Application of SAW method for finding best input factors for CBN grinding Al6106 T6

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ABSTRACT

The outcomes of a multi-criteria decision-making (MCDM) study in CBN grinding Al6061 T6 to determine the optimal input process parameters to achieve both low surface roughness (Ra) and maximum material removal speed (MRS) are described in this study. The MCDM problem was addressed using the simple additive weighting (SAW) method, and the weights of the criterion were computed using the MEREC (Method based on the Removal Effects of criterion) technique. In addition, four process input factors were investigated: wheel speed (WS), feed rate (Fe), depth of cut (a_{ed}), and down feed (D_f). The experiment was designed with the 2-level 1/2 fraction type in mind. The experimental output outcomes, including the SR and MRS, were measured and entered into the MCDM issue. Based on the study's findings, the ideal input parameters for CBN grinding Al6061 T6 were identified.

Keywords: MCDM; SAW method; MEREC method; CBN grinding; Surface roughness; Material removal speed; Al6061 T6.

1. INTRODUCTION

CBN wheels are made of cubic boron nitride, which has the same hardness as diamond. Because of their great abrasion resistance and heat conductivity, as well as their ability to retain sharp cutting edges, they are becoming more common in mechanical processing. As a result, CBN grinding research is a fascinating subject. Several studies on CBN grinding have been conducted to date. The authors in [1] presented the wear and life expectancy of electroplated CBN grinding wheels using experiment and modeling methods. The performance of two distinct types of CBN grinding wheels in nodular cast iron plunge grinding is compared in [2]. It was discovered that the abrasive used has a considerable impact on the economics of the grinding process. In [3] reported the effect of several grinding fluids employed in a low-volume cooling-lubrication mode on surface integrity in Inconel 718 CBN grinding. The authors in [4] presented a study comparing the grindability of Ti-6Al-4V in various settings with CBN and diamond brazed type mono-layered grinding wheels. [5] investigated the impact of CBN grit shape on the grindability of 100Cr6 low alloy chrome steel. [6] discussed present and anticipated improvements in high-speed grinding research, as well as the development of high-speed CBN camshaft grinding. [7] investigated the effect of cutting variables such as cutting depth, feed rate, and wheel speed on grinding time during CBN grinding tablet shape punches on a CNC milling machine. [8] describes a study on MCDM in CBN grinding 9CrSi tool steel, and [9] suggested the TOPSIS method for calculating the suitable dressing input parameters for CRN cylindrical grinding En-31 samples.

While there have been various studies on CBN grinding, according to the above investigation, there is still a lack of MCDM studies utilizing the SAW approach to find the best input grinding variables for CBN grinding Al6061 T6 in order to achieve both low SR and maximum MRS.

The paper presents a study on MCDM in CBN grinding Al6061 T6 that takes into account two criteria: minimal Ra and maximum MRS. Furthermore, the SAW methodology was used to solve the MCDM problem, and the MEREC method was used to determine the criteria weights. The best input factors for CBN grinding Al6061 T6 were recommended based on the study's findings.

2. METHODOLOGY

2.1. Method for multi-criteria decision making

In 2006, the SAW technique was originally recommended [10]. The following are the steps for putting this strategy into action.

Step 1: Making decision-making matrix (X) by:

$$X = \begin{matrix} \\ A_1 \\ A_2 \\ \cdots \\ A_m \end{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_n \\ \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & xy_{22} & \cdots & y_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \end{matrix} \quad (1)$$

Where *m* is the alternative number and *n* is the criterion number.

Step 2: Determining the normalized matrix by:

$$n_{ij} = \frac{r_{ij}}{maxr_{ij}} \quad (2)$$

$$n_{ij} = \frac{minr_{ij}}{r_{ij}} \quad (3)$$

Equation (2) is used for criterion as material removal speed, while (3) is used for crite-rion as the surface roughness.

