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SELECTION OF MATERIAL FOR BEARING USING MADM APPROACH

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Abstract— *In Industries, there are several reasons of failure of bearing and this rate of failure of bearing can be avoided by proper selection of bearing materials. Numerous authors have presented different ranking methods to rank alternatives, during the last two decades. A novel multiple attribute decision making (MADM) method for material selection for a considered design problem was purposed. In this paper analytic hierarchy process (AHP) method, Simple Additive Weighting (SAW) and Weighted Product Method (WPM) have been applied to rank out the material of bearing among of five materials.*

Keywords— *AHP method, SAW method, WPM method, Journal bearing*

I. INTRODUCTION

In the past few years, wood, iron and skin have been used as journal bearing materials. Later, brass, bronze and white metal have also found some applications. Currently, in addition to these bearing materials, aluminum and zinc based materials are used as journal bearing materials. With technological improvements, self-lubricated sintered bearings and plastic materials are used where continuous lubricating is impossible. Therefore, it is essential that the bearing material be chosen depending upon area of application.[1]

There are several reasons for failure of bearing such as wear, fatigue, oil starvation, improper selection of material etc., The Failure rate of Bearing can be controlled by proper selection of material. The improper selection of materials may result in loss of productivity and efficiency. The selection of materials should not be restricted to technical aspects only but focus should be made on environmental considerations also. Literature review reveals that various methodologies have already been used by the past researchers for proper material selection. [1]

Numerous authors have presented different ranking methods to rank alternatives, during the last two decades. A novel multiple attribute decision making (MADM) method for material selection for a considered design problem was purposed. The proposed method suggested by the researchers has applied in the different fields.

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision [2]. AHP is known as a practical versatile approach [3]. Simple Additive Weighting (SAW) which is also known as weighted linear combination or scoring methods is a simple and most often used multi attribute decision technique. The method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by decision maker followed by summing of the products for all criteria [4]. Weighted Product Method (WPM) is a more rigorous method in penalizing the alternatives with least significance. It is dimensionless and ranking abnormality issue does not apply to WPM. The preference index of each alternative is independent of the other alternatives and one can set a threshold for an acceptable preference index to minimize the number of unnecessary handovers [5].

II. PROBLEM FORMULATION

On the basis of our application, five materials such as lead base babbit, tin base babbit, Znal, Cusn10 and Cuzn30 have been selected for the selection of material for bearing. Many properties effect to the efficiency and failure rate of bearing, main seven properties such as Hardness (BH) in HB, Tensile strength (TS) in Mpa, Thermal conductivity (TC), Corrosion resistance (CR), Conformability(C), density (D) in g/cc and Elongation in % (E) has been considered in the present research work. Detail properties of this material are given in table 3.

Table 1. Details of the various attributes

	BH	TS	TC	CR	E	D	C
Lead base babbit	19	70Mpa	poor	Fair to good	19%	10.6g/cc	good
Tin base babbit	27	69 Mpa	poor	excellent	27%	7.46g/cc	good
ZnAl	70	210 Mpa	fair	excellent	70%	6.3g/cc	Poor to fair
Cusn10	100	370 Mpa	Fair to good	Poor to fair	100%	8.7g/cc	poor
Cuzn30	120	500 Mpa	good	poor	120%	8.53g/cc	fair

Table 2. Rating

Excellent	Good	Fair to good	Fair	Poor to fair	Poor
10	9	8	7	6	5

Table 3. Different materials, properties and its value

	BH	TS	TC	CR	E	D	C
Lead base babbit	19	70	5	8	19	10.6	9
Tin base babbit	27	69	5	10	27	7.46	9
ZnAl	70	210	7	10	70	6.3	6
Cusn10	100	370	8	6	100	8.7	5
Cuzn30	120	500	9	5	120	8.53	7

III.THE AHP APPROACH

This is the most popular Technique among all MADM methods. Saaty TL [3] developed Analytical Hierarchy Process (AHP) in 1980. As the name it has, it makes the whole problem into a system of hierarchies of objectives and alternatives. Steps are given below.[2] [12][18]

3.1 The AHP Approach [2][12]

Step:-1 Determine the objectives and attributes. Develop hierarchical structure.

Step:-2 Identifying suitable weights

(a)Construct a pair wise comparison matrix by using scale of relative importance

(b)Calculate the Geometric mean and weights

$GMj = [\prod_{j=1}^{M} b_{ij}]^{1/M}$

$$Wj = GM / \sum_{j=1}^{M} GMj$$

(c)Calculate A3 and A4 matrices such that

$A_3=A_1 \times A_2$

$A4 = A_3/A_2$

Where A1 is relative importance of matrix, A_2 is weight matrix [w_1, w_2 , ….w_j upto j attributes]

(d)Determine the maximum Eigen value λmax, by taking the average of A4 matrix

(e)Determine Consistency index CI = λmax – M / M-1.

