Application of SAW Technique for Finding the Best Dressing Mode for Surface Grinding Hardox 500

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Abstract—This paper presents the findings from the multi-criteria decision-making (MCDM) approach study on selecting the best dressing mode (DM) for surface grinding (SG) Hardox 500. The study employed the Simple Additive Weighting (SAW) approach to solve the MCDM problem, and the Entropy method was utilized to estimate the weights of the criteria. Moreover, material removal rate (MRR) and surface roughness (RS) were selected as the two criteria for the investigation. Additionally, the five dressing parameters - fine dressing depth (T_f), rough dressing depth (T_r), rough dressing times (Nr), and non-feeding dressing (N_{non}) - were investigated. 16 L16 (4^4x2^1) experimental runs were also designed and executed. For the first time, the MCDM for the SG process of Hardox 500 has been successfully solved using the SAW approach. From the results of the work, alternative No. 5 is the best option and the ideal input parameters (IP) of the dressing process were proposed.

Keywords—Surface grinding, Hardox 500, Surface Roughness, Material removal rate, MCDM, SAW method.

I. INTRODUCTION

SG is a popular method of grinding that's used to give flat surfaces a smooth finish. As a result, many publications on optimum IP in SG processes have been done. In practice, there are many methods to get the best IP for SG including conducting optimization problems or solving MCDM issues. For example, ideal IPs have been found in [1], [2] for single and in [3], [4] for multi-target optimization problems. Moreover, the application of MCDM methods to deal with this task has also attracted many scientists.

Until now, there have been several studies on the determination of optimum grinding IP with the use of MCDM methods. The IP of the CBN grinding process for getting minimal SR and maximal MRS when processing Al6061 was proposed in [5] by application of the WASPAS technique. The Data Envelopment Analysis-based Ranking (DEAR) technique was employed by the authors in [6] to determine the input variable values that would simultaneously ensure the lowest SR and the maximum MRR. The authors in [7] used four MCDM approaches (MAIRCA, MARCOS, EAMR, and TOPSIS) to find the optimal IP for internal grinding of 90CrSi. In order to determine the ideal DM for the external grinding (EG) SKD11 steel, the MABAC method was utilized, [8].

The TOPSIS approach was used by the authors in [9] to select abrasive materials for grinding. In [10], the WASPAS technique was applied to get the optimum dressing values for minimum roundness and maximum life of the wheel when EG SKD11 tool steel. Besides, the EDAS method has been used to find the best dressing mode in internal grinding SKD11 steel, [11]. The optimal IP for getting the maximal life of the wheel and minimal SR using the MCDM method was described in [12]. This technique (the MOORA method) was also used for grinding with CBN wheels, [13].

In this study, the results of an MCDM work for getting the best IP in SG for processing Hardox 500 were described. The MCDM procedure of the investigation utilized the SAW technique, while the Entropy method was performed to determine the weights of the criterion. Using the SAW technique, the MCDM for the Hardox 500's SG process has been successfully solved for the first time. Furthermore, when the MCDM issue was solved using the two requirements, SR and MRR, the optimal DM was suggested.

II. Methodology

Methodology for MCDM

The SAW method was initially proposed around 2006, [14]. The stages to implementing this method are as follows.

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

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

In which *m* and *n* are the alternative and criterion numbers.

Step 2: Finding the normalized matrix by:

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

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

Note that MRR criterion is employed in equation (2), while the SR criterion is used in equation (3).

Step 3: Determining the preference value for each option:

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

Step 4: Arrange the options according to the principle that the option with the highest V_i is the best one.

Methodology for finding criterion weight

The entropy technique has been applied to establish criterion weights for the investigation. It is determined as follows, [15].

Step 1: Calculating indicator normalized values:

$$p_{ij} = \frac{x_{ij}}{m + \sum_{i=1}^{m} x_{ij}^2} \quad (5)$$

Step 2: Determining the Entropy for each indicator:

$$me_j = -\sum_{i=1}^{m}\left[p_{ij} \times ln(p_{ij})\right] - \left(1 - \sum_{i=1}^{m} p_{ij}\right) \times ln\left(1 - \sum_{i=1}^{m} p_{ij}\right) \quad (6)$$

Step 3: Finding the weight of each indicator:

$$w_j = \frac{1 - me_j}{\sum_{j=1}^{m}(1 - me_j)} \quad (7)$$

III. Experimental Setup

Fig. 1 Setup of experiment

In this work, an experiment has been performed to find the optimal dressing factor for SG Hardox 500. Using the Minitab R19 tool, an L16 (4^4x2^1) design and 16 experimental runs were done. The levels of initial IP are described in Table I. The setup of the experiment is displayed in Fig. 1. A SG machine (PSG-CL3060AH, Taiwan), a dressing tool (3908-0088C type 2, Russia), a piezoelectric dynamometer (Kistler 9257BA, Germany), and a grinding wheel (Cn60MV1G V1, 350x40x127 35 (m/s)) make up the setup. The following is how the experiment was conducted: Each experiment was carried out three times. An SJ201 SR meter has been applied for measuring SR. The amount of time it takes for grinding to begin after dressing and utilizing a standard Py spike is what determines the wheel life. The experiment was conducted as follows: Every component's processing time was tracked during the experiment. Additionally, weight measurements of the components will be obtained prior to and following milling. Once the experiment is over, measure SR (Ra) and calculate MRR using formula (8).

$$MRR = \sum_{i=1}^{n} \frac{m_{pbi}}{m_{pai}} \quad (8)$$

where m_{pbi} and m_{pai} represent the mass of part I before and after machining (mg), and i is the number of parts.
Table II illustrates the setup of experiments and the outcomes (SR and MRR). The average of three SR observations and MRR calculations are shown in this table.

