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Original Article

Application of PSI and CoCoSo Methods for Selection of Magnetic Abrasive Finishing Process Parameters for SS316 Material

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Abstract *- Selection and evaluation of the Magnetic Abrasive Finishing (MAF) process parameters now have been receiving significant consideration in the current manufacturing environment because the MAF process offers opportunities to improve productivity, competitiveness and profitability. Selection of the optimal MAF process parameters while considering the multiple conflicting criteria is often a difficult task for decision-makers. This study presents the use of the preference selection index method (PSI) and Combined Compromise Solution (CoCoSo) method for the selection of the optimal MAF process parameters for desired output for stainless steel SS316 material. Further, results obtained using PSI and CoCoSo methods are verified with the Weighted Aggregated Sum Product Assessment (WASPAS) method.*

Keywords *- MAF process, Stainless steel SS316 material, PSI method, CoCoSo method, WASPAS method and Taguchi design.*

1. Introduction

The MAF process is an important advanced machining technique to manufacture intricate shapes with great accuracy and a good surface finish. In MAF, the workpiece is subjected to a controlled magnetic field, and guiding abrasive particles remove material from the workpiece surface. The process can be tailored for various finishing profiles, including cylindrical, inner, and plane surfaces. The MAF is characterized by its ability to produce high-quality surfaces with improved roughness. Hence, this method is especially relevant in industries where precision and excellence in surface quality are paramount. The versatility of MAF allows for the efficient finishing of diverse materials, including stainless-steel SS316, super-alloys, composites and advanced ceramics.

Jain et al. [1] looked into how the working gap and circumferential speed affected the percentage increase in surface finish and material removal rate.

It is concluded from this study that the material removal rate decreases by reducing the working gap or by increasing the circumferential speed of the workpiece. Singh et al. [2] applied the Taguchi design of the experiment on the MAF process to identify the significant parameters that have effects on surface roughness. Wang and Hu [3] analyzed the material removal rate of tubes composed of three distinct materials—Ly12 aluminum alloy, 316L stainless steel, and H62 brass and it was significantly influenced by three factors: speed, magnetic abrasive substance, and grain size. Singh et al. [4] investigated the impact of force acting during MAF and presented the relationship between forces and surface finish.

Mulik and Pandey [5] concentrated on the mechanism of surface finishing in the magnetic abrasive finishing process with ultrasonic assistance.

Vasantha et al. [6] conducted experiments to improve the surface roughness value on a cylindrical component while considering the different MAF process parameters. Additionally, few researchers have applied the multi-criteria decision-making methods to select the optimum MAF process parameters in the literature, such as Farwaha et al. [7], had applied of taguchi method and TOPSIS method to select the optimum parameters for ultrasonic assisted electrochemical magnetic abrasive machining (UEMAM). Sharma et al. [8] examined the effect of the MAF process parameter for the machining of SUS-304L tube material using the taguchi design in the experiments and the WASPAS method. Singh et al. [9] developed the taguchi-based GRA method and combined it with the simulated annealing (SA) method to optimize the micro-finished aluminum 6060 using the MAF process. Anjaneyulu and Venkatesh [10] applied the GRA method, Genetic algorithm and Jaya algorithm to optimize MAF process parameters during the finishing of the MS plate. Ahmed et al. [11] used the sintering process to create the Al_2O_3-SiO_2 based magnetic abrasive and investigated how well it worked on Ti-6Al-4V during magnetic abrasive finishing.

A thorough evaluation was carried out by Qian et al. [12], taking into account the MAF tools, MAF principles, MAF modeling and simulation MAF characteristics and magnetic abrasive preparation.

Xu and Zou [13] developed a new magnetic abrasive finishing process with renewable abrasive particles using the circulatory system. Babbar et al. [14] applied the taguchi technique with GRA to find the optimal combination of the MAF process parameters. Yang et al. [15] finished the inside surface of a thick-walled tube using a magnetic abrasive finishing method and an additional magnetic machining tool.

Song et al. [16] finished the inner wall of the Co-Cr alloy tube utilized to make the cardiovascular stent using the MAF process.

Anjaneyulu and Venkatesh [17] did the finishing of Hastelloy C-276 using an ultrasonic-assisted magnetic abrasive finishing process.

