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Multi-criteria Decision Making Approach: selection of Blanking Die Material

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ABSTRACT

Proper selection of material in manufacturing firms is a vital role of designer depending upon the different era of application. The material selection problem is very complex and challenging task today. Erroneous cull of material frequently leads to astronomically immense cost involution, and finally drives towards unfortunate component or product breakdown. Thus, the designer necessitates discovering and culling the felicitous materials with concrete functionalities in order to obtain the desired output with least cost involution and definite applicability. It is an intension for simple, logical and rational methods or statistical implements to direct decision makers while considering number of cull attributes and their interrelations. This paper introduce a way to work out the material selection problem by one of the most Multi-Criteria decision making (MCDM) approaches in which ranking of the best material is computed using the multi-objective optimization on the basis of ratio analysis (MOORA) method.

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1. INTRODUCTION

With the expansion of technology and worldwide competitiveness, scientists and technologists in the modern organizations are now facing challenging of various problems in selecting correct product, process designs, materials, machinery, equipment and manufacturing strategies.

For the design and manufacturing variants of mechanical component, materials play a paramount role in which types of material properties, cost, design consideration and its influence are indispensable. With the introduction of newer and harder materials, the selection decisions regarding material become more complex because each material has its individual applications, advantages, characteristics and limits.

When culling materials for felicitous application, a well-defined understanding of the requisites for every individual element is requisite and different significant attributes need to be well thought-out. These attributes incorporate mechanical, physical, and thermal properties, material shape, cost, availability, performance characteristics and aesthetic considerations [1].

While selecting a proper material for the application, generally decision makers should apply trial-error method or implement his/her knowledge of the past experiments. Over the past, numbers of approach have been given by researchers for selecting the proper material for engineering applications. In order to concentrate on the difficulty to select material, various methods had been projected in the past research paper, such as GTMA (graph theory and matrix approach), TOPSIS (technique of order preference by similarity to ideal solution), AHP (Ashby approach, analytic hierarchy process), Entropy, standard deviation method, VIKOR (VIsekriterijumska optimizacija Kompromisno Resenje), GRA (gray relation analysis) and COPRAS (COmplex PRoportional ASsessment). Kumar and Ray [2] conferred a method to decide optimal material for engineering design in which TOPSIS method was applied to find the best alternatives among others. Rao and Patel [1] found a novel fuzzy MADM method to choose material for a design problem in which choice-based on subjective preferences /objective weights or simultaneously on both. Singh and Rao [3] proposed the

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use of hybrid decision-making method of GTMA and AHP for solving problems of the industrial environment. Gorener et al. [4] provided the outline of Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis to handle decision situations. They enhanced SWOT analysis with AHP. Dey et al. [5] applied fuzzy multi-criteria decision-making technique entailing MOORA in the selection of alternatives in a supply chain. Brauers and Zavadskas [6] presented MOORA method for multi-objective optimization with discrete alternatives and applied to privatization in a transition economy. Chakladar and Chakraborty [7] used TOPSIS and an AHP to choose the most proper nontraditional machining (NTM) processes as a definite work material and contour characteristic combination. Chakraborty [8] solved the problem of decision making in manufacturing era through MOORA method. Harbi et al. [9] presented AHP as a potential decision-making method for use in project management. Gadakh et al. [10] applied MOORA method for choosing optimal process parameters in special welding processes. Bose and Mahapatra [11] investigated the experimental data using Grey Relational Analysis (GRA) to optimize multiple performances in which different levels combination of the factors was ranked based on grey relational grade. Maniya et al. [12] performed multi-attribute evaluation of water jet weaving machines alternatives using AHP. Madic et al. [13] introduced one of the most unexplored OCRA (operational competitiveness ratings, analysis) MCDM methods for solving the non-conventional machining process (NCMP) selection problems. Mukherjee et al. [14] utilized six mainly famous GA (genetic algorithm), PSO (particle swarm optimization), SFA(sheep flock) algorithm, AC (ant colony optimization), ABC (artificial bee colony) and biogeography-based optimization algorithms for single as well as multi-objective optimization of two WEDM processes. Gadakh [15] applied MOORA method to solve multi-criteria optimization problem in the milling process. Chaturvedi et al. [16] explained parametric optimization of Electrochemical machining process on MRR by MOORA method to select best parameter combination. Brauers et al. [17] solved the problem in road construction as multi-objective optimization by MOORA method. Gaidhani and Kalamani [18] presented a deep study of a newer non-conventional technique of machining i.e., abrasive water jet machining and also focus on the selection of various process parameters with the help of AHP. R. Tavakkoli-Moghaddam and S.M. Mousavi [19] applied AHP and VIKOR method to select the appropriate site for developing a new manufacturing firm.

