*Journal of Harbin Engineering University*
*ISSN: 1006-7043*

Vol 45 No. 2
February 2024

# Using the EAMR Method for Determining the Best Dressing Parameters in Surface Grinding Hardox 500

**Dinh Van Thanh[1], Vu Duong[2], Vu Duc Binh[3], Nguyen Van Trang[4], Nguyen Thanh Tu[4,*]**

[1] East Asia University of Technology, Hanoi, Vietnam
[2] Duy Tan University, Da Nang, Vietnam
[3] Viet Tri University of Industry, Viet Tri, Vietnam
[4] Thai Nguyen University of Technology, Thai Nguyen, Vietnam

**Abstract:** The results of the multi-criteria decision-making (MCDM) method study on the optimal dressing mode selection for surface grinding Hardox 500 are presented in this work. The MCDM problem was solved in the study using the evaluation by area-based method of ranking (EAMR) methodology, and the weights of the criteria were estimated using the entropy method. Furthermore, the two criteria chosen for the inquiry were surface roughness (RS) and material removal rate (MRR). In addition, research was done on the five dressing parameters: rough dressing depth ($T_r$), rough dressing times ($N_r$), non-feeding dressing ($N_{non}$), fine dressing times ($N_f$ ) and fine dressing depth ($T_f$). Additionally, 16 L16 (44x21) experimental runs were planned and carried out. The issue with MCDM has been resolved. The results of the analysis indicate that, given 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, Surface Roughness, Material removal rate, MCDM, EAMR method.

## 1. Introduction

Finishing and semi-finishing are frequent uses for grinding, a type of mechanical processing. Approximately 20–25% [1] of the entire cost of machining is spent on grinding. Thus, many scientists have been interested in researching the best input parameters for the grinding process.It is possible to solve single- and multi-objective optimization problems to find the ideal input parameters for the grinding process. Furthermore, MCDM research can be used to identify the best grinding process input parameters. Numerous studies have employed different MCDM techniques to determine the optimal grinding mode. The Data Envelopment Analysis-based Ranking (DEAR) method was applied in [2] to determine the input parameter values that would simultaneously ensure the lowest surface roughness and the maximum MRR criterion.

The best input process parameters for CBN grinding Al6061 were found in [3] using the WASPAS method in order to achieve both maximum MRS and minimum SR. In order to obtain the lowest roundness and the longest wheel life, this technique was also utilized to calculate the ideal input process parameters for the dressing stage of external grinding of SKD11 steel [4]. An article about the TOPSIS method of selecting grinding abrasive materials was published in [5]. The authors in [6] used four MCDM approaches (TOPSI, MARCOS, EAMR, and MAIRCA) to find the optimal input parameters for internal grinding of 90CrSi. In order to determine the best dressing mode for the external grinding SKD11 tool test, the MABAC technique was utilized [7]. In order to address the MCDM issue for the CBN grinding of SKD11 tool steel, the MOORA approach was employed in [8]. The EDAS technique was used to determine the optimal input process parameters for the dressing stage of the internal grinding of SKD11 tool steel. The outcomes are recorded in [9]. The CURLI (Collaborative Unbiased Rank List Integration) technique was used to identify the ideal grinding mode in order to concurrently achieve the lowest feasible surface roughness and minimum flatness tolerance [10]. The MCDM approach was also used to find the ideal input process parameters for dressing in the external grinding of SKD11 steel in order to minimize RS and optimize wheel life [11]. used four MCDM approaches (TOPSI, MARCOS, EAMR, and MAIRCA) to find the optimal input parameters for internal grinding of 90CrSi. In order to determine the best dressing mode for the external grinding SKD11 tool test, the MABAC technique was utilized [7]. In order to address the MCDM issue for the CBN grinding of SKD11 tool steel, the MOORA approach was employed in [8]. The EDAS technique was used to determine the optimal input process parameters for the dressing stage of the internal grinding of SKD11 tool steel. The outcomes are recorded in [9]. The CURLI (Collaborative Unbiased Rank List Integration) technique was used to identify the ideal grinding mode in order to concurrently achieve the lowest feasible surface roughness and minimum flatness tolerance [10]. The MCDM approach was also used to find the ideal input process parameters for dressing in the external grinding of SKD11 steel in order to minimize RS and optimize wheel life [11].

