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AUTOMOBILE WHEEL MATERIAL SELECTION USING MULTI-OBJECTIVE OPTIMIZATION ON THE BASIS OF RATIO ANALYSIS (MOORA) METHOD

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ABSTRACT:

Material selection is one of the most vital decisions in finest design of any manufacturing process and product. Proper material selection plays an elementary role for a productive manufacturing system with better product and process superiority along with cost optimization. Improper material selection often causes huge cost contribution and drives an organization towards unripe product failure. In this paper, multi-objective optimization on the basis of ratio analysis (MOORA) method is applied to solve magnesium alloy material selection problem to use in automotive wheel applications. A comprehensive list of all the prospective materials from the best to the worst is obtained, taking into account multi-conflicting material selection attributes. The ranking performance of the method is also compared with that of the past researchers. It is observed that the method is very simple to understand, easy to implement and provide almost exact rankings to the automotive wheel material alternatives

KEYWORDS: Automotive wheel material selection, MOORA method, Muti-Criteria Decision Making.

I. INTRODUCTION:

The choice of materials plays an important role in the decision-making process of any automobile organization. To select the material for a particular application is a very tough because numbers of material with their multiple criteria are available in the market. There is a vast array of automotive materials with diverse mechanical, physical and chemical properties from which the decision maker has to choose the most suitable material satisfying different design requirements. The huge number of existing automotive materials, together with the complex relationships between a variety of selection parameters, frequently makes the selection procedure a difficult job. Materials to play an important role in engineering design. Now-a-days, a large number of materials with varying properties are available in the market. The design engineer has to think twice before selecting the proper material for a particular product. Any mistake in selecting the material may create problem during production and assembly. The design engineer has to consider a variety of attributes, like physical, electrical, magnetic, mechanical, chemical and manufacturing properties, material cost, environmental effect, performance characteristics, availability etc. while selecting the material for a particular product, which makes the selection process more complex than before. Thus, while selecting the most suitable automotive material for a particular automobile application, a more precise mathematical approach is often required. As the automotive material selection decision for a specific application involves multiple conflicting criteria and a finite set of candidate alternatives, it is a typical MCDM problem. In this paper, multi-objective optimization on the basis of ratio analysis (MOORA) method is applied to solve magnesium alloy material selection problem to use in automotive wheel applications [1-3].

II. LITERATURE REVIEW:

For the selection of appropriate material from the available alternatives for a given engineering application, the past researchers have presented different mathematical approaches. Athawale et al. [4] focused on solving two real time material selection problems using utility additive (UTA) method, which had been an almost unexplored MCDM tool to solve such type of complex decision-making problems. Cui et al. [5] proposed a novel material performance index and procedure to guide systematic material selection for multi-material automotive bodies. The proposed method would enable to characterize the crashworthy performance of complex-shaped thin-walled beams in multi-material automotive bodies according to material types. Zander and Sandström [6] determined merit indices which were generalized to cooling systems where heat flow and strength had been the design criteria in a material optimization framework. Merit indices were used to rank materials and of fundamental importance in material selection. Chauhan and Vaish [7] investigated MEM'S material selection using MADM approaches and compared the obtained results with that of the Ashby approach. Almost similar material rankings indicated that MADM approaches would also be efficient and easy to apply without any prior mathematical calculation for material properties-application relation. Maity et al. [8] applied COPRAS method with grey to solve cutting tool material selection problem. Maity and Chakraborty [9] applied fuzzy analytic network process (FANP) to select the most appropriate material for a supercritical boiler. Rene 41 was the best supercritical boiler material, whereas, Haynes 230 was the worst preferred choice. Athawale et al. [10] focused on solving the gear material selection problems using VIKOR method which had become a popular MCDM tool.

Although a good amount of research work has been carried out in the past on materials selection employing different mathematical approaches (especially MCDM methods), any prior study has not demonstrated the application of MOORA method, for solving automotive wheel material selection problems.