The literature survey discloses that most of the studies are finishing different alloys using the MAF process with different abrasive particles, and few of the studies are related to the selection or optimization of process parameters using the GRA method. Hence, the main aim of the present study is to show the application of Multi-Attribute Decision-Making (MADM) methods, especially the PSI method and CoCoSo method, for the selection of optimal process parameters of MAF process for work material stainless steel SS-316 and the results obtained using PSI and CoCoSo methods are verified with the WASPAS method.

2. MADM Methods

The selection of alternatives while taking into account the various factors involved in the decision-making process is the focus of the MADM methodologies. The first step of using these methods is to prepare a derision matrix, which shows how each alternative performs in relation to each quality. The alternatives are assessed in relation to each attribute using the information from the decision matrix, and a performance score is assigned to each alternative. The primary topics of this study are the application of the WASPAS technique, the CoCoSo method, and the PSI method for the selection of the optimal process parameter of the MAF process with stainless steel (SS-316) as the work material.

2.1. PSI Method

The PSI approach for choosing the right process parameter for the MAF process is explained in this section. The PSI approach was created by Maniya and Bhatt (2010) to solve the MADM difficulties. Below is a description of the PSI method's primary steps.

Step 1: Formulate the MAF process parameter selection problem.

Conduct the possible experiments for MAF process parameter selection on the selected work materials and measure the output characteristics for all the conducted experiments. Let E_i be a set of MAF process experiments, C_j is a set of MAF process selection attributes, and M_{ij} is the performance measure of MAF selection process parameters.

Step 2: Prepare the decision matrix.

This step describes the collection of MAF process parameter selection data in the tabular format, as shown in Table 1.

Table 1. Decision matrix

MAF experiments Alternatives	MAF process parameter selection Criteria				
	C_1	C_2	…	….	C_n
E_1	M_{11}	M_{12}	…	….	M_{1n}
E_2	M_{21}	M_{22}	…	….	M_{2n}
	:	:	:	:	:
	:	:	:	:	:
E_m	M_{m1}	M_{m2}	…	….	M_{mn}

Step 3: Normalize the MAF selection process parameter measure using Equations (1) and (2).

If the greater value of the MAF selection parameters is anticipated, then it can be normalized as:

$$R_{ij} = \frac{M_{ij}}{M_{max}} \quad (1)$$

If the lesser value of the MAF selection parameters is anticipated, then it can be normalized as:

$$R_{ij} = \frac{M_{min}}{M_{ij}} \quad (2)$$

Step 4: Determine the normalized data's mean value for each MAF selection parameter using Equation (3).

$$\bar{R}_j = \frac{1}{n}\sum_{i=1}^{n} R_{ij}, \forall i, j \quad (3)$$

Step 5: Determine the preference variation value for each MAF selection parameter using Equation (4).

$$PV_j = \sum_{i=1}^{n} \left[R_{ij} - \bar{R}_j \right]^2 \quad (4)$$

Step 6: Determine the deviation in preference value for each MAF selection parameter using Equation. (5).

$$\Phi_j = \left| 1 - PV_j \right| \quad (5)$$

Step 7: Determine the deviation in overall preference value (Ψ_j) for each MAF selection parameter using Equation (6), and the summation of it should be one. i.e. $\sum_{j=1}^{m} \Psi_j = 1$.

$$\Psi_j = \frac{\Phi_j}{\sum_{j=1}^{m} \Phi_j} \quad (6)$$

Step 8: Determine the PSI value for each MAF alternative using Equation (7).

$$\Theta j = \sum_{j=1}^{m} Rij \times \Psi j \quad (7)$$

Step 9: In this step, all MAF process parameter selection alternatives are ranked starting from one having the PSI value and so on and that alternative which is ranked one will be considered the best one and MAF selection parameters values involved in alternative one is considered the optimal value for the machining of the work material.

2.2. Combined Compromise Solution (CoCoSo) Method

The CoCoSo approach was created by Yazdani et al. (2019), and it is based on the combination of the two most widely used MCDM techniques, namely Exponentially Weighted Product (MEP) and Simple Additive Weighting (SAW). The following are the steps in the CoCoSo method

Step 1: Prepare the decision matrix.