The results of an MCDM analysis for choosing the best dressing mode for surface grinding Hardox 500 are presented in this work. The MCDM approach of the study utilized the EAMR method, while the weights of the criteria were determined by the application of the entropy method. After the MCDM problem was solved using the two criteria, SR and MRR, the optimal dressing technique was suggested.

## 2. Methodology

### *2.1. Method for MCDM*

The following stages are used to carry out the EAMR approach [12].

Step 1: Making the decision matrix by:

$$X_d = \begin{bmatrix} x_{11}^d & \cdots & x_{1n}^d \\ x_{21}^d & \cdots & x_{21}^d \\ \vdots & \cdots & \vdots \\ x_{m1}^d & \cdots & x_{mn}^d \end{bmatrix} \quad (1)$$

Where 1 ≤d ≤ k, where k is the decision maker number, and d is an indication of the decision maker.

Step 2: Determine the mean value of each alternative for each criterion by:

$$\bar{x}_{ij} = \frac{1}{k}\left(x_{ij}^1 + x_{ij}^2 + \cdots + x_{ij}^k\right) \quad (2)$$

Step 3: Calculating the creation weights.

Step 4: Finding the weighted average for each criterion:

$$\bar{w}_j = \frac{1}{k}\left(w_j^1 + w_j^2 + \cdots + w_j^k\right) \quad (3)$$

Step 5: Determining $n_{ij}$ by:

$$n_{ij} = \frac{\bar{x}_{ij}}{e_j} \quad (4)$$

Where $e_j$ can be foudn by:

$$e_j = max_{i\in\{1,\dots,m\}}\left(\bar{x}_{ij}\right) \quad (5)$$

Step 6: Calculating the normalized weight by:

$$v_{ij} = n_{ij} \cdot \bar{w}_j \quad (6)$$

Step 7: Finding the normalized score of the criteria.

If criterion *j* is as big as possible,

$$G_i^+ = v_{i1}^+ + v_{i2}^+ + \cdots + v_{im}^+ \quad (7)$$

If criterion j is as smaller as possible:

$$G_i^- = v_{i1}^- + v_{i2}^- + \cdots + v_{im}^{-+} \quad (8)$$

Step 8: Determining the values of the ranking (RV) from $G_i^+$ and $G_i^-$.

Step 9: Finding the evaluation score of the alternatives by:

$$S_i = \frac{RV(G_i^+)}{RV(G_i^-)} \quad (9)$$

Choose the option with the largest $S_i$ as the best one.

### *2.2. Method for finding the weight of criteria*

The weights of the criteria in this investigation were determined using the entropy technique. These steps can be used to determine it [13].

Step 1: Finding indicator normalized values:

$$p_{ij} = \frac{x_{ij}}{m + \sum_{i=1}^{m} x_{ij}^2} \quad (10)$$

Step 2: Calculating the entropy for each indicator:

$$me_j = -\sum_{i=1}^{m}\left[p_{ij} \times ln(p_{ij})\right] - \left(1 - \sum_{i=1}^{m} p_{ij}\right) \times ln\left(1 - \sum_{i=1}^{m} p_{ij}\right) \quad (11)$$

Step 3: Determining the weight of each indicator:

$$w_j = \frac{1 - me_j}{\sum_{j=1}^{m}(1 - me_j)} \quad (12)$$

## 3. Experimental setup

**Fig. 1. Experimental setup**

To determine the ideal dressing factor for surface grinding Hardox 500, an experiment was carried out. This experiment was created using an L16 (44x21) design and 16 experimental runs using the Minitab R19 tool. The levels of the input parameters 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), Vietnam). 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. The wheel life is determined by how long it takes for grinding to start after dressing and using a typical Py spike. This is how the experiment was carried out: Throughout the experiment, the processing times of each component were monitored. Furthermore, weight measurements of the constituents will be acquired both before and after milling. After the experiment is finished, use formula (8) to calculate MRR and measure SR (Ra).

$$MRR = \sum_{i=1}^{n} \frac{m_{pbi}}{m_{pai}} \quad (13)$$

where i is the number of pieces, and mpbi and mpai stand for the mass of part i both before and after machining (mg).

