

Table 4

Degree of deviation

Degree of deviation	C_1	C_2	C_3	C_4
d_j	0.001924	0.002927	0.000975	0.478635

Step 4: Determining the weight coefficients by using equation (4) [2, 4].

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{4}$$

Weights coefficients for selection of solid carbide drill for drilling with high pressure coolant is shown in Table 4.

Table 5

Weights coefficients

Weights coefficients	C_1	C_2	C_3	C_4
w_j	0.003972	0.006042	0.002012	0.987974

3. COPRAS method

COPRAS (COmplex PRoportional ASsessment) method was developed by researchers of Vilnius Gediminas Technical University, Zavadskas and Kaklauskas [5]. COPRAS method means the ranking based on the relative importance (weight) of each alternative. By using this method determined the best alternative (solution),

taking into account the positive and negative-ideal-an ideal solution. COPRAS method consists of six steps:

Step 1: Determining the decision making matrix (4) [2]:

$$X = \left[x_{ij}\right]_{m \times n} = \begin{vmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{vmatrix} \tag{4}$$

Where: x_{ij} is the performance of the *i*-th alternative in relation to the *j*-th criteria, *m*-a number of alternatives and *n*-a number of criteria. Based on the Table 1., a decision matrix is defined (5). Each row refers to one alternative, and each column to one criterion.

$$X = \begin{vmatrix} 140 & 0.45 & 45 & 6.9 \\ 122 & 0.406 & 40 & 7.7 \\ 140 & 0.48 & 40 & 6.7 \\ 120 & 0.38 & 40 & 8 \end{vmatrix} \tag{5}$$

Step 2: Normalized decision making matrix using the equation (1), from the equation normalized matrix is shown in Table 1.

Step 3: Difficult normalized decision making matrix represents normalized the multiplication of the normalized matrix elements of the column with the appropriate weight coefficients using equation (6) [2, 6]:

$$v_{ij} = r_{ij} \cdot w_j \tag{6}$$

Difficult normalized decision making matrix for a selection drill for drilling with high pressure coolant is shown in Table 6. The weight coefficients are wj= (0.003972, 0.006042, 0.002012, 0.987974) previously determined using the entropy method.

Table 6

Difficult normalized decision making matrix

A$_1$	0.001065	0.001584	0.000549	0.232663
A$_2$	0.000928	0.001429	0.000488	0.259638
A$_3$	0.001065	0.00169	0.000488	0.225919
A$_4$	0.000913	0.001338	0.000488	0.269754

Step 4: Determining the sums of difficult normalized values of alternative to the maximum criteria using the equation (7) and minimum criteria using the equation (8) [2,6]:

$$S_{+i} = \sum_{j=1}^{n} v_{ij} \tag{7}$$

$$S_{-i} = \sum_{j=1}^{n} v_{ij} \tag{8}$$

Sums of difficult normalized values for maximum and minimum criteria are given in Table 7.

Table 7

Sums of difficult normalized values

Alternative	S_{+i}	S_{-i}
A_1	0.003198	0.232663
A_2	0.002846	0.259638
A_3	0.003243	0.225919
A_4	0.002739	0.269754

The values of S_{+i} and S_{-i} show level of achievement of the goals of each alternative. The higher value of S_{+I}, the alternative is better, as the lower value of the S_{-i} and alternative is better.

Step 5: Determining of the relative significance of alternatives over the utility function Q_i using the equation 9 [7], Table 8.

$$Q_i = S_{+i} + \frac{S_{-\min} \cdot \sum_{i=1}^{m} S_{-i}}{S_{-i} \cdot \sum_{i-1}^{m} \left(\frac{S_{-\min}}{S_{-i}} \right)} \tag{9}$$

Where: $i=1,...,m$ i S_{-min} represent the minimum value of S_{-i}.

Table 8

Values of the utility function

Alternative	Q_i
A_1	0.263984
A_2	0.236536
A_3	0.271813
A_4	0.227666

Step 6: Determining the coefficient of efficiency alternative U_i, using the equation (10) [2, 7]:

$$U_i = \frac{Q_i}{Q_i^{\max}} \cdot 100\% \tag{10}$$

Where $Q_i^{\max}$ is the maximum value of the utility function. Based on the coefficient of efficiency, ranking of alternatives is performed. Values coefficient of efficiency alternative is varying from 0 to 100%.

Efficiency of alternatives for a selection solid carbide drll for drilling with high pressure coolant is shown in Table 9.

Coefficient of efficiency and rank

Alternative	Ui	Rank
A_1	97.1196	2
A_2	87.02169	3
A_3	100	1
A_4	83.75836	4

Base on the Table 9 the order of the alternatives is A3-A1-A2-A4, which means that in the first place it is an alternative A3, solid carbide drill SD205 of manufacturer Seco.

4. Conclusion

Drilling with high pressure coolant is a new approach in machining technology. The selection of solid carbide drill for drilling with high pressure was carried out using CORPAS multi-criteria decision-making method and entropy method for determining the weight coefficients. Drill manufacturers (Iscar, Sandvik, Seco and Kennametal) were used as selection alternatives, while the selection criteria were: cutting speed, feed per revolution, pressure coolant and machining time. Base on the defined criteria and alternatives the first choice is drill SD205 (Seco), then SCD-ACG5 (Iscar), R840 (Sandvik) and finally B285 (Kennametal).

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R E F E R E N C E S

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