This step describes the collection of MAF process parameter selection data and writes all the data in the following format.

$$X = \begin{bmatrix} X_{11} & X_{12} & -- & X_{1n} \\ X_{21} & X_{22} & -- & X_{2n} \\ -- & -- & -- & -- \\ X_{m1} & X_{m2} & -- & X_{mn} \end{bmatrix}; i = 1,2,\ldots,m; j = 1,2,\ldots,n;$$

Step 2: Normalize the MAF selection process parameter measure using Equations (8) and (9).

If the greater value of the MAF selection parameters is anticipated, than it can be normalized as:

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \quad (8)$$

If the lesser value of the MAF selection parameters is anticipated, then it can be normalized as:

$$r_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \quad (9)$$

Step 3: Find the weighted comparability (S_i) sequence and the power weighted comparability sequences (P_i) for each MAF alternative as follows;

$$S_i = \sum_{j=1}^{n} (W_j * r_{ij}) \quad (10)$$

$$P_i = \sum_{j=1}^{n} (r_{ij})^{Wj} \quad (11)$$

Step 4: Find the relative performance scores of each MAF alternative.

In this stage, the following equations are employed to calculate the relative performance scores of the alternatives based on three aggregated evaluation scores.

$$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m} (P_i + S_i)} \quad (12)$$

$$k_{ib} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i} \quad (13)$$

$$k_{ic} = \frac{\lambda(S_i) + (1-\lambda)P_i}{\lambda \max_i (S_i) + (1-\lambda) \max_i P_i}; 0 \le \lambda \le 1. \quad (14)$$

Generally, decision-makers select λ =0.5 in Equation (14)

Step 5: Better positioning of the options in the ranking pre-order is indicated by greater ki values. The ultimate ranking of the options is determined by using ki values.

$$k_i = (k_{ia} * k_{ib} * k_{ic})^{(1/3)} + \frac{1}{3}(k_{ia} + k_{ib} + k_{ic}) \quad (15)$$

2.3. WASPAS Method

In order to improve the ranking accuracy of alternatives and solve multi-criteria choices making (MCDM) problems, The WASPAS approach was presented by Zavadskas et al. [19]. The WASPAS approach consists of the two well-known MCDM techniques, WSM and WPM. The WASPAS technique entails the subsequent steps as below.

Step 1: Construct a Normalized decision matrix of performance measures.

Normalize the MAF selection process parameter measure using Equations (16) and (17).

If the greater value of the MAF selection parameters is anticipated, then it can be normalized as:

$$(x_{ij}^*) = \frac{x_{ij}}{Max_i\ x_{ij}} \quad (16)$$

If the lesser value of the MAF selection parameters is anticipated, then it can be normalized as:

$$(x_{ij}^*) = \frac{Min_i\ x_{ij}}{x_{ij}} \quad (17)$$

Step 2: Constructing matrices of total relative relevance.

The WSM approach uses Equation (18) to assess the overall relative value of each alternative.

In accordance with the WSM method, the total relative importance of i^{th} alternative is evaluated using Equation (18).

$$Qi^{(1)} = \sum_{j=1}^{n} x_{ij}^{*}\, w_j \qquad (18)$$

Here, w_j indicates the relative weight of MAF selection parameters. In view of the WPM method, the total relative importance of i^{th} alternative is evaluated as follows:

$$Qi^{(2)} = \prod_{j=1}^{n} (x_{ij}^{*})^{w_j} \qquad (19)$$

Step 3: Find the variances for the total relative importance matrices.

Variance for the relative importance of the WSM and the WPM methods are calculated as follows;

For, WSM:

$$\sigma^2(Q_i^{(1)}) = \sum_{j=1}^{n} \sigma^2(x_{ij}^{*})\, w_j^2 \qquad (20)$$

For, WPM:

$$\sigma^2(Q_i^{(2)}) = \sum_{j=1}^{n} \sigma^2(x_{ij}^{*}) \left[\frac{Q_i^{(2)} w_j}{(x_{ij}^{*})^{wj}(x_{ij}^{*})^{1-wj}}\right]^2 \qquad (21)$$

Step 4: Find the coefficient **λ**.

The coefficient λ represents the result's scattering or spreading. The ideal value of λ yields the exciting relative importance function. When evaluating the coefficient λ,

$$\lambda_i = \frac{\sigma^2(Q_i^{(2)})}{\sigma^2(Q_i^{(1)}) + \sigma^2(Q_i^{(2)})} \qquad (22)$$

Step 5: The generalized total relative importance index equation is as follows:

The total relative significance index (Qi), which is the result of all performance acts combined, is the single solution. The following is a generalized equation that uses a weighted sum and multiplicative technique aggregate:

$$Q_i = \lambda_i(Q_i^{(1)}) + (1 - \lambda_i)(Q_i^{(2)}) \qquad (23)$$

3. Case Study

The following section describes the case study considered for the selection of the MAF process parameters using the MADM methods described in the above Section 2.