The experimental plan and results (SR and MRR) are displayed in Table 2. This table displays the average of three SR measurements and MRR computations.

**Table 1. Input dressing parameters**

| No | Parameters | 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. | Tr | Nr | Nf | Nnon | Tf | SR (μm) | MRR (mm3/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 |

## 4. Determining the best dressing factors

### *4.1. Determining the weights for the criteria*

The following formulas are used to determine the weights of the criterion using the entropy technique (see Section 2.2): First, compute the normalized values pij using equation (10). To determine the entropy value for each indication mej, use equation (11). Lastly, to get the weight of the criteria wj, utilize Equation (12). Ra and MRR were found to have weights of 0.5645 and 0.4355, respectively.

### *4.2. Determining the best dressing factors*

The following procedures (see Section 2.1) are followed in order to apply the EAMR approach to MCDM: The decision matrix should be set up in accordance with formula (1), noting that there is only one result set and that k = 1. Using Equation (2), get the mean of the options for each criterion, keeping in mind that since k = 1, Next, as mentioned in Section 5.1, determine what the criteria's weights are. Next, use formula (3) to get the average weighted values, keeping in mind that k = 1. Determine nij using the formula (4) and the definition of ej provided by (5). Next, compute vij using formula (6). The values of Gi are determined by using equations (7) and (8). Finally, use formula (9). to compute the Si value. The results of the calculations and the ranking of the options are shown in Table 3. It is clear from this table that option number five is the best. The relationship between choices and Si values is depicted in Figure 2. The figure makes it obvious that option 5, which is shown by the red circle, is the best choice because it has the highest Si value.

Option 5 is the greatest option in Table 3 out of all of them. This is due to its maximum utility function value, $S_i$ = 1.7664. Thus, the variables $N_r$ = 1 (times), $N_f$ = 1 (times), $T_f$ = 0.01 (mm), $N_{non}$ = 2, $T_r$ = 0.02 (mm), and so on comprise the optimal solution.

**Table 3. Some calculated results and ranking of options**

| Trial. | nij | | vij | | Gi | | Si | Rank |
|---|---|---|---|---|---|---|---|---|
| | Ra | MRR | Ra | MRR | Ra | MRR | | |
| 1 | 2.0534 | 0.4868 | 1.1592 | 0.2120 | 1.1592 | 0.2120 | 0.1829 | 16 |
| 2 | 0.4265 | 0.4849 | 0.2408 | 0.2112 | 0.2408 | 0.2112 | 0.8769 | 7 |
| 3 | 0.4292 | 0.4675 | 0.2423 | 0.2036 | 0.2423 | 0.2036 | 0.8403 | 9 |
| 4 | 0.4675 | 0.5462 | 0.2639 | 0.2378 | 0.2639 | 0.2378 | 0.9012 | 6 |
| 5 | 0.3150 | 0.7214 | 0.1778 | 0.3142 | 0.1778 | 0.3142 | 1.7664 | 1 |
| 6 | 0.3468 | 0.4435 | 0.1958 | 0.1931 | 0.1958 | 0.1931 | 0.9863 | 5 |
| 7 | 0.4461 | 0.2851 | 0.2518 | 0.1241 | 0.2518 | 0.1241 | 0.4929 | 13 |
| 8 | 0.5672 | 1.0000 | 0.3202 | 0.4355 | 0.3202 | 0.4355 | 1.3600 | 2 |
| 9 | 0.3266 | 0.4794 | 0.1844 | 0.2088 | 0.1844 | 0.2088 | 1.1323 | 4 |
| 10 | 0.5869 | 0.5545 | 0.3314 | 0.2415 | 0.3314 | 0.2415 | 0.7288 | 10 |
| 11 | 0.8786 | 0.3374 | 0.4960 | 0.1469 | 0.4960 | 0.1469 | 0.2962 | 15 |
| 12 | 0.6320 | 0.5102 | 0.3568 | 0.2222 | 0.3568 | 0.2222 | 0.6227 | 12 |
| 13 | 0.6814 | 0.6289 | 0.3847 | 0.2738 | 0.3847 | 0.2738 | 0.7119 | 11 |
| 14 | 0.5010 | 0.5648 | 0.2828 | 0.2459 | 0.2828 | 0.2459 | 0.8696 | 8 |
| 15 | 1.0000 | 0.4759 | 0.5645 | 0.2072 | 0.5645 | 0.2072 | 0.3671 | 14 |
| 16 | 0.5590 | 0.9430 | 0.3156 | 0.4106 | 0.3156 | 0.4106 | 1.3012 | 3 |

