Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 45 No. 2
February 2024

Using the MAIRCA Method for Determining the Best Dressing Factors in Surface Grinding Hardox 500

Dinh Van Thanh[1], Vu Duc Binh[2], Vu Duong[3], Nguyen Thanh Tu[4], Nguyen Van Trang[4,*]
[1]East Asia University of Technology, Hanoi, Vietnam
[2]Viet Tri University of Industry, Viet Tri, Vietnam
[3]Duy Tan University, Da Nang, Vietnam
[4]Thai Nguyen University of Technology, Thai Nguyen, Vietnam

Abstract

The results of the study on choosing the optimal dressing mode for surface grinding Hardox 500 using the multi-criteria decision-making (MCDM) method are presented in this paper. The MCDM problem was solved in the study using the Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA) method, and the weights of the criteria were determined using the entropy method. Furthermore, the two criteria for the inquiry were chosen to be surface roughness (RS) and material removal rate (MRR). The five dressing parameters were also examined: fine dressing depth (T_f), rough dressing depth (T_r), rough dressing times (N_r), fine dressing times (N_f), and non-feeding dressing (N_{non}). Additionally, 16 L16 (44x21) experimental runs were planned and carried out. The issue with MCDM has been resolved. The results of the analysis demonstrate that, for the input parameters T_r = 0.02 (mm), N_r = 1 (times), N_f = 1 (times), T_f = 0.01 (mm), and N_{non} = 2, option No. 5 is the optimal dressing regime.

Keywords: Surface grinding, Hardox 500, MCDM, MAIRCA method, Entropy method, Surface Roughness, Material removal rate.

1. Introduction

In mechanical manufacturing, grinding is a crucial machining technique that is frequently used for finishing and semi-finishing. Scientists are therefore very interested in finding the ideal grinding mode. The best grinding mode for several grinding applications, including surface [1-4], internal [5-7], and external grinding [5, 8, 9], was determined. Solving single- [1-4, 9] and multi-objective optimization problems [5, 7] or applying MCDM techniques [8, 10] are the strategies used to research this issue.

To day, numerous studies have employed various MCDM techniques to determine the optimal grinding mode. In order to determine the ideal dressing mode for the external grinding SKD11 tool test, the MABAC technique was utilized in [8]. The ideal input process parameters for CBN grinding Al6061 were found in [11] using the WASPAS method in order to achieve both minimum SR and maximal MRS. The Data Envelopment Analysis-based Ranking (DEAR) method was applied in [10] to determine the input parameter values that would simultaneously ensure the maximum MRR criterion and the least surface roughness. Using four MCDM techniques-TOPSI, MARCOS, EAMR, and MAIRCA-the optimal input parameters for internal grinding of 90CrSi were selected in [12].

A paper on the TOPSIS approach to abrasive material selection for grinding was released [13]. In order to achieve the lowest roundness and the longest wheel life during the dressing stage of external grinding of SKD11 steel, the WASPAS technique was utilized to identify the ideal input process parameters [14]. The EDAS technique was used to identify the ideal input process parameters for dressing in the external grinding of SKD11 steel in order to minimize RS and optimize wheel life [15]. In [16], the MCDM problem for the CBN grinding of SKD11 tool steel was solved using the MOORA technique. The EDAS technique was used to determine the ideal input process parameters for the dressing stage in the internal grinding of SKD11 tool steel. The findings are recorded in [17].

The results of an MCDM analysis for choosing the best dressing mode when surface grinding Hardox 500 are presented in this paper. The MCDM approach of the study utilized the MAIRCA method, and the weights of the criteria were determined using the entropy method. After the MCDM problem was solved using two criteria, SR and MRR, the optimal dressing input factors were suggested.

2. Methodology

2.1. Method for MCDM

Using the MAIRCA technique, the MCDM problem was solved. Using this strategy requires completing the following phases [12]:

Step 1: Making the initial matrix by:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ x_{21} & \cdots & x_{2n} \\ \vdots & \cdots & \vdots \\ x_{mn} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Where x_{mn} is the outcome of criterion *n* in variant *m*.