3.1. Experimental Details

In accordance with the robust design philosophy based on the Taguchi technique, an orthogonal array L27 has been utilized to assess the primary influencing factors that impact material hardness, surface roughness, and material removal rate. The experiment is conducted as per the Design of Experiments (DOE). The schematic diagram of the experimental setup is shown in Figure 1, and the real setup is shown in Figure 2. The range of process parameters is chosen by conducting preliminary testing. The workpiece material's quality declined if the process parameter was taken into account outside of the defined range. The MAF process experimental conditional data is represented in Table 2, and specific material properties are shown in Table 3.

Table 2. Experimental conditionals

Parameter	Value
Workpiece Material and size	Stainless steel SS316 Ø 25 x Ø 23 x 100 mm
Permanent Magnet material and size (mm)	Material: - Nd-Fe-B (50x15x5)
RPM of workpiece	320, 480, 640
Working gap (mm)	1.5, 2.0, 2.5
Magnetic Density (Tesla)	0.1, 0.2, 0.3
Abrasive Material	SiC
Abrasive Material Mesh Size (micron)	400, 600, 800
Ferro-Magnetic Abrasive Particles Weight Percentage and Quantity (gm)	Weight Percentage = 80:20 Quantity= 20, 25, 30
Time for each experiment (minutes)	30

Table 3. Important properties of SS316

Modulus of elasticity (E)	193 GPa
Hardness (Brinell)	146 kg/mm^2
Hardness (Knoop)	166 kg_f/mm^2
Hardness (Vickers)	152 kg_f/mm^2
Tensile strength	540 MPa
Yield Strength	205 MPa
Density, ρ	8.0 g/cc
Thermal conductivity, K	16.2 W/m-k
Melting Temperature, T	1400 °C

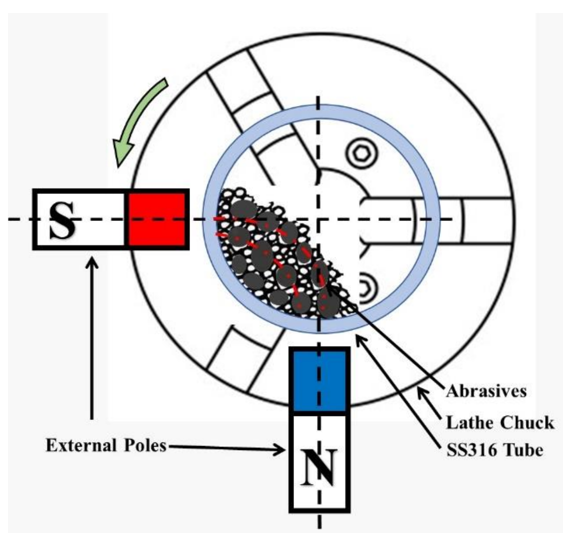

Fig. 1 Schematic diagram of experimental set-up

Fig. 2 MAF process set up

The surface roughness tester is used to measure the surface roughness (*Ra*), as shown in Figure 3(a). The internal surface of the workpieces is initially finished with traditional finishing methods like conventional grinding. Further, workpieces were thoroughly cleaned with acetone solution, dried and then accurately weighed before and after the experiment on high precision six-digit electronic balance having the least count of 0.1 mg, which is shown in Figure 3(b) and the micro vickers hardness testing machine used to measure micro hardness the as shown in Figure 3(c).

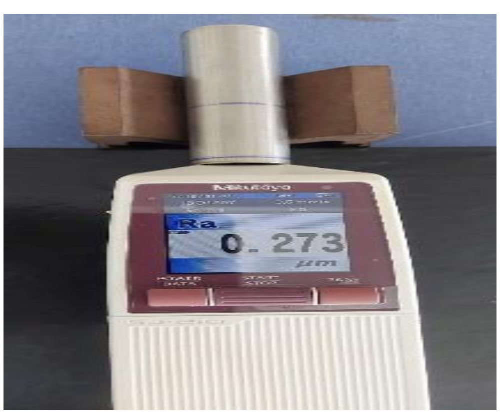

Fig. 3(a) Surface Roughness Tester

Fig. 3 (b) Weight measurement machine

Fig. 3(c) Micro hardness tester

For the MAF process, five parameters, each having three levels, were considered for the experiments, as shown in Table 4. The percentage improvement in the surface roughness, material removal rate and the percentage change in the hardness were determined as follows.