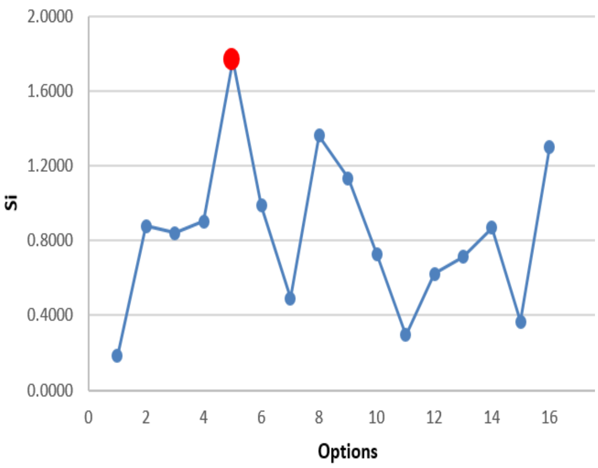


**Fig. 2. Relation between options and $S_i$**

## 5. Conclusions

In this work, the EAMR approach was used to determine the best dressing modes for surface - grinding Hardox 500 steel. Based on the study's findings, option 5 is advised in order to simultaneously achieve the biggest 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 $S_i$ = 1.7664. The optimal dressing modes for surface grinding were found to be $T_r$ = 0.02 (mm), $N_r$ = 1 (times), $N_f$ = 0 (times), $T_f$ = 0.01 (mm), and $N_{non}$ = 2. This was obtained using the EAMR approach.

**Acknowledgment**

This work was supported by Thai Nguyen University of Technology.

**Refrences**

[1] Marinescu, I.D., et al., Handbook of machining with grinding wheels. 2006: Crc Press. https://doi.org/10.1201/9781420017649. eBook ISBN9780429136115

[2] 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. https://doi.org/10.1051/e3sconf/202130901220

[3] 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.,262-269. DOI:10.1007/978-3-031-22200-9_28

[4] 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.

[5] 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. DOI:10.1080/10426914.2012.700159

[6] 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. https://doi.org/10.3390/machines10050303.

[7] Le, H.-A., et al., Determining the best dressing parameters for external cylindrical grinding using MABAC method. Applied Sciences, 2022. 12(16): p. 8287. https://doi.org/10.3390/app12168287

[8] 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.

[9] 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.

[10] Trung, D.D., N.N. Ba, and D.H. Tien, Application of the Curli method for multi-critical decision of grinding process. Journal of Applied Engineering Science, 2022. 20(3): p. 634-643.

[11] 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.

[12] Amiri, M. and J. Antucheviciene, Evaluation by an area-based method of ranking interval type-2 fuzzy sets (EAMRIT-2F) for multi-criteria group decision-making. Transform Bus Econ, 2016. 15(3): p. 39.

[13] 13. 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.