Step 2: Determining options based on vairious selection P_{A_j} by:

$$P_{A_j} = \frac{1}{m} \text{ , j = 1, 2, …, n} \tag{2}$$

Step 3: Finding the components t_{pij} by:

$$t_{p_{ij}} = P_{A_j} \cdot w_j \text{ , i = 1, 2, …, m; j = 1, 2,…} \tag{3}$$

Where w_j is the weight of the jth criterion.

Step 4: Calculating t_{rij} by:

+) In the event that condition j is maximally large:

$$t_{r_{ij}} = t_{p_{ij}} \cdot \left(\frac{x_{ij} - x_i^-}{x_i^+ - x_i^-}\right) \tag{4}$$

+) In the event that condition j is as tiny as feasible:

$$t_{r_{ij}} = t_{p_{ij}} \cdot \left(\frac{x_{ij} - x_i^+}{x_i^- - x_i^+}\right) \tag{5}$$

Step 5: Determining the complete gap matrix g_{ij} by:

$$g_{ij} = t_{p_{ij}} - t_{r_{ij}} \tag{6}$$

Step 6: Determine the ultimate values (Q_i) of the criterion functions using the available options:

$$Q_i = \sum_{i=1}^{m} g_{ij}$$

2.2. Method for determining of the weight of criteria

The weights of the criteria were determined for this study using the entropy technique. You can implement this method by doing the following [18].

Step 1: Determining indicator normalized values:

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

Step 2: Finding the Entropy for each indicator:

$$me_j = -\sum_{i=1}^{m}\left[p_{ij} \times ln(p_{ij})\right] - \left(1 - \sum_{i=1}^{m} p_{ij}\right) \times ln\left(1 - \sum_{i=1}^{m} p_{ij}\right) \tag{9}$$

Step 3: Calculating the weight of each indicator:

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

3. Experimental setup

To determine the ideal dressing factor for surface grinding Hardox 500, an experiment was carried out. This experiment was designed with an L16 (44x21) design and 16 experimental runs using the Minitab R19 tool. The levels of the input factors are displayed in Table 1. In Figure 1, the experimental setup is shown. The setup consists of a piezoelectric dynamometer (Kistler 9257BA, Germany), a surface grinding machine (PSG-CL3060AH, Taiwan), a dressing tool (3908-0088C type 2, Russia), and a grinding wheel (Cn60MV1G V1, 350x40x127, 35 m/s). The experiment was carried out as follows: Every experiment was conducted three times. The surface roughness (SR) was measured using an SJ201 surface roughness meter. Wheel life is determined by how long it takes for grinding to start after dressing and using a normal Py spike. This is how the experiment was carried out: Throughout the experiment, the processing time of each component was monitored. Furthermore, weight measurements will be taken of the components both before and after machining. After the experiment is complete, measure SR (Ra) and use formula (11) to get MRR.

$$MRR = \sum_{i=1}^{n} \frac{m_{pbi}}{m_{pai}}$$

Where *i* is the number of pieces and m_{pbi} and mpai are the masses of part i before and after machining (mg).

Fig. 1. Experimental setup

The experimental design and the output outcomes (SR and MRR) are displayed in Table 2. This table displays the mean of three SR measurements and MRR calculations.

Table 1. Input dressing parameters

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 2. Experimental plan 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

Table 3. Somecalculated results and ranking of options

Trial.	kij		lij		Qi	Rank
	Ra	MRR	Ra	MRR		
1	0.0264	0.0077	0.0089	0.0195	0.0284	10
2	0.0295	0.0076	0.0057	0.0196	0.0254	7
3	0.0294	0.0069	0.0059	0.0203	0.0262	9
4	0.0274	0.0099	0.0079	0.0173	0.0251	6
5	0.0353	0.0166	0.0000	0.0106	0.0106	1