Percentage improvement in Surface roughness;

$$\Delta \text{Ra} = \frac{\text{Initial surface roughness} - \text{Final surface roughness}}{\text{Initial surface roughness}} \text{x}100 \quad (24)$$

Material Removal Rate;

$$\text{MRR (mg/min)} = \text{Initial weight} - \text{Final weight} \quad (25)$$

Percentage change in Micro Hardness;

$$(\%\text{Hv}) = \frac{\text{Workpiece hardness after process} - \text{Workpiece hardness before process}}{\text{Workpiece hardness before process}} \text{ x } 100 \quad (26)$$

Table 4. Input parameters of the MAF process

Input Parameters					
(No. of Experiments)	**(I) Chuck RPM**	**(I) Magnetic Flux Density**	**(I) Abrasive Mesh Size**	**(I) Working Gap (mm)**	**(I) % Weight of Abrasives (gram)**
E1	320	0.1	400	1.5	20
E2	320	0.1	400	1.5	25
E3	320	0.1	400	1.5	30
E4	320	0.2	600	2.0	20
E5	320	0.2	600	2.0	25
E6	320	0.2	600	2.0	30
E7	320	0.3	800	2.5	20
E8	320	0.3	800	2.5	25
E9	320	0.3	800	2.5	30
E10	480	0.1	600	2.5	20
E11	480	0.1	600	2.5	25
E12	480	0.1	600	2.5	30
E13	480	0.2	800	1.5	20
E14	480	0.2	800	1.5	25
E15	480	0.2	800	1.5	30
E16	480	0.3	400	2.0	20
E17	480	0.3	400	2.0	25
E18	480	0.3	400	2.0	30
E19	640	0.1	800	2.0	20
E20	640	0.1	800	2.0	25
E21	640	0.1	800	2.0	30
E22	640	0.2	400	2.5	20
E23	640	0.2	400	2.5	25
E24	640	0.2	400	2.5	30
E25	640	0.3	600	1.5	20
E26	640	0.3	600	1.5	25
E27	640	0.3	600	1.5	30

3.2. Result of MAF Process Parameters

This paper's primary goal is to demonstrate how easily the three preference ranking techniques can be computed while handling MAF process parameter selection issues with both ordinal and cardinal attribute data. In this case, greater values are always preferred for the percentage change in the surface roughness, material removal rate, and the percentage change in the microhardness. The MAF process parameter selection options' output values are displayed in Table 5, and the three attributes' relative weight values were ascertained utilizing the AHP method given by Saaty [20] and its result is summarized in Table 6.

4. Results and Discussion

This section includes the results obtained using MADM methods considered for the selection of the MAF process parameters.

Table 5. MAF output parameters of the MAF process

Alternative	∆Ra	MRR	(%Hv)
E1	34.57	1.2	3.35
E2	44.03	2.6	3.89
E3	36.70	0.7	4.59
E4	32.56	1.7	4.83
E5	39.93	2.3	5.57
E6	31.28	1.7	6.16
E7	33.95	2.6	2.86
E8	47.95	3.6	3.35
E9	41.18	2.2	4.26
E10	42.41	1.6	3.66
E11	48.69	3.52	4.40
E12	49.87	2.3	5.17
E13	35.72	2.1	2.36
E14	40.62	3.2	2.90
E15	41.30	3.1	3.54
E16	49.90	2.8	5.47
E17	56.88	3.9	6.06
E18	53.10	3.3	6.89
E19	31.66	5.4	3.69
E20	39.09	8.1	4.32
E21	33.92	6.6	5.08
E22	52.09	3.4	6.35
E23	54.44	5.2	7.00
E24	54.95	4.7	7.90
E25	56.94	5.4	9.83
E26	60.61	6	10.36
E27	60.82	5.7	11.10

Table 6. The weightage (w_j) of the selection parameters

Criteria	∆Ra	MRR	(%Hv)
Weight	0.309	0.582	0.109

4.1. Result of PSI Method

Here, the results obtained using the PSI method, as described in Section 2.1 are summarized below. In the PSI method, the decision matrix is the same as shown in Table 5, and it is normalized using Equation (1), PV_j values using Equation (4), deviation in PV_j values using Equation (5) are determined and summarized the Table 7. Further, PSI values for each MAF process parameter alternative are determined using Equation (7) and its results are summarized in Table 8.