The objective of this paper is to discover a MCDM method to handle material selection problems with weighing both qualitative and quantitative attributes. The MCDM problems are grouped into two categories: continuous and discrete type depending upon the various types of alternatives. A distinctive MCDM problem consists of three key components, i.e. (i) alternatives, (ii) criteria (attributes), and (iii) significance (weight) of each criterion. One of the most MCDM approach (MOORA) has been explored to select a suitable material for blanking die manufactured by WEDM process.

2. THE MOORA METHOD

The MOORA method was introduced through Brauers and Zavadskas [6]. Because of its easiness and inclusiveness, it has previously been effectively used in manufacturing by Chakraborty [8], management & construction engineering by Brauers et al. [17]. MOORA is the process of concurrently optimizing more than two conflicting attributes (objectives) subject to certain constraints. It has been previously observed that MOORA method is very ease, steady and robust, and it requires least statistical calculations and estimating time [8, 10, 15-17] .

Step I: The foremost step is to decide the objective as well as to determine the relevant attributes.

Step II: The subsequently step is to prepare decision matrix according to Table 1 which shows information regarding all selected attributes.

Step III: Afterwards normalization of each performance alternative with respect to attributes is computed using following expression as below:

$$R_{ij} = \frac{x_{ij}}{\sqrt{\left[\sum_{j=1}^{M} x^2_{ij}\right]}} \tag{1}$$

where x_{ij} is a dimensionless number which belongs to interval [0, 1] representing normalized performance data of i^{th} alternative on j^{th} attribute.

Step IV: For beneficial attributes; Normalized performances are added in case of maximization and for non-beneficial attributes; normalized performances are subtracted in case of minimization.

TABLE 1. Decision Matrix [20]

Alternatives	**Attributes**					
	C_1 (w_1)	C_2 (w_2)	C_3 (w_3)	- (-)	- (-)	C_M (W_M)
A_1	x_{11}	x_{12}	x_{13}	-	-	x_{1M}
A_2	x_{21}	x_{22}	x_{23}	-	-	x_{2M}
A_3	x_{31}	x_{32}	x_{33}	-	-	x_{3M}
-	-	-	-	-	-	-
-	-	-			-	-
A_N	x_{N1}	x_{N2}	x_{N3}	-	-	x_{NM}

Then, the optimization problem becomes:

$$Y_i = \sum_{j=1}^{k} R_{ij} - \sum_{j=k+1}^{n} R_{ij} \tag{2}$$

where k is the number of attributes to be maximized, (n−k) the number of attributes to be minimized, and Yi is the normalized assessment value of i_{th} alternative with respect to all the attributes.

In several instances, there is frequently noted that some attributes are more significant than the others. In this case, the weight of the attributes are considered, and then Eq. 2 becomes:

$$Y_{(i)} = \sum_{j=1}^{k} w_j R_{ij} - \sum_{j=k+1}^{n} w_j R_{ij} \tag{3}$$

where W_j is the weight of jth attribute, which can be determined by applying Entropy method. The outcome of Equation (3) restrain higher value is the most excellent rank and smaller value got a lowest rank that way rating is in diminishing order.

3. DECISION MAKING PROBLEM

To express and confirm the utilization of the aforementioned decision making approaches for solving blanking die material selection for WEDM Process problems, the subsequent reliable-existence example is mentioned.