6	0.0336	0.0060	0.0016	0.0212	0.0228	5
7	0.0285	0.0000	0.0067	0.0272	0.0340	13
8	0.0223	0.0272	0.0130	0.0000	0.0130	2
9	0.0347	0.0074	0.0006	0.0198	0.0204	4
10	0.0213	0.0103	0.0140	0.0170	0.0310	11
11	0.0063	0.0020	0.0290	0.0252	0.0543	15
12	0.0190	0.0086	0.0163	0.0186	0.0350	14
13	0.0164	0.0131	0.0189	0.0141	0.0330	12
14	0.0257	0.0106	0.0096	0.0166	0.0261	8
15	0.0000	0.0073	0.0353	0.0200	0.0552	16
16	0.0227	0.0250	0.0126	0.0022	0.0147	3

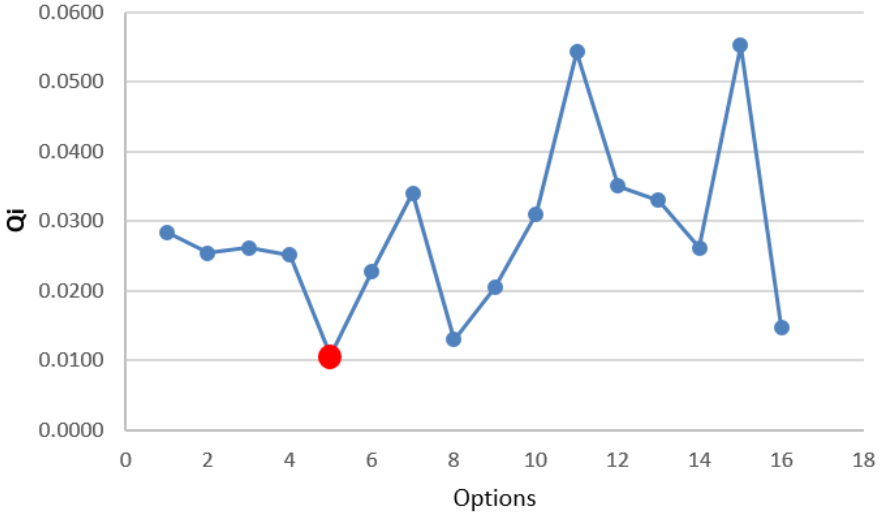

Fig. 2. Relation between options and Qi

4. Determining the best dressing parameters

4.1. Determining the weights for the criteria

The weights of the criterion are determined by applying the entropy technique (refer to Section 2.2) as follows: To begin with, compute the normalized value p_{ij} using equation (8). To determine the entropy value for each indication m_{ej}, apply equation (9). Lastly, determine the weight of the criteria wj using Equation (10). Ra and MRR were found to have weights of 0.5645 and 0.4355, respectively.

2.2. Determining the best dressing parameters

Adopting the measures recommended in Section 2.1, in particular: After the starting matrix is set up, the priority, or criterion, is calculated by applying equation (2). As Ra and MRS are assigned the same weight, their priority is 1/16 = 0.0625. Moreover, the weight of the criterion is determined in Section 2.2, and the value of the parameter is found using Equation (3). values of 0.0353 and 0.0272, respectively, were obtained by Ra and MRS. The values of are then determined using equations (4) and (5), while the values of g_{ij} are determined using equation (6). Lastly, we may determine the values of the criteria functions Q_i by utilizing equation (7). Table 3 displays the traits and scores that were produced using the MAIRCA technique for the various rating options. Furthermore, each solution's Qi values are displayed in Figure 2.

Option 5 is the greatest option out of all those in Table 3. This is a result of Q^{i*}=0.0106, its minimal utility function value. Consequently, the following values comprise the ideal solution: N_{non} = 2, T_r = 0.02 (mm), N_r = 1 (times), Nf = 1 (times), and T_f = 0.01 (mm).