4.2. Results of CoCoSo Method and WASPAS Method

In this section, the results of the CoCoSo method and the WASPAS method are summarized; those are obtained using the methodology described in Sections 2.2 and 2.3, respectively, in Tables 9 and 10.

Table 7. Normalized decision matrix

Alternative	∆Ra	MRR	(%Hv)
E1	0.57	0.15	0.30
E2	0.72	0.32	0.35
E3	0.60	0.09	0.41
E4	0.54	0.21	0.43
E5	0.66	0.28	0.50
E6	0.51	0.21	0.55
E7	0.56	0.32	0.26
E8	0.79	0.44	0.30
E9	0.68	0.27	0.38
E10	0.70	0.20	0.33
E11	0.80	0.43	0.40
E12	0.82	0.28	0.47
E13	0.59	0.26	0.21
E14	0.67	0.40	0.26
E15	0.68	0.38	0.32
E16	0.82	0.35	0.49
E17	0.94	0.48	0.55
E18	0.87	0.41	0.62
E19	0.52	0.67	0.33
E20	0.64	1.00	0.39
E21	0.56	0.81	0.46
E22	0.86	0.42	0.57
E23	0.90	0.64	0.63
E24	0.90	0.58	0.71
E25	0.94	0.67	0.89
E26	1.00	0.74	0.93
E27	1.00	0.70	1.00
R_j	0.73	0.43	0.48
PVj	0.62	1.31	1.11
Φ_j	0.38	0.31	0.11
Ψ_j	0.48	0.39	0.13

Table 8. PSI values

Alternative	θ_i	Rank
E1	0.37	27
E2	0.52	16
E3	0.38	26
E4	0.40	25
E5	0.49	19
E6	0.40	24
E7	0.43	22
E8	0.59	13
E9	0.48	20
E10	0.45	21
E11	0.60	11

E12	0.57	14
E13	0.41	23
E14	0.51	18
E15	0.52	17
E16	0.59	12
E17	0.71	7
E18	0.66	8
E19	0.55	15
E20	0.75	6
E21	0.64	10
E22	0.65	9
E23	0.76	4
E24	0.75	5
E25	0.83	3
E26	0.89	1
E27	0.88	2

5. Comparison of Results and Discussion

In this section results obtained for selection of the MAF process parameter alternatives using the PSI method and the CoCoSo methods are compared with the result of the WASPAS method, as shown in Table 11.

This result shows that experiment run or alternative 26 is the most suitable alternative from the 27 experiment runs, and it suggests the optimal combination of the input process parameters of MAF, which gives the optimal output for experiment number 26.

Hence, the input process parameters of experiment 26 are selected for the machining of the workpiece using the MAF process to get the optimum output for a given application.

Table 9. Results of the CoCoSo method

Alternative	Si	Pi	Kia	Kib	Kic	K	Rank
E1	0.09	1.50	1.59	2.63	0.44	1.33	25
E2	0.30	2.05	2.35	5.77	0.65	2.66	17
E3	0.08	1.45	1.54	2.55	0.42	1.29	27
E4	0.12	1.56	1.68	3.12	0.46	1.53	23
E5	0.26	1.99	2.25	5.16	0.62	2.41	19
E6	0.13	1.23	1.35	2.80	0.37	1.34	24
E7	0.18	1.66	1.84	3.95	0.51	1.87	22
E8	0.41	2.21	2.62	7.27	0.72	3.27	12
E9	0.25	1.95	2.20	4.99	0.61	2.34	20
E10	0.20	1.84	2.05	4.38	0.56	2.08	21
E11	0.43	2.27	2.70	7.51	0.74	3.37	11
E12	0.36	2.16	2.52	6.52	0.69	2.97	14
E13	0.16	0.94	1.09	2.85	0.30	1.30	26
E14	0.30	1.97	2.27	5.67	0.62	2.60	18
E15	0.31	2.04	2.35	5.83	0.65	2.68	16
E16	0.40	2.24	2.64	7.12	0.73	3.22	13
E17	0.57	2.48	3.05	9.35	0.84	4.12	7
E18	0.49	2.39	2.87	8.34	0.79	3.72	9
E19	0.39	1.84	2.23	6.59	0.61	2.92	15
E20	0.69	2.51	3.20	10.84	0.88	4.69	4
E21	0.53	2.23	2.76	8.61	0.76	3.78	8
E22	0.48	2.37	2.85	8.22	0.78	3.66	10
E23	0.65	2.61	3.26	10.54	0.90	4.60	5
E24	0.63	2.58	3.22	10.24	0.88	4.48	6
E25	0.73	2.71	3.44	11.56	0.95	5.01	3
E26	0.82	2.81	3.64	12.76	1.00	5.49	1
E27	0.81	2.80	3.61	12.60	0.99	5.42	2