III MULTI-OBJECTIVE OPTIMIZATION ON THE BASIS OF RATIO ANALYSIS METHOD:

In many real world applications, multi-objective optimization problems with multiple conflicting criteria often arise where the decision maker has to choose the best alternative. An important task in multi-objective optimization is to identify a set of optimal trade-off solutions between the conflicting criteria, which helps gain a better understanding of the problem structure and supports the decision maker in selecting the best compromise solution for the considered problem. Therefore, multi-objective optimization techniques seem to be an suitable tool for ranking or choosing one or more alternative from a set of available options based on multiple, usually contradictory attributes. The MOORA (multi-objective optimization on the basis of ratio analysis) method is such a multi-objective optimization technique that can be successfully applied to solve various types of complex decision-making problems in the manufacturing environment [29-30].

The MOORA method starts with the following decision matrix showing the performance of different alternatives with respect to various attributes (objectives).

	Attribute 1	Attribute 2	…	…	Attribute n
Alternative 1	x_{11}	x_{12}	…	…	x_{1n}
Alternative 2	X_{21}	x_{22}	…	…	x_{2n}
…	…	…	…	…	…
…	…	…	…	…	…
Alternative m	x_{m1}	x_{m2}	…	…	x_{mn}

where x_{ij} is the performance measure of i^{th} alternative on j^{th} attribute.

Then a ratio system is developed in which each performance of an alternative on an attribute is compared to a denominator which is a representative for all the alternatives concerning that attribute. For MOORA method, the following ratio system is adopted.

$$x_{ij}^{*} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad (1)$$

Where x_{ij}^{*} is a dimensionless number in the [0,1] interval representing the normalized performance of i^{th} alternative on j^{th} criterion. Although brauers (2004) proposed the following normalization procedure, it is occasionally observed that when a decision matrix has a very large value for a particular criterion, the normalized value for that criterion exceeds one.

$$x_{ij}^{*} = x_{ij} \Big/ \left[\sum_{i=1}^{m} x_{ij}^{2} \right]^{1/2} \quad (j = 1,2,\ldots,n) \qquad (2)$$

So, it is always advised to employ Eqn. (1) for normalization of the elements of the decision matrix in MOORA method-based analysis. For multi-objective optimization, these normalized performances are added in case of maximization (for beneficial attributes) and subtracted in case of minimization (for non-beneficial attributes). Then the optimization problem becomes:

$$y_i = \sum_{j=1}^{g} x_{ij}^{*} - \sum_{j=g+1}^{n} x_{ij}^{*} \qquad (3)$$

where g is the number of criteria to be maximized, (n-g) is the number of criteria to be minimized and y_i is the assessment value of i^{th} alternative with respect to all the criteria. The y_i value can be positive or negative depending of the totals of its maxima (beneficial attributes) and minima (non-beneficial attributes) in the decision matrix. An ordinal ranking of y_i shows the final ranking. The most suited alternative has the highest y_i value, while the worst alternative has the lowest y_i value. As MOORA method performs non-subjective analysis of the alternatives, it does not require weights of the attributes because it incorporates in-house normalization and treats all the attributes equally important.

IV.ILLUSTRATIVE EXAMPLE:

Automobile wheel material selection is a most vital component in an automobile. It support and abide the entire load and suffers not only with the vertical force but also the uneven and impact forces resulting from braking, road bumps , car's ride, cornering, and all shocks in the process of moving on an rough road. Due to high speed rotation, its quality has a vast impact on wheel stability, handling and their characteristics [8]. Automobile wheel generally made of Steel, aluminum or Magnesium alloys. Magnesium is vastly used in race cars and more preferable than the other material because of lower density. This automotive wheel material selection problem involves recognition of different magnesium alloy materials that are used in the manufacturing of alloy wheels and to choose the most excellent among them. In this selection problem eight Magnesium alloys and their ten selection attributes (Density, Thermal conductivity, UTS, YTS, Fatigue Strength, Impact, Hardness, % Elongation, specific heat and Coefficient of thermal expansion) has been considered as shown in table 1[23]. Among the several selection criteria some are beneficial and some are non beneficial in nature. Thermal conductivity, UTS, YTS, Fatigue Strength, Impact, Hardness and specific heat are beneficial in nature whose higher values are desirable and remaining attributes are non beneficial in nature.