Step 3: Calculating the preference value for each option:

$$V_i = \sum_{j=1}^{n} w_j \cdot n_{ij} \quad (4)$$

Step 7: Rank the options using the idea that the best solution is the one with the highest V_i.

2.2. Method for calculation of criterion weights

In this study, the MEREC technique is used to establish the weights of the criteria. To use this approach, follow the steps outlined below [11]:

Step 1: Build the initial matrix using equation (1).

Step 2: Estimate the normalized values by:

$$h_{ij} = \frac{minx_{ij}}{x_{ij}} \quad (5)$$

$$h_{ij} = \frac{x_{ij}}{maxx_{ij}} \quad (6)$$

Where (5) is applied for criterion Ra, and (6) is employed for criterion MRS.

Step 3: Calculate the alternative performance Si by:

$$S_i = ln\left[1 + \left(\frac{1}{n}\sum_j \left|ln\left(h_{ij}\right)\right|\right)\right] \quad (7)$$

Step 4: Find the performance of ith alternative S'_{ij} by:

$$S'_{ij} = Ln\left[1 + \left(\frac{1}{n}\sum_{k,k\neq j}\left|\ln\left(h_{ij}\right|\right)\right] \quad (8)$$

Step 5: Determine the elimination effect of the j^th criterion E_j using:

$$E_j = \sum_i \left|S'_{ij} - S_i\right| \quad (9)$$

Step 6: Determine the criteria weight by:

$$w_j = \frac{E_j}{\sum_k E_k} \quad (10)$$

3. EXPERIMENTAL WORK

An experiment was carried out to address the MCDM issue. This experiment, which used a 2-level 1/2 fraction design, was created using the Minitab R19 application. As a result, $2^{4-1} = 8$ test runs were carried out. The input factors and their levels are described in table 1. The experimental setup contains a CNC milling machine (Japan Model M-V50C), a CBN grinding wheel, CBN wheel dresser equipment (V-TDM-2 type), Al6061 workpiece samples, and a roughness meter (SURFTEST SV-3100). Figure 1 shows the setup for wheel dressing. table 2 describes the experimental plan in greater detail. The SR and MRS values were measured and computed after the experiment. Table 2 displays the average SR and MRS statistics in the first and second columns from the right.

Table 1. *Input factors.*

Factor	Unit	Low	High
Wheel speed (WS)	rpm	4000	5000
Feed Rate (Fe)	mm/min.	2000	3000
Depth of cut (a_{ed})	mm	0.01	0.025
Down feed (D_f)	mm/double journey	0.5	2

Table 2. *Experimental plan and output results.*

Run Order	R_{pm}	F_e	a_{ed}	D_f	Ra (μm)	MRS (g/h)
1	4000	2000	0.01	0.5	0.1497	3.4779
2	4000	3000	0.025	0.5	0.1510	4.3989
3	5000	2000	0.025	0.5	0.1257	3.5631
4	5000	3000	0.01	0.5	0.1300	4.0997
5	5000	2000	0.01	2	0.3377	10.6490
6	5000	3000	0.025	2	0.1900	16.2297
7	4000	2000	0.025	2	0.1857	11.6366
8	4000	3000	0.01	2	0.1673	13.9366

Figure 1. *Experimental setup for wheel dressing.*

4. DETERMINING THE BEST INPUT FACTORS FOR CBN GRINDING Al6061 T6

4.1. Calculating creation weights

To estimate the weights for the criteria using the MEREC technique, repeat the processes in section 2.2: calculate S_i and S_{ij}' using equations (7) and (8), the criterion removal effect with equation (9), and the weight of the criteria w_j using equation (10). Furthermore, the Ra and MRS weights were found to be 0.4908 and 0.5092, respectively.