3. 1. Selection of Blanking Die Material In the dynamic and competitive scenario, industries need to respond to the demand and changes in the market to survive. To meet the production task at large scale within a short period, dies and mold systems are applied in every manufacturing industry. The shape, size, and materials of dies and molds vary according to the application. One can distinguish between dies and molds for the plastic industries like extrusion, injection molding; hot work dies for forging and casting; dies for bending, drawing and for powder metallurgy manufacture. The performance of a die is a function of its surface characteristics and dimensional precision which depends on material’s physical and chemical properties, machining parameters setting etc. The aspect, rate and lead times of dies and molds influence the finance of producing a very huge quantity of parts and assemblies. These dies must have several qualities like as good material, precise surface finish, and exact dimensional tolerance. Die material affect the overall die quality related to strength, wear resistance and durability. Good surface finish significantly affects the die robustness and qualities. Exact dimensional tolerance can eliminate additional machining and finishing. The essential properties of die material contain composition, grain size, physical and thermal properties, etc., which play an important role in machinability as well as performance. The word machinability refers to the ease with which a metal can be cut permitting faster material removal with good surface condition at low cost.

So, the selection of best material for making a blanking die in industries is a major problem. In this problem, machinability, cost, density, melting temperature, wear resistance, hardness, toughness, compressive strength, thermal conductivity, thermal expansion, creep strength, yield tensile strength and bending strength are most affecting attributes for selecting a best material for blanking die machining by WEDM.

In the present study, a study of various manufacturing industries, various catalogues of manufacturers, experience of users or customers and Material data handbook, material selection problem was formulated with seven alternatives and fifteen attributes, which are presented in Table 2.

4. RESULT AND DISCUSSION

The subjective data of the eight attributes machinability, wear resistance, fatigue strength, compressive strength, toughness, yield tensile strength, creep strength and bending strength are converted into appropriate objective data using Table 3 [20] which is presented in Table 4. Then, apply Equation (1) to find normalized value of all attributes as shown in Table 5. The weighting of all the fifteen considered attributes are estimated as w_1=0.0563, w_2=0.0517, w_3= 0.0739, w_4=0.0739, w_5=0.0739, w_6=0.0660, w_7=0.0648, w_8=0.0648, w_9=0.0677, w_{10}=0.0658, w_{11}=0.0728, w_{12}=0.0648, w_{13}=0.0738, w_{14}=0.0648 and w_{15}=0.0648 using entropy method. In multi-objective optimization, for beneficial attributes; normalized performances are added and for non-beneficial attributes; normalized performances are subtracted [10]. Machinability, density, specific heat, wear resistance, fatigue strength, compressive strength, toughness, thermal conductivity, yield tensile strength, hardness, creep strength and bending strength are considered as higher values (beneficial) of attributes, while cost, melting temperature and thermal expansion are considered as lower values (non-beneficial) attributes. After that, apply Equation (3) which gives the normalized assessment values (Yi) of all the alternatives regarding to all attributes. Table 6 shows the results of the MOORA method, which gives a proportional ranking of the alternative when arranged in accordance with the descending order of their assessed values; by this method, SKD 11 is the best material among other alternatives and AISI S7 is the worst material among alternatives.

TABLE 2. Decision Matrix for Attributes

Blanking Die _Material selection Criteria							
Material	**Machinability**	**Cost Rs./Kg**	**Density g/cc**	**Specific Heat J/Kg K**	**Melting Temp. C**	**Wear Resistance**	**Fatigue strength**
AISI A2	Good	550	7.86	461	1424	Good	Best
SKD 11	Low	300	7.7	460	1421	Best	Best
AISI O1	Good	199	7.8	460	1421	Fair	Good
AISI O6	Best	250	7.67	460	1421	Fair	Good
AISI L6	Good	200	7.85	460	1421	Fair	Fair
AISI S7	Good	400	7.83	460	1421	Good	Fair
AISI D3	Low	199	7.7	460	1421	Good	Good
Compressive Strength	**Toughness**	**TC* w/mk**	**TE* 10^-6/C**	**Yield Tensile Strength**	**Hardness**	**Creep Strength**	**Bending strength**
Best	Fair	26	11.6	Best	62	Best	Best
Best	Fair	20	10.5	Best	64	Best	Best
Good	Good	34	10.6	Good	62	Good	Good
Good	Good	20.5	12.3	Good	63	Good	Good
fair	Fair	36	11.3	Fair	62	Fair	Fair
Fair	Fair	28.5	13.7	Fair	57	Fair	Fair
Good	Low	20	12	Good	64	Good	Good