Table 1 Decision matrix for automobile wheel Material [23]

Material	AZ91 (A1)	AM60 (A2)	AM50 (A3)	AZ31 (A4)	ZE41 (A5)	EZ33 (A6)	ZE63 (A7)	ZC63 (A8)
Density (g/cm3)	1.81	1.79	1.77	1.771	1.84	1.8	1.87	1.87
Thermal conductivity	72.7	62	65	96	113	99.5	109	122
UTS	230	241	228	260	205	200	295	240
YTS	150	131	124	200	140	140	190	125
Fatigue Strength	97	80	75	90	63	40	79	93
Impact	2.7	2.8	2.5	4.3	1.4	0.68	2.3	1.25
Hardness	63	65	60	49	62	50	75	60
%Elongation	3	13	15	15	3.5	3.1	7	4.5
Sp. Heat	0.8	1	1.02	1	1	1.04	0.96	1
Coff. Of Thermal Exp.	26	26	26	26	26	26.4	27	26

Table 2 Normalized Decision matrix

Material	A1	A2	A3	A4	A5	A6	A7	A8
Density (g/cm3)	0.3525	0.3486	0.3447	0.3449	0.3583	0.3505	0.3642	0.3642
Thermal conductivity	0.2709	0.2311	0.2422	0.3578	0.4211	0.3708	0.4062	0.4547
UTS	0.3401	0.3564	0.3372	0.3845	0.3032	0.2958	0.4363	0.3549
YTS	0.3478	0.3038	0.2875	0.4638	0.3247	0.3247	0.4406	0.2899
Fatigue Strength	0.4338	0.3578	0.3354	0.4025	0.2818	0.1789	0.3533	0.4159
Impact	0.3851	0.3994	0.3566	0.6134	0.1997	0.0970	0.3281	0.1783
Hardness	0.3652	0.3768	0.3478	0.2840	0.3594	0.2898	0.4347	0.3478
%Elongation	0.1119	0.4848	0.5594	0.5594	0.1305	0.1156	0.2610	0.1678
Sp. Heat	0.2886	0.3608	0.3680	0.3608	0.3608	0.3752	0.3463	0.3608
Coff. Of Thermal Exp.	0.3512	0.3512	0.3512	0.3512	0.3512	0.3566	0.3647	0.3512

Table 2 depicts the normalized decision matrix of automobile wheel material selection problem using the Eq. (1). to comparable each other. Table 3 represent the weight of different criteria which was calculated using entropy method as mentioned by past researcher [23]. The normalized decision matrix is multiplied with the entropy weights of each criterion and get the weighted normalized matrix which is portrayed in Table 4.

Table 3 Weight of the Criteria

Material	Weight
Density (g/cm3)	0.0005
Thermal conductivity	0.069
UTS	0.0194
YTS	0.0391
Fatigue Strength	0.0691
Impact	0.2838
Hardness	0.0203
%Elongation	0.4919
Sp. Heat	0.0067
Coff. Of Thermal Exp.	0.0002

Table 4 Weighted Normalized Decision matrixes

Material	A1	A2	A3	A4	A5	A6	A7	A8
Density (g/cm3)	0.00018	0.00017	0.00017	0.00017	0.00018	0.00018	0.00018	0.00018
Thermal conductivity	0.01869	0.01594	0.01671	0.02469	0.02906	0.02559	0.02803	0.03137
UTS	0.00660	0.00691	0.00654	0.00746	0.00588	0.00574	0.00846	0.00689
YTS	0.01360	0.01188	0.01124	0.01813	0.01269	0.01269	0.01723	0.01133
Fatigue Strength	0.02998	0.02472	0.02318	0.02781	0.01947	0.01236	0.02441	0.02874
Impact	0.10930	0.11335	0.10121	0.17408	0.05668	0.02753	0.09311	0.05060
Hardness	0.00741	0.00765	0.00706	0.00577	0.00730	0.00588	0.00882	0.00706
%Elongation	0.05503	0.23846	0.27515	0.27515	0.06420	0.05686	0.12840	0.08255
Sp. Heat	0.00193	0.00242	0.00247	0.00242	0.00242	0.00251	0.00232	0.00242
Coff. Of Thermal Exp.	0.00007	0.00007	0.00007	0.00007	0.00007	0.00007	0.00007	0.00007

Table 5 performance score and Rank comparison of the alternatives

Material	Yi	Rank	TOPSIS
AZ91(A1)	0.132245	1	1
AM60(A2)	-0.05583	7	5
AM50(A3)	-0.10698	8	8
AZ31(A4)	-0.01504	6	7
ZE41(A5)	0.06904	2	6
EZ33(A6)	0.035194	5	4
ZE63(A7)	0.053732	4	2
ZC63(A8)	0.055615	3	3

