A NEW HYBRID DECISION MAKING MODEL TO OPTIMIZE MACHINING OPERATIONS

Mehmet Alper Sofuoğlu

Eskişehir Osmangazi University, Mechanical Engineering Department, 26480, Eskişehir, Turkey
Corresponding author:asofuoglu@ogu.edu.tr

Abstract: Multi criteria decision making models (MCDM) are extensively used in material and process selection in engineering. In this study, a novel hybrid decision making model is developed. Best-Worst (BWM) and entropy methods are combined and hybridized with Reference Ideal Method. The model is tested in a face milling case study taken from literature. The developed model produced similar results with literature. The proposed model can be used by engineers and operators in manufacturing environment.

Keywords: Multi criteria decision making, Best-Worst method, Reference Ideal Method, Micromachining, face milling

Introduction

In recent years, there has been an increasing amount of literature on MCDM. When the studies in literature are investigated, MCDM techniques are grouped under 15 topics: Energy-environment-sustainability, supply chain management, material, quality management, Geographic Information Systems (GIS), construction and project management, safety and risk management, manufacturing systems, technology management, operation research and soft computing, strategic management, knowledge management, production management, tourism management and the other fields (Mardani et al., 2015). For MCDM techniques, there are a lot of studies in the area of material science (Jahan et al., 2011) production technologies (Streimikiene et al., 2013), mass production (Chang et al., 2013), manufacturing sector (Bagočius, 2013) manufacturing systems (Jana et al., 2013), global production (Tzeng and Huang, 2012) and production strategies (Yurdakul, 2004).

One of the new methods developed in recent years is Best-Worst method. This method provides to score only best and worst criteria. Therefore, pairwise calculations are only between best and worst criteria and calculations are simple. Furthermore, it is more consistent than AHP method. Reference Ideal method is another new MCDM method to rank the alternatives by using subjective decision matrix. Entropy method is an objective weighting method to determine criteria weights. By using this method, the entropy weights are calculated by using the information entropy (Razaei, 2015; Cables et al., 2016; Li et al., 2016).

Up to now, for MCDM techniques, previous studies are generally carried out in Operation Research-Soft Computing and energy-environment-sustainability. In machining operations, researchers rarely developed MCDM models. Furthermore, developed model in this study is a new hybrid decision making model and it is used for the first time in the literature.

In this study, Best-Worst and Entropy methods are combined and hybridized with Reference Ideal Method. The proposed model is tested in a face-milling operation. The criteria weights are calculated by using Best-Worst and entropy method. Using these criteria weights, the experiments are ranked by using Reference Ideal Method. In the second part of the study, methods used in the study are explained briefly. In the third section, case study taken from literature is summarized. In the final sections, results and discussion, conclusion sections are given, respectively.

Materials and Methods

The case study is taken from Yan and Li's study (Yan and Li, 2013). The experiments are carried out by using CNC micromachining center. Face milling operation is performed. 3 flutes carbide tool is used in dry cutting operations. The dimension of the workpiece is 50×30×1.2 mm. The measurements are carried out by changing four parameters: spindle speed, feed rate, depth of cut and width of cut. Three levels are used for experimental design. The design of the experiments is given in Table 1. The purpose of the study is to maximize material removal rate (MRR) and to minimize surface roughness (SR) and cutting energy (CE).

Table 1. The design matrix of case study

Experiment no	Spindle speed (r/min)	Feed rate (mm/min)	Depth of cut(mm)	Width of cut (mm)	MRR (mm^3/min)	SR (µm)	CE (kj)
1	1000	200	0.2	5.00	200	2.15	555.802
2	1000	200	0.3	10.00	600	2.2	204.929
3	1000	200	0.4	15.00	1200	1.54	108.519
4	1000	250	0.2	5.00	250	3.28	446.109
5	1000	250	0.3	10.00	750	4.71	166.05
6	1000	250	0.4	15.00	1500	3.13	89.823
7	1000	300	0.2	5.00	300	4.43	381.832
8	1000	300	0.3	10.00	900	4.31	142.976
9	1000	300	0.4	15.00	1800	2.83	73.988
10	1500	200	0.2	5.00	400	3.05	357.042
11	1500	200	0.3	10.00	900	0.94	162.727
12	1500	200	0.4	15.00	400	3.48	319.031
13	1500	250	0.2	5.00	500	3.44	289.604
14	1500	250	0.3	10.00	1125	1.88	133.648
15	1500	250	0.4	15.00	500	3.73	258.476
16	1500	300	0.2	5.00	600	2.73	233.559
17	1500	300	0.3	10.00	1350	2.1	112.551
18	1500	300	0.4	15.00	600	1.99	213.109
19	2000	200	0.2	5.00	600	3.18	264.303
20	2000	200	0.3	10.00	300	3.89	445.797
21	2000	200	0.4	15.00	800	2.65	185.62
22	2000	250	0.2	5.00	750	2.58	213.939
23	2000	250	0.3	10.00	375	2.92	358.579
24	2000	250	0.4	15.00	1000	2.92	151.343
25	2000	300	0.2	5.00	900	2.39	180.886
26	2000	300	0.3	10.00	750	2.09	306.85
27	2000	300	0.4	15.00	1200	1.84	128.147

Results and Discussion

The purpose of the study is to maximize material removal rate (MRR) and to minimize surface roughness (SR) and cutting energy (CE). First, Best-Worst method is used to obtain these outputs' weights. According to five experts, criteria points are presented in Table 2. The average value of five experts' points are taken. Consistency ratio is lower than 0.1, so the analysis is consistent.

Table 2. Criteria points according to 5 experts.