4.2. Determining the best input factors

Table 3. *Several calculated results and rankings of options.*

Solutions	n_{ij}		V_i	Rank
	SR	MRS		
1	0.840	0.214	0.521	7
2	0.832	0.271	0.546	6
3	1.000	0.220	0.603	5
4	0.967	0.253	0.603	4
5	0.372	0.656	0.517	8
6	0.661	1.000	0.834	1
7	0.677	0.717	0.697	3
8	0.751	0.859	0.806	2

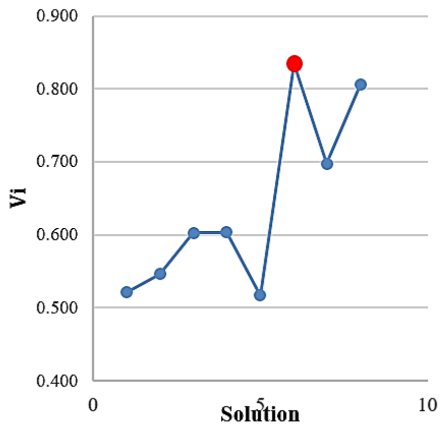

Figure 2. *Experimental setup for wheel dressing.*

Section 2 explains how to perform MCDM using the WAS approach. To begin, use equation (1) to compute the decision-making matrices. Then, using formulas (2) and (3), normalize the initial matrix. V_i is then calculated using the formula (4). Finally, arrange the options so that the one with the highest V_i is the best. Table 3 displays the results of many criteria as well as alternative rankings. Figure 2 also depicts the relationship between V_i values and options.

Option 6 is the best option, according to table 3 and figure 2. This is due to the fact that it has the highest V_i rating (V_i = 0.834). As a result, the best process input parame-ters for CBN grinding Al6061 T6 are: WS = 5000 (rpm), Fe = 3000 (mm/min.), a_{ed} = 0.025 (mm), and D_f = 2 (mm/double journey).

5. CONCLUSIONS

The outcomes of a study on MCDM in CBN grinding Al6061 T6, which employed the SAW technique to solve the MCDM problem and the MEREC method to estimate the criteria weights, were described in this paper. A 2-level 1/2 fraction design experiment was used to accomplish this. The study's findings led to several conclusions:

- On the first occasion, the SAW process was employed to address the MCDM issue in CBN grinding Al6061 T6.

- To achieve the lowest SR and highest MRS, the following input process parameters were found to be optimal for CBN grinding Al6061 T6: WS = 5000 (rpm), Fe = 3000 (mm/min.), a_{ed} = 0.025 (mm), and D_f = 2 (mm/double journey).

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TÓM TẮT

Ứng dụng phương pháp SAW để xác định các thông số đầu vào tốt nhất khi mài CBN nhôm Al6106 T6

Bài báo này trình bày kết quả nghiên cứu ra quyết định đa tiêu chí (MCDM) nhằm xác định các thông số đầu vào tốt nhất khi mài nhôm Al6061 T6 bằng đá mài CBN để đạt nhám bề mặt (Ra) nhỏ nhất và tốc độ bóc tách vật liệu (MRS) lớn nhất. Phương pháp SAW đã được sử dụng để giải bài toán MCDM và phương pháp MEREC đã được dùng để xác định trọng số cho các tiêu chí. Thêm vào đó, bốn thông số đầu vào bao gồm tốc độ quay của đá (WS), tốc độ chạy đá (Fe), chiều sâu mài (a_{ed}), và lượng ăn dao (D_f) đã được khảo sát. Thí nghiệm đã được thiết kế theo kiểu 1/2 phân số. Các thông số đầu ra của thí nghiệm gồm SR và MRS đã được xác định và sử dụng cho bài toán MCDM. Từ kết quả của bài toán, các thông số đầu vào tốt nhất khi mài CBN Al6061-T6 đã được xác định.

Từ khoá: MCDM; Phương pháp SAW; Phương pháp MEREC; Mài CBN; Nhám bề mặt; Tốc độ bóc tách vật liệu; Al6061 T6.