The y_i value can be positive or negative depending of the totals of its maxima (beneficial attributes) and minima (non-beneficial attributes) in the decision matrix. An ordinal ranking of y_i shows the ultimate preference. Thus, the best alternative has the highest y_i value, while the worst alternative has the lowest y_i value. Therefore the final ranking of the alternative materials are computed Eq. (3). and depicted in Table 5. The material having high performance score is considered to be the serviceable material. From the Table 5, it is found that the AZ91 (A1) is the leading material for automobile wheel material followed by ZE41 (A_5), which represent the quite similar with TOPSIS method. The final ranking as obtained by MOORA method as $A_1 > A_5 > A_8 > A_7 > A_6 > A_4 > A_2 > A_3$. The ranking comparison of the TOPSIS and MOORA methods is shown in Fig. 1.

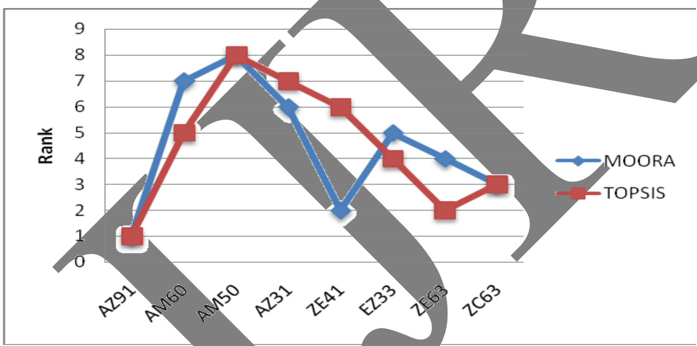

Figure1 Ranking Comparison of MOORA and TOPSIS

V.CONCLUSION:

Automobile wheel material selection is the one of the major area of automotive sector. The MOORA method is recommended for decision making in the automotive sector which provides in selecting the most suitable option among a big number of alternatives for a given problem.In this research paper, multi-objective decision making problem for the automobile wheel material handled and resolve by the MOORA method. The results of the method suggest that the AZ91 (A1) is the best alternative. It is found that the ranked one alternative exactly match with the past researcher. There are minor discrepancies among the intermediate rankings of the alternatives which may be attributed for the subjective decision taken by the decision makers. Finally MOORA method found as appropriate tool for ranking or selecting the best alternative from a set of alternatives because of satisfactory results. MOORA method is computationally very ease and robust which can concurrently judge any number of quantitative and qualitative selection criteria, while presenting a more objective and logical selection approach. In future studies, the simple and effective method can be applied to different domain of the manufacturing sector.

REFERENCES:

1) Edwards, K.L. (2005), *Selecting materials for optimum use in engineering components, Materials and Design*, 26, 469-472.
2) Deng, Y-M. and Edwards, K.L.(2007), *The role of materials identification and selection in engineering design, Materials and Design,* 28, 131-139
3) Ljungberg, L.Y.(2007), Materials *selection and design for development of sustainable products, Materials and Design,* 28, 466-479.
4) Athawale, V.M., Kumar, R. and Chakraborty, S. (2011), *Decision making for material selection using the UTA method,* International Journal of Advanced Manufacturing Technology, 57, 11-22.
5) Cui, X., Zhang, H., Wang, S., Zhang, L. and Ko, J.(2011), *Design of lightweight multi-material automotive bodies using new material performance indices of thin-walled beams for the material selection with crashworthiness consideration*, Materials & Design, 32, 815-821.
6) Zander, J. and Sandström, R.(2011), *Materials selection for a cooling plate using control area diagrams, Materials & Design,* 32, 4866-4873.
7) Chauhan, A. and Vaish, R.(2012), *A comparative study on material selection for micro-electromechanical systems,* Materials &Design, 41, 177-181.
8) Maity, S. R., Chatterjee, P. and Chakraborty, S.(2012) *Cutting tool material selection using grey complex proportional assessment method, Materials & Design,* 36, 372-378.
9) Maity, S. R. and Chakraborty, S.(2012*), Supercritical boiler material selection using fuzzy analytic network process, Management Science Letters,* 2, 1083-1096.
10) Athawale. V.M., Maity, S. R. and Chakraborty, S.(2012), *Selection of gear material using compromise ranking method, International Journal of Materials and Structural Integrity*, 6, 257-269.

