

Selection of Best Process Factors for CBN Grinding SS304 using TOPSIS Method

¹Dinh Van Thanh, ²Tran Quoc Hung, ³Vu Duong, ⁴Ha Toan Thang,

⁵Nguyen Van Trang, ⁶Luu Anh Tung,

¹East Asia University of Technology, Hanoi, Vietnam

²Ha Noi University of Industry, Hanoi, Vietnam

³Duy Tan University, Da Nang, Vietnam

⁴Vietnam-Korea College of Technology in Bac Giang, Vietnam

⁵Thai Nguyen University of Technology, Thai Nguyen, Vietnam

⁶Thai Nguyen University of Technology, Thai Nguyen, Vietnam

***Corresponding author: Luu Anh Tung**

^{*}Thai Nguyen University of Technology, Thai Nguyen, Vietnam

Abstract

The Multi-Criteria Decision Making (MCDM) study findings for CBN grinding cylindrical parts made of stainless steel SS304 on a CNC milling machine are presented in this paper. In this work, the MCDM problem was solved using the TOPSIS approach, and the weighting of the criterion was determined using the Entropy method. Two criteria were chosen to solve this task: material removal speed (MRS) and surface roughness (SR). Furthermore, an investigation utilizing the Taguchi design 2^4 was carried out. Four input parameters were analyzed: the down feed D_f (mm/double journey), the feed rate F_e (mm/min), the wheel speed Rpm (rpm), and the depth of the dressing cut a_{ed} (mm). The study's conclusions were used to determine the optimal process variables.

Keywords: CBN grinding, Stainless steel, CNC milling machine, MCDM, TOPSIS.

1. Introduction

Parts with high precision and good surface quality can be produced by the grinding process. It is therefore often used to produce objects that need to have excellent surface quality and great precision.

Numerous research has used MCDM to choose the best grinding mode thus far. In [1], four MCDM methods including TOPSIS, MARCOS, EAMR and MAIRCA have been chosen to find optimal input parameters for internal grinding 90CrSi. A report on the TOPSIS method's abrasive material selection for grinding was published in [2]. Eight grinding wheel abrasives are assessed in this paper using seven different criteria. This grinding wheel abrasive material selection problem is also solved by applying the fuzzy strategy for order performance by similarity to ideal solution method. When machining SKD11 steel, the WASPAS approach was used to determine the optimal input process parameters for the dressing step in external grinding in order to simultaneously obtain the lowest possible roundness and the longest possible wheel life [3]. Six input process parameters were

examined in this work: dressing feed rate, non-feeding dressing, coarse dressing depth, coarse dressing passes, and fine dressing depth. Based on the results of this investigation, the optimal dressing mode for external cylindrical grinding has been suggested. The MABAC technique has been applied in [4] in order to ascertain the optimal dressing mode for the external grinding SKD11 tool test. The goal of the research is to determine the optimal dressing mode that will simultaneously minimize surface roughness, maximize wheel life, and minimize roundness. The WASPAS approach has been applied in [5] for CBN grinding Al6061 in order to ascertain the optimal input process parameters to achieve both minimal SR and maximal MRS. For CBN grinding SKD11 tool test, the MOORA approach was utilized to address the MCDM problem in [6]. Two criteria, namely RS and MRS, were chosen for this investigation, and the optimal experimental setup was suggested based on the findings. The EDAS approach was used to determine the optimal input process parameters for dressing in external grinding SKD11 steel in order to achieve minimal RS and maximum wheel life [7]. Six input parameters have

been examined in this work: dressing feed rate, fine dressing depth, coarse dressing passes, fine dressing depth, and non-feeding dressing. The optimal dressing mode for external grinding has been suggested based on the work's findings. The optimal input process parameters for the dressing process in internal grinding of SKD11 tool steel have been found using the EDAS approach, and the results are given in [8]. The goal was to minimize RS while maximizing wheel life. Six input factors were investigated in this work: dressing feed rate, non-feeding dressing, fine dressing depth, fine dressing passes, and coarse dressing depth. Additionally, based on the study's findings, the optimal dressing mode for internal cylindrical grinding has been suggested.

The aforementioned research shows that numerous studies have used MCDM techniques to date in order to identify the ideal input parameters for various grinding processes. However, the use of the TOPSIS method for CBN grinding SS304 on a CNC milling machine has not yet been studied. The findings of this study's application of the TOPSIS and Entropy methods to determine the ideal input parameters for SS304 stainless steel surface grinding on a CBN grinding wheel are presented.

2. Methodology

2.1 Method for multi-criteria decision making

The MCDM problem in this study was resolved using the TOPSIS approach. To use this approach, the following actions need to be taken [9]:

Step 1: Creating the first decision-making grid:

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

In which, m and n are the alternative and the criteria number; x_{mn} is the value of n in m.

Step 2: Determining the normalized values k_{ij} :

$$k_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (2)$$

Step 3: Finding the weighted normalized decision matrix by:

$$l_{ij} = w_j \times k_{ij} \quad (3)$$

Step 4: Calculating the best alternative A+ and the worst s alternative A- by the following equations:

$$A^+ = \{l_1^+, l_2^+, \dots, l_j^+, \dots, l_n^+\} \quad (4)$$

$$A^- = \{l_1^-, l_2^-, \dots, l_j^-, \dots, l_n^-\} \quad (5)$$

In which, l_j^+ and l_j^- are the best and worst values of the j criterion (j=1,2, ..., n).