Table 10. Results of the WASPAS method

Alternative	Q1	Q2	Qi	Rank
E1	0.29	0.24	0.27	26
E2	0.45	0.42	0.43	18
E3	0.28	0.19	0.23	27
E4	0.33	0.30	0.32	25
E5	0.42	0.39	0.41	19
E6	0.34	0.31	0.32	24
E7	0.39	0.37	0.38	21
E8	0.54	0.51	0.52	13
E9	0.41	0.37	0.39	20
E10	0.37	0.31	0.34	23
E11	0.54	0.52	0.53	12
E12	0.47	0.42	0.44	17
E13	0.36	0.33	0.34	22
E14	0.46	0.44	0.45	16
E15	0.47	0.45	0.46	15
E16	0.51	0.47	0.49	14
E17	0.63	0.60	0.61	8
E18	0.57	0.54	0.56	10
E19	0.59	0.57	0.58	9
E20	0.82	0.79	0.81	3
E21	0.70	0.68	0.69	6
E22	0.57	0.54	0.56	11
E23	0.72	0.71	0.71	5
E24	0.69	0.68	0.69	7
E25	0.77	0.76	0.77	4
E26	0.84	0.83	0.84	1
E27	0.83	0.82	0.82	2

Table 11. Ranking comparison table

Alternative	PSI	CoCoSo	WASPAS
E1	27	25	26
E2	16	17	18
E3	26	27	27
E4	25	23	25
E5	19	19	19
E6	24	24	24
E7	22	22	21
E8	13	12	13
E9	20	20	20
E10	21	21	23
E11	11	11	12
E12	14	14	17
E13	23	26	22
E14	18	18	16
E15	17	16	15
E16	12	13	14
E17	7	7	8
E18	8	9	10
E19	15	15	9
E20	6	4	3
E21	10	8	6
E22	9	10	11
E23	4	5	5
E24	5	6	7
E25	3	3	4
E26	1	1	1
E27	2	2	2

6. Concluding Remarks

According to research, the PSI and CoCoSo methods are suitable for complicated evaluation of MAF process parameter alternatives. The optimal MAF parameter range can be chosen for any number of possibilities by using these techniques. Comparing the PSI approach to the CoCoSo method, which requires the relative importance of the selection criteria to determine their weight, the latter yields a different outcome without taking this into account. Researchers working in the field of MAF process and other manufacturing areas would also benefit from the methods used in this study to determine the optimal MAF process parameter.

References

[1] V.K. Jain et al., "Effect of Working Gap and Circumferential Speed on the Performance of Magnetic Abrasive Finishing Process," *Wear*, vol. 250, no. 1-12, pp. 384-390, 2001. [CrossRef] [Google Scholar] [Publisher Link]

[2] Dhirendra K. Singh, V.K. Jain, and V. Raghuram, "Parametric Study of Magnetic Abrasive Finishing Process," *Journal of Materials Processing Technology*, vol. 149, no. 1-3, pp. 22-29, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[3] Yan Wang, and Dejin Hu, "Study on the Inner Surface Finishing of Tubing by Magnetic Abrasive Finishing," *International Journal of Machine Tools and Manufacture*, vol. 45, no. 1, pp. 43-49, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[4] Dhirendra K. Singh, V.K. Jain, and V. Raghuram, "Experimental Investigations into Forces Acting During a Magnetic Abrasive Finishing Process," *The International Journal of Advanced Manufacturing Technology*, vol. 30, pp. 652-662, 2006. [CrossRef] [Google Scholar] [Publisher Link]