*TC- Thermal Conductivity, *TE- Thermal Expansion

TABLE 3. Conversion of linguistic terms into fuzzy score [20]

Linguistic term	**Crisp score**
Low	0.335
Fair	0.5
Good	0.665
Best	0.955

As compared to other MADM methods studied by past researchers, MOORA methods is very easy, simple and comprehendible to use for any decision making environment. These methods require less computing time because they require minimum number of mathematical steps as well as being useful to the decision makers who have less command in mathematics. For this reason, MOORA method is very robust for different decision making problem.

TABLE 4. Objective value of all attributes

Blanking Die _Material selection Criteria							
Material	**Machinability**	**Cost Rs./Kg**	**Density g/cc**	**Specific Heat J/Kg K**	**Melting Temp. C**	**Wear Resistance**	**Fatigue strength**
AISI A2	0.665	550	7.86	461	1424	0.665	0.955
SKD 11	0.335	300	7.7	460	1421	0.955	0.955
AISI O1	0.665	199	7.8	460	1421	0.5	0.665
AISI O6	0.995	250	7.67	460	1421	0.5	0.665
AISI L6	0.665	200	7.85	460	1421	0.5	0.5
AISI S7	0.665	400	7.83	460	1421	0.665	0.5
AISI D3	0.335	199	7.7	460	1421	0.665	0.665
Compressive Strength	**Toughness**	**TC w/mk**	**TE 10^-6/C**	**Yield Tensile Strength**	**Hardness**	**Creep Strength**	**Bending strength**
0.955	0.5	26	11.6	0.955	62	0.955	0.955
0.955	0.5	20	10.5	0.955	64	0.955	0.955
0.665	0.665	34	10.6	0.665	62	0.665	0.665
0.665	0.665	20.5	12.3	0.665	63	0.665	0.665
0.5	0.5	36	11.3	0.5	62	0.5	0.5
0.5	0.5	28.5	13.7	0.5	57	0.5	0.5
0.665	0.335	20	12	0.665	64	0.665	0.665

TABLE 5. Normalized data of attributes

Material	Machineability	Cost Rs./Kg	Density g/cc	Specific Heat J/Kg K	Melting Temp. C	Wear Resistance	Fatigue strength	Compressive Strength	Toughness	TC w/mk	TE 10^-6/C	Yield Tensile Strength	Hardness	Creep Strength	Bending strength
AISI A2	0.3850	0.6419	0.3822	0.3787	0.3786	0.3847	0.4998	0.4998	0.3538	0.3619	0.3729	0.4998	0.3777	0.4998	0.4998
SKD 11	0.1940	0.3501	0.3744	0.3778	0.3779	0.5524	0.4998	0.4998	0.3538	0.2784	0.3375	0.4998	0.3899	0.4998	0.4998
AISI O1	0.3850	0.2322	0.3793	0.3778	0.3779	0.2892	0.3480	0.3480	0.4706	0.4733	0.3407	0.3480	0.3777	0.3480	0.3480
AISI O6	0.5761	0.2918	0.3729	0.3778	0.3779	0.2892	0.3480	0.3480	0.4706	0.2854	0.3954	0.3480	0.3838	0.3480	0.3480
AISI L6	0.3850	0.2334	0.3817	0.3778	0.3779	0.2892	0.2617	0.2617	0.3538	0.5011	0.3632	0.2617	0.3777	0.2617	0.2617
AISI S7	0.3850	0.4668	0.3807	0.3778	0.3779	0.3847	0.2617	0.2617	0.3538	0.3967	0.4404	0.2617	0.3473	0.2617	0.2617
AISI D3	0.1940	0.2322	0.3744	0.3778	0.3779	0.3847	0.3480	0.3480	0.2371	0.2784	0.3857	0.3480	0.3899	0.3480	0.3480