5. Conclusions

Using the MAIRCA technique, the several best dressing modes for surface grinding Hardox 500 steel were determined in this work. Based on the study's findings, it is advised to use option 5 in order to simultaneously achieve the maximum MRR and the lowest SR. Out of the 16 test runs, Solution No. 5 had the best performance characteristic, with a maximum utility function value of R^{i*}=0.7844. The optimal dressing modes for surface grinding, as determined by the MAIRCA method, are T_r = 0.02 (mm), N_r = 1 (times), N_f = 0 (times), T_f = 0.01 (mm), and N_{non} = 2.

Acknowledgment

This work was supported by Thai Nguyen University of Technology.

Refrences

[1] Tran, T.H., et al. Effect of Dressing Parameters on Material Removal Rate when Surface Grinding SKD11 Tool Steel. in Materials Science Forum. 2021. Trans Tech Publ.

[2] Tran, T.H., et al. Improvement of wheel life by optimization of dressing parameters in surface grinding of SKD11 steel. in Materials Science Forum. 2021. Trans Tech Publ.

[3] Tran, T.H., et al. Influence of dressing conditions on surface roughness when surface grinding SKD11 steel. in Materials Science Forum. 2021. Trans Tech Publ.

[4] Tran, T.H., et al. Optimizing dressing conditions for minimum flatness tolerance when grinding SKD11 tool steel. in Materials Science Forum. 2021. Trans Tech Publ.

[5] Giang, T.N., et al., Studying the influence of dressing parameters on the surface roughness when conducting the external grinding of SKD11 steel. Solid State Phenomena, 2021. 324: p. 45-51.

[6] Hung, L.X., et al., Determining the optimum set of dressing parameters satisfying minimum surface roughness when conducting the internal grinding of hardened SKD11 steel. Solid State Phenomena, 2021. 324: p. 58-65.

[7] Tuan, N.A., et al. Optimization of dressing parameters for minimum surface roughness and maximum material removal rate in internal grinding of SKD11 tool steel. in E3S Web of Conferences. 2021. EDP Sciences.

[8] Le, H.-A., et al., Determining the best dressing parameters for external cylindrical grinding using MABAC method. Applied Sciences, 2022. 12(16): p. 8287.

[9] Le, H.A., et al. Impacts of dressing conditions on wheel lifetime when external grinding of SKD11 steel. in International Conference on Engineering Research and Applications. 2021. Springer.

[10] Trung,D.D ., et al. Combining Taguchi method and DEAR method for multi-objective optimization of grinding process. in E3S Web of Conferences. 2021. EDP Sciences.

[11] Khai, D.Q., et al. Determining Best Input Parameters for CBN Grinding Al6106 T6 Using WASPAS Method. in International Conference on Engineering Research and Applications. 2022. Springer.

[12] Nguyen, H.-Q., et al., A comparative study on multi-criteria decision-making in dressing process for internal grinding. Machines, 2022. 10(5): p. 303.

[13] Maity, S.R. and S. Chakraborty, Grinding wheel abrasive material selection using fuzzy TOPSIS method. Materials and Manufacturing Processes, 2013. 28(4): p. 408-417.

[14] Danh, T.H., et al. Application of WASPAS Method for Determining Best Process Factors in External Grinding. in International Conference on Engineering Research and Applications. 2022. Springer.

[15] Danh, T.H., et al. Selection of Input Parameters in External Cylindrical Grinding Using EDAS Method. in International Conference on Engineering Research and Applications. 2022. Springer.

[16] Danh, B.T., et al. Study on Multi-criteria Decision Making in CBN Grinding SKD11 Tool Steel. in International Conference on Engineering Research and Applications. 2022. Springer.

[17] Huy, T.Q., et al. Application of EDAS Method for Best Dressing Mode for Internal Cylindrical Grinding. in International Conference on Engineering Research and Applications. 2022. Springer.

[18] Hieu, T.T., N.X. Thao, and L. Thuy, Application of MOORA and COPRAS Models to Select Materials for Mushroom Cultivation. Vietnam Journal of Agricultural Sciences, 2019. 17(4): p. 32-2331.