[5] Rahul S. Mulik, and Pulak M. Pandey, "Mechanism of Surface Finishing in Ultrasonic-Assisted Magnetic Abrasive Finishing Process," *Materials and Manufacturing Processes*, vol. 25, no. 12, pp. 1418-1427, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[6] N. Vasantha Prasath, A. Vasanth, and T. Abdul Gaffar, "Performance Characteristics of Magnetic Abrasive Finishing (MAF) of Al 4061," *International Journal of Engineering Research & Technology*, vol. 9, no. 2, pp. 61-65, 2020. [Google Scholar] [Publisher Link]

[7] Harnam Singh Farwaha, Dharmpal Deepak, and Gurinder Singh Brar, "Mathematical Modeling and Process Parameters Optimization of Ultrasonic Assisted Electrochemical Magnetic Abrasive Machining," *Journal of Mechanical Science and Technology*, vol. 34, pp. 5063-5073, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[8] Rahul Sharma, and Swastik Pradhan, "Investigation of Machinability Criteria During Micro-Abrasive Finishing of SUS-304L Steel using Fuzzy Combined with WASPAS Approach," *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, vol. 42, pp. 1-12, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[9] Rajneesh Kumar Singh, Swati Gangwar, and D.K. Singh, "Exploration of GRA Based Multiobjective Optimization of Magnetic Abrasive Finishing Process using Simulated Annealing," *Faculty of Mechanical Engineering Transactions*, vol. 48, no. 1, pp. 195-203, 2020. [Google Scholar] [Publisher Link]

[10] Kamepalli Anjaneyulu, and Gudipadu Venkatesh, "Optimization of Process Parameters of Magnetic Abrasive Finishing using Jaya Algorithm," *Materials Today: Proceedings*, vol. 41, no. 5, pp. 1035-1040, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[11] S. Ahmad, R.M. Singari, and R.S. Mishra, "Development of Al_2O_3-SiO_2 Based Magnetic Abrasive by Sintering Method and its Performance on Ti-6Al-4V During Magnetic Abrasive Finishing," *Transactions of the Institute of Metal Finishing: The International Journal of Surface Engineering and Coatings*, vol. 99, no. 2, pp. 94-101, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[12] Cheng Qian et al., "A Review on Magnetic Abrasive Finishing," *The International Journal of Advanced Manufacturing Technology*, vol. 112, pp. 619-634, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[13] Jiaye Xu, and Yanhua Zou, "Development of a New Magnetic Abrasive Finishing Process with Renewable Abrasive Particles using the Circulatory System," *Precision Engineering*, vol. 72, pp. 417-425, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[14] Atul Babbar, Ankit Sharma, and Parminderjeet Singh, "Multi-objective Optimization of Magnetic Abrasive Finishing using Grey Relational Analysis," *Materials Today: Proceedings*, vol. 50, no. 5, pp. 570-575, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] Yanzhen Yang et al., "A Magnetic Abrasive Finishing Process with an Auxiliary Magnetic Machining Tool for the Internal Surface Finishing of a Thick-Walled Tube," *Machines*, vol. 10, no. 7, pp. 1-19, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[16] Zhuang Song et al, "Study on Finishing Inner Wall of Co–Cr Alloy Cardiovascular Stent Tube via Novel Atomized CBN/Metal Spherical Magnetic Abrasive Powders," *Journal of Manufacturing Process*, vol. 92, pp. 206-225, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[17] Kamepalli Anjaneyulu, and Gudipadu Venkatesh, "Experimental Investigation of Finishing Forces on Hastelloy C-276 using UAMAF Process," *International Journal of Interactive Design and Manufacturing*, vol. 17, pp. 703-715, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[18] Morteza Yazdani et al., "A Combined Compromise Solution (CoCoSo) Method for Multi-Criteria Decision-Making Problems," *Management Decision*, vol. 57, no. 9, pp. 2501-2519, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[19] E.K. Zavadskas et al., "Optimization of Weighted Aggregated Sum Product Assessment," *Electronics and Electrical Engineering*, vol. 122, no. 6, pp. 3-6, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[20] Thomas L. Saaty, *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, McGraw-Hill International Book Company, pp. 1-287, 1980. [Google Scholar] [Publisher Link]