EXPERT-1	SR	CE	MRR	Objective function value
Best:MRR	4	2	1	2.2e-7
Worst:SR	1	2	4	
EXPERT-2	SR	CE	MRR	
Best:MRR	3	3	1	7.5e-7
Worst:SR	1	1	3	
EXPERT-3	SR	CE	MRR	
Best:MRR	3	1	1	1.204e-7
Worst:SR	1	3	3	
EXPERT-4	SR	CE	MRR	
Best:MRR	4	4	1	2e-7
Worst:SR	1	1	4	
EXPERT-5	SR	CE	MRR	
Best:MRR	4	1	1	2.79e-7
Worst:SR	1	4	4	

By using experimental results, entropy weights are calculated. All the weights used in the model is given in Table 3.Three different weights are used in the analysis.

Table 3. Criteria weights used in the analysis

Methods	**MRR**	**SR**	**CE**
Case study (Yan and Li, 2013).	0.3315	0.2329	0.4356
Entropy	0.4400	0.1700	0.3900
Best Worst	0.5400	0.1500	0.3100

Range and reference ideal matrices are determined as follows.
Range matrix: AB = [100, 2000, 0.5, 6, 50, 600]
Reference ideal matrix: CD = [1800, 1800, 0.94, 0.94, 74, 74]
By using criteria weights from Table 3, RIM is developed. In Table 4, RIM results are presented.

Table 4. RIM results according to different weighting methods.

Weighting methods	**Rankings**
Case study (Yan and Li, 2013)	27-13-4-25-15-3-24-11-1-22-7-21-20-6-19-16-2-14-18-26-10-12-23-8-9-17-5
Best worst	27-14-4-25-12-2-24-10-1-22-8-21-20-6-19-16-3-15-18-26-11-13-23-7-9-17-5-16-4
Entropy	27-15-4-25-13-2-24-10-1-22-8-21-20-6-19-17-3-16-18-26-11-12-23-7-9-14-5

In Table 5, correlation coefficients of these rankings are given. The correlation coefficients are significant at 5% level which means there is no significant difference between rankings.

Table 5. Correlation matrix (r/p)

Methods	**Case study**	**Best-Worst**	**Entropy**
Case study	1.000/0.000	0.995/0.000	0.991/0.000
Best-Worst	0.995/0.000	1.000/0.000	0.996/0.000
Entropy	0.991/0.000	0.996/0.000	1.000/0.000

In Table 6, comparison of the results with literature is given. Experiment #9 is the optimum experiment, so the optimum cutting conditions are the same.

Table 6. Comparison of the results (Yan and Li, 2013).

Studies	Spindle speed	Feed rate	Depth of cut	Width of cut
Literature study	1000	300	0.4	15
Current study	1000	300	0.4	15

Conclusion

In this study, a new hybrid decision-making model is proposed. Best-Worst and entropy methods are used to calculate criteria weights and reference ideal method is used to determine the final rankings Face milling optimization problem was taken from the literature as a case study. The developed model was tested with this problem. The obtained results showed that calculated rankings are nearly same. There is no difference between these rankings at 5% significance level. The developed model can be used different optimization problems.

Acknowledgements

The author M.Alper SOFUOĞLU was supported by TÜBİTAK 2228-B

References

Bagočius, V., Zavadskas, E. K., and Turskis, Z., (2013), Multi-criteria selection of a deep- water port in Klaipeda. *Procedia Engineering*, 57, 144–148.

Cables, E., Lamata, M.T.; Verdegay, J.L., (2016). RIM-reference ideal method in multi criteria decision making. *Information Science*, 337-338, 1-10.

Chang, A.-Y., Hu, K.-J., and Hong, Y.-L., (2013), An ISM-ANP approach to identifying key agile factors in launching a new product into mass production. *International Journal of Production Research*, 51, 582–597.

Jahan, A., Mustapha, F., Ismail, M. Y., Sapuan, S., and Bahraminasab, M. (2011), A comprehensive VIKOR method for material selection. *Materials and Design*, 32, 1215–1221.

Jana, T. K., Bairagi, B., Paul, S., Sarkar, B., and Saha, J., (2013), Dynamic Schedule execution in an agent based holonic manufacturing system. *Journal of Manufacturing Systems*, 32, 801– 816.

Li, A., Zhao, J., Gong, Z., Lin, F., (2016), Optimal selection of cutting tool materials based on multi-criteria decision-making methods in machining, Al-Si piston alloy, *International Journal Advanced Manufacturing Technology*, 86:1055

Mardani, A., Jusoh, A., MD Nor K., Khalifah Z., Zakwan, N. and Valipour A., (2015), Multiple criteria decision-making techniques and their applications – a review of the literature from 2000 to 2014, *Economic Research-Ekonomska Istraživanja*, 28:1, 516-571.

Rezaei, J., (2015), Best-worst multi-criteria decision-making method, *Omega*, 53, 49–57.

Streimikiene, D., Balezentis, T., Krisciukaitienė, I., and Balezentis, A., (2012), Prioritizing sustainable electricity production technologies: MCDM approach. *Renewable and Sustainable Energy Reviews*, 16, 3302–3311.

Tzeng, G.-H., and Huang, C.-Y., (2012), Combined DEMATEL technique with hybrid MCDM methods for creating the aspired intelligent global manufacturing and logistics systems. *Annals of Operations Research*, 197, 159–190.

Yan, J., Li, L., (2013), Multi-objective optimization of milling parameters-the trade-offs between energy, production rate and cutting quality, *Journal of Cleaner Production*, 52:462-471.

Yurdakul, M., (2004), AHP as a strategic decision-making tool to justify machine tool selection. *Journal of Materials Processing Technology*, 146, 365–376.