Step 5: Finding the values of better options D_i^+ and worse options D_i^- by:

$$D_i^+ = \sqrt{\sum_{j=1}^n (l_{ij} - l_j^+)^2} \quad (6)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (l_{ij} - l_j^-)^2} \quad (7)$$

With $i = 1, 2, \dots, m$.

Step 6: Determining closeness coefficient values R_i of each alternative by:

$$R_i = \frac{D_i^-}{D_i^- + D_i^+} \quad (8)$$

Wherein, $i = 1, 2, \dots, m$; $0 \leq R_i \leq 1$

Step 7: Sorting the options in ascending order by R value maximization.

2.2 Gearbox efficiency determination

In this work, the weights of the criterion were determined using the Entropy approach. This approach can be implemented using the methods listed below [10].

Step 1: Finding indicator normalized values:

$$p_{ij} = \frac{x_{ij}}{m + \sum_{i=1}^m x_{ij}^2} \quad (9)$$

Step 2: Determining the Entropy for each indicator:

$$me_j = - \sum_{i=1}^m [p_{ij} \times \ln(p_{ij})] - \left(1 - \sum_{i=1}^m p_{ij}\right) \times \ln\left(1 - \sum_{i=1}^m p_{ij}\right) \quad (10)$$

Step 3: Fining the weight of each indicator:

$$w_j = \frac{1 - me_j}{\sum_{j=1}^m (1 - me_j)} \quad (11)$$

3. Methods

In this work, an experiment was conducted to find the optimal solution that simultaneously satisfies the least SR and maximum MRS criterion. Four input parameters and their corresponding levels were chosen especially for this experiment (Table 1). A CNC milling machine, CBN wheels, SS304 workpieces, and an SURFTEST SV-3100 roughness meter (Japan) were utilized in the

experiment. In Figure 1, the grinding schema is displayed. In addition, the Taguchi approach using design 2^4 was used. After conducting the test runs, the SR was measured and the MRS was calculated. Table 2 describes the experimental design as well as the output outcomes (SR and MRS values).

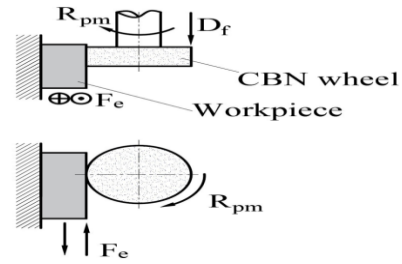


Fig. 1. Grinding schema

Table 1. Input parameters

No.	Factors	Symbol	Unit	Level	
				Low	High
1	Spindle speed	R_{pm}	rpm	4000	5000
2	Feed rate	F_e	mm/min.	2000	3000
3	Depth of dressing cut	a_{ed}	mm	0.01	0.025
4	Down feed	D_f	mm/double journey	0.5	2

$a_{ed}=0.025$ (mm), $D_f=2$ (mm/double trip), and $R_{pm}=5000$ (rpm).

4. Methods

4.1 Finding the weights for criteria

The weights of criteria are determined using the Entropy technique (see Section 2.2) as follows: To find the normalized values p_{ij} , use equation (9) Using Equation (10), determine the Entropy value for each indication m_{ej} . Lastly, determine the weight of the criteria w_j using Equation (11). It was determined that the weights of RS and MRS were, respectively, 0.434 and 0.566.

4.1 Determining the best process factors

How to solve the MCDM problem using the TOPSIS method is explained in Section 2.1. As a result, equation (2) is used to calculate the normalized values of k_{ij} , and equation (3) is used to calculate the normalized weighted values of lij (3). The A^+ and A^- values of SR and MRS (5) are found using equations (4) and (5). For A^+ , RS and MRS are equal to 0.1174 and 0.3569, whereas for A^- , they are equivalent to 0.2354 and 0.0269. Moreover, formulae (6) and (7) have been used to get the D_i^+ and D_i^- values. (7). Lastly, the ratio R_i has been calculated using Equation (8). The results of rating the options using the TOSIS approach and computing many parameters are displayed in Table 3.

The greatest option from Table 3 is number 6. The reason for this is because its proximity coefficient value ($R_1=0.9031$) is the highest. The optimal solution therefore has the following: $F_e=2000$ (mm/min),

5. Conclusion

In this article, the TOPSIS approach was used to determine the ideal input process parameters for SS304 grinding on a CNC milling machine with CBN wheels. Based on the study's findings, it is advised that option 6 be used in order to simultaneously obtain the maximum MRS and the lowest SR. The best result was shown in Experiment No. 6, which had a proximity coefficient value of 0.9031. The ideal input process parameters are $F_e=2000$ (mm/min), $a_{ed}=0.025$ (mm), $D_f=2$ (mm/double trip), and $R_{pm}=5000$ (rpm), according to the TOPSIS approach.

Acknowledgment

This work was supported by Thai Nguyen University of Technology

References

- [1] 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.
- [2] 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.
- [3] 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.

- [4] Le, H.-A., et al., Determining the best dressing parameters for external cylindrical grinding using MABAC method. *Applied Sciences*, 2022. 12(16): p. 8287.
- [5] 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.
- [6] 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.
- [7] 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.
- [8] 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.
- [9] Hwang, C.-L., Y.-J. Lai, and T.-Y. Liu, A new approach for multiple objective decision making. *Computers & operations research*, 1993. 20(8): p. 889-899.
- [10] 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.