TABLE I. Input dressing factors

No.	Factors	Symbol	Level			
			1	2	3	4
1	Rough dressing depth (mm)	T_r	0.015	0.02	0.025	0.03
2	Rough dressing times	N_r	1	2	3	4
3	Fine dressing depth (mm)	T_f	0.005	0.01	-	-
4	Fine dressing times	N_f	0	1	2	3
5	Non-feeding dressing	N_{non}	0	1	2	3

TABLE II. Experimental matrix and output results

No.	T_r	N_r	N_f	N_{non}	T_f	SR (μm)	MRR (mm^3/s)
1	0.015	1	0	0	0.005	0.674	5.732
2	0.015	2	1	1	0.005	0.590	5.709
3	0.015	3	2	2	0.010	0.594	5.505
4	0.015	4	3	3	0.010	0.647	6.431
5	0.020	1	1	2	0.010	0.436	8.494
6	0.020	2	0	3	0.010	0.480	5.222
7	0.020	3	3	0	0.005	0.617	3.356
8	0.020	4	2	1	0.005	0.785	11.774
9	0.025	1	2	3	0.005	0.452	5.645
10	0.025	2	3	2	0.005	0.812	6.529
11	0.025	3	0	1	0.010	1.216	3.973
12	0.025	4	1	0	0.010	0.875	6.007
13	0.030	1	3	1	0.010	0.943	7.404
14	0.030	2	2	0	0.010	0.693	6.650
15	0.030	3	1	3	0.005	1.384	5.603
16	0.030	4	0	2	0.005	0.774	11.103

IV. FINDING BEST DRESSING FACTORS

Finding weights for the criteria

By using the Entropy approach (see Section 2.2), the weights of the criterion are ascertained as follows: First, use equation (5) to compute the normalized values pij. Use equation (6) to find the Entropy value for each indicator mej. Finally, use Equation (7) to get the weight of the criteria w_j. The weights of R_a and MRR were determined to be 0.5645 and 0.4355, respectively.

Finding the best dressing factors

The way of applying the SAW technique for MCDM is explained in Section 2. First, calculate the decision-making matrices using equation (1). The first matrix should then be normalized using formulas (2) and (3). After that, Vi is computed using formula (4). In the end, sort the alternatives to ensure the optimal alternative has the highest Vi. Table III shows alternative ranks in addition to the outcomes of other criteria. Besides, the relation between Vi values and options is also shown in Fig. 2. Since option 5 has the highest value of Vi, it is evident from the Figure that it is the best choice.

Among all the options in Table III, option 5 is the best choice. Its greatest utility function value, Vi = 0.879, is the cause of this. From that and from Table 2, the ideal solution (option 5) consists of the following values: Nr = 1 (times), N_f = 1 (times), T_f = 0.01 (mm), N_{non} = 2, and Tr = 0.02 (mm). With this ideal mode, SR=0.436 (μm), and MRR=8.494 (mm^3/s) will be produced.

TABLE III. Some outcomes and option ranking

Solutions	nij		Vi	Rank
	SR	MRS		
1	0.647	0.487	0.577	10
2	0.739	0.485	0.628	6
3	0.734	0.468	0.618	8
4	0.674	0.546	0.618	7
5	1.000	0.721	0.879	1
6	0.908	0.443	0.706	5
7	0.706	0.285	0.523	13
8	0.555	1.000	0.749	3
9	0.965	0.479	0.753	2
10	0.537	0.555	0.544	11
11	0.359	0.337	0.349	16
12	0.498	0.510	0.504	14
13	0.462	0.629	0.535	12
14	0.629	0.565	0.601	9
15	0.315	0.476	0.385	15
16	0.564	0.943	0.729	4

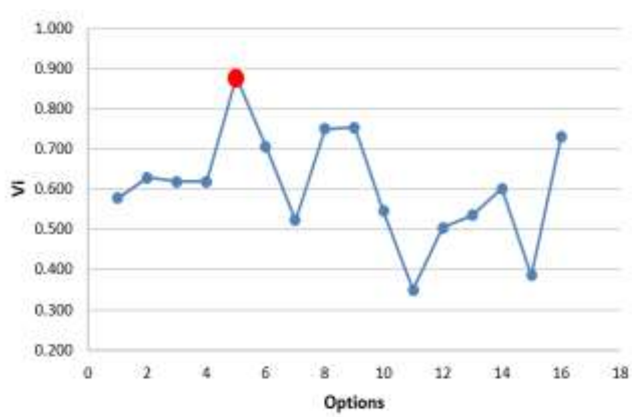

Fig. 2 Relation between options and Vi

V. CONCLUSIONS

In this work, the optimal DM for SG Hardox 500 steel was identified using the SAW process. It is recommended to select option 5 with the goal to achieve both the largest MRR and lowest SR, based on the study's findings. With a maximum utility function value of Vi = 0.879, Solution No. 5 had the best performance characteristic among the 16 test runs. The

SAW approach determined that T_r = 0.02 (mm), N_r = 1 (times), N_f = 0 (times), T_f = 0.01 (mm), and N_{non} = 2 are the best DM for SG. Also, this study has not addressed how IP affects SR and MRR. This is because, like other MCDM techniques, the SAW methodology only looks for the best solution among the available test plans; it does not evaluate how factors affect the objective functions. Therefore, further research is needed to determine the influence of IP on SR and MRR.

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