TABLE 6. Normalized assessment values (Yi)

Material	Machineability	Cost Rs./Kg	Density g/cc	Specific Heat J/Kg K	Melting Temp. C	Wear Resistance	Fatigue strength	Compressive Strength	Toughness	TC w/mk	TE 10^-6/C	Yield Tensile Strength	Hardness	Creep Strength	Bending strength	Yi	RRank
Weight	0.0563	0.0517	0.0739	0.0739	0.0739	0.0660	0.0648	0.0648	0.0677	0.0658	0.0728	0.0648	0.0738	0.0648	0.0648		
AISI A2	0.0217	0.0332	0.0282	0.0280	0.0280	0.0254	0.0324	0.0324	0.0240	0.0238	0.0271	0.0324	0.0279	0.0324	0.0324	0.2526	2
SKD 11	0.0109	0.0181	0.0277	0.0279	0.0279	0.0365	0.0324	0.0324	0.0240	0.0183	0.0246	0.0324	0.0288	0.0324	0.0324	0.2654	1
AISI O1	0.0217	0.0120	0.0280	0.0279	0.0279	0.0191	0.0226	0.0226	0.0319	0.0311	0.0248	0.0226	0.0279	0.0226	0.0226	0.2356	3
AISI O6	0.0324	0.0151	0.0276	0.0279	0.0279	0.0191	0.0226	0.0226	0.0319	0.0188	0.0288	0.0226	0.0283	0.0226	0.0226	0.2269	4
AISI L6	0.0217	0.0121	0.0282	0.0279	0.0279	0.0191	0.0170	0.0170	0.0240	0.0330	0.0264	0.0170	0.0279	0.0170	0.0170	0.2001	5
AISI S7	0.0217	0.0241	0.0281	0.0279	0.0279	0.0254	0.0170	0.0170	0.0240	0.0261	0.0321	0.0170	0.0256	0.0170	0.0170	0.1795	7
AISI D3	0.0109	0.0120	0.0277	0.0279	0.0279	0.0254	0.0226	0.0226	0.0161	0.0183	0.0281	0.0226	0.0288	0.0226	0.0226	0.1998	6

5. CONCLUDING REMARKS

The application of the MOORA method is recommended for decision making in the manufacturing era which used to select the most appropriate choice among a large number of alternatives for a given application. The MOORA method helps the engineer to choose any type of best alternatives to develop any new product from design to production process. This decision-making approach is mathematically easy, robust and coherent which can concurrently consider huge number of quantitative and qualitative selection attributes. The result of the MOORA method highlight the alternative SKD 11 and is the best choice among the 7 alternatives for blanking die manufacturing using WEDM process. Applying other MCDM methods to validate the result of MOORA method for future attempts.

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چکیده

انتخاب مناسب مواد در شرکت‌های تولیدی از نقش‌های حیاتی طراح در دوره‌های مختلف کاربرد آن است. امروزه مساله‌ی انتخاب مواد بسیار پیچیده و چالش برانگیز است. انتخاب نادرست مواد اغلب منجر به ایجاد هزینه‌های نجومی، و در نهایت به سمت از دست دادن تاسف‌بار قطعه یا ازکارافتادگی آن می‌شود. بنابراین، طراح مکلف به انتخاب مواد درست با ویژگی‌های اساسی به منظور کسب خروجی مورد نظر با حداقل هزینه و کارایی لازم است. هدف، یافتن روش‌های ساده، منطقی و عقلانی یا استفاده از ابزارهای آماری برای هدایت تصمیم گیرندگان در ضمن توجه به تعدادی از ویژگی و روابط متقابل آنهاست. در این مقاله روشی برای حل مشکل انتخاب مواد با بهره‌گیری از یکی از مهم‌ترین روش‌های تصمیم گیری چند معیاره (MCDM) که در آن رتبه بندی از بهترین مواد با استفاده از بهینه سازی چندهدفه بر اساس تحلیل نسبت‌ها(MOORA) محاسبه می‌شود، معرفی شده است.

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