11) Girubha, R. J. and Vinodh, S.(2012), *Application of fuzzy VIKOR and environmental impact analysis for material selection of an automotive component, Materials & Design*, 37, 478-486.
12) Karande, P. and Chakraborty, S. (2012), *Application of multi-objective optimization on the basis of ratio analysis (MOORA) method for materials selection, Materials & Design*, 37, 317-324.
13) Chatterjee, P. and Chakraborty, S. (2012), *Material selection using preferential ranking methods, Materials & Design,* 35, 384-393.
14) Findik, F. and Turan, K. (2012), *Materials selection for lighter wagon design with a weighted property index method*, Materials & Design, 37, 2012, 470-477.
15) Huda, Z., Edi, P. (2012), Materials *selection in design of structures and engines of supersonic aircrafts: A review,* Materials & Design, 46, 552-560.
16) Maity, S. R. and Chakraborty, S.(2012), *Grinding wheel abrasive material selection using Fuzzy TOPSIS method, Materials and Manufacturing Processes*, 28, 2012, 408-417.
17) Milani, A.S., Shanian, A., Lynam, C. and Scarinci, T.(2013), *An application of the analytic network process in multiple criteria material selection*, Materials & Design, 44, 622-632.
18) Karande, P., Gauri, S. K. and Chakraborty, S.(2013), *Applications of utility concept and desirability function for materials selection,* Materials & Design, 45, 349-358.
19) Çalışkan, H., Kursuncu, B., Kurbanoglu, C. and Guven, S.Y.(2013), *Material selection for the tool holder working under hard milling conditions using different multi criteria decision making methods*, Materials & Design, 45, 473-479.
20) Chatterjee, P. and Chakraborty, S. (2013), *Gear Material Selection using Complex Proportional Assessment and Additive Ratio Assessment-based Approaches: A Comparative Study*, International Journal of Materials Science and Engineering 1(2), 104-111.
21) Sharma, A., Sharma, A. and Sachdeva, A.(2014), *Selection of the Best Material for an Axle in Motorcycle using fuzzy AHP and Fuzzy TOPSIS Methods,* MIT International Journal of Mechanical Engineering, 4(1), 29-36.
22) Özdemir, Z. and Genç, T. (2014), *Crackable Connecting Rod Material Selection by Using TOPSIS Method,* Journal of Mechanical Engineering and Automation, 4(1), 43-48.
23) Kumar, D.S. and Suman, K.N.S.(2014) , *Selection of Magnesium Alloy by MADM Methods for Automobile Wheels*, International Journal of Engineering and Manufacturing, 2, 31-41.
24) Chothani , H.G., Kuchhadiya, B.B. and Solanki, J.R. (2015), Selection *of Material for Hacksaw Blade using AHP-PROMETHEE Approach,* International Journal of Innovative Research in Advanced Engineering (IJIRAE), 2(1), 26-30.
25) Sasanka , T. and Ravindra, K. (2015), *Implementation of VIKOR Method for Selection of Magnesium Alloy to Suit Automotive Applications,* International Journal of Advanced Science and Technology, 83, 49-58.
26) Thakur, A. and Bhatia, O.S. (2016), *Selection of Automotive Brake Friction Materials using Hybrid Entropy-Topsis Approach*, Journal of Scientific and Engineering Research, 3(1), 122-128.
27) Singh, T., Patnaik, A., Chauhan, R. and Chauhan, P. (2016), *Selection of Brake Friction Materials Using Hybrid Analytical Hierarchy Process and Vise Kriterijumska Optimizacija Kompromisno Resenje Approach*, Polymer Composites, 1-8.
28) Pohane , R.K., Kongare, S.C. and Daf, S.P. (2016), *Selection of composite material for disk brake by using MCDM tool and techniques: An comparative Approach,* International Journal of Advance Research and Innovative Ideas in Education, 2(3) 3692-3697.
29) Chakraborty S (2011), "*Application of the MOORA Method for Decision Making in Manufacturing Environment*", International Journal of Advanced Manufacturing Technology, 54(9-12), 1155-1166.
30) Brauers W.K.M. (2004), *Optimization Methods for a Stakeholder Society. A Revolution in Economic Thinking by Multiobjective Optimization*, Kluwer Academic Plublishers, Boston.