(a)Obtain the Random index value from Table 4 , for the required attributes

(b)Calculate Consistency ratio CR = CI / RI

In general CR value <0.1 is acceptable, if CR value is greater 0.1 then we have to re think the relative importance

Table 4. Random Index Value [2] [12]

Attributes	3	4	5	6	7	8	9
RI	0.52	0.89	1.11	1.25	1.35	1.4	1.45

Step:-3: Perform the relative mode & absolute mode

The relative mode can be used when decision maker have prior knowledge of the attributes for different alternatives to be used. The absolute mode is used when data of attributes for different alternatives to be evaluated are readily available.

Step:-4: Obtain the overall performance score for the alternatives by multiplying the relative normalized weight (w_j)
Step:-5 Ranking will be given to each alternative based on the score

Lead base babbit, Tin base babbit, ZnAl, cusn10 and cuzn30 materials have been selected for the selection of material for journal bearing. In present work, brittle hardness, elongation (%), tensile strength (Mpa), thermal conductivity, corrosion resistance, Density (g/cc) and conformability has been considered.

Three level hierarchy model of the decision problem is developed in such a way that the selection of material is positioned at the first level refers to the goal, with seven properties such as brittle hardness, tensile strength (Mpa), thermal conductivity, corrosion resistance, elongation (%), Density (g/cc) and conformability on second levels and finally alternatives like Lead base babbit, Tin base babbit, ZnAl, cusn10 and cuzn30 at the third level. The figure 1 shows such a Three level hierarchy model.

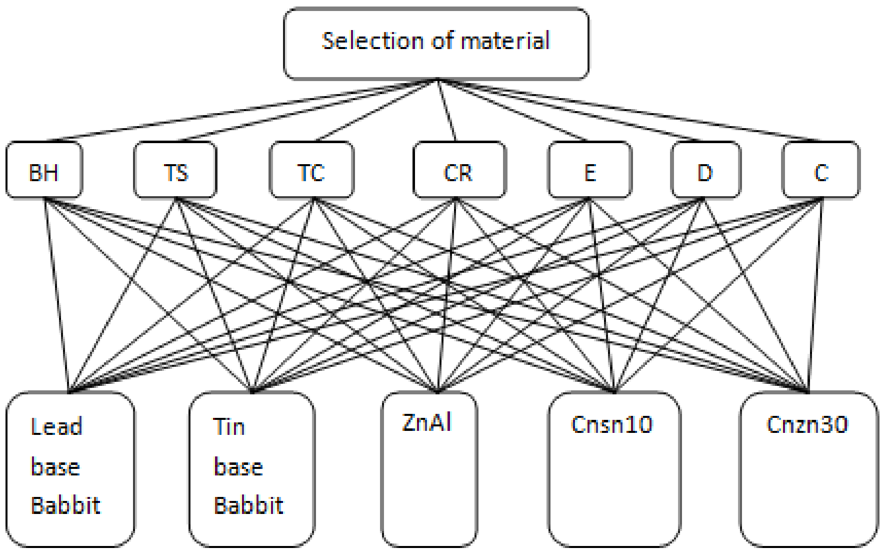

Fig.1. Three level hierarch diagram

Table 5. Normalized matrix for calculating weights

	BH	TS	TC	CR	E	D	C
Lead base babbit	0.1590	0.1400	0.5570	0.8000	0.3130	0.5950	1.0000
Tin base babbit	0.2250	0.1380	0.5560	1.0000	0.0630	0.8450	1.0000
znAl	0.5840	0.4200	0.7780	1.0000	0.1180	1.0000	0.6670
Cusn10	0.8340	0.7400	0.8890	0.6000	1.0000	0.7250	0.5560
Cuzn30	1.0000	1.0000	1.0000	1.0000	1.0000	0.7390	0.7780

Table 6. Scale for comparison

scale	Degree of preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Values for inverse comparison

By Implementing Table 6 the pair wise comparison matrix is shown in table

Table 7. The pair wise comparison matrix

	BH	TS	TC	CR	E	D	C
BH	1.0000	3.0000	3.0000	5.0000	5.0000	7.0000	7.0000
TS	0.3333	1.0000	1.0000	3.0000	4.0000	5.0000	5.0000
TC	0.3333	1.0000	1.0000	3.0000	3.0000	5.0000	5.0000
CR	0.2000	0.3333	0.3333	1.0000	3.0000	3.0000	3.0000
E	0.2000	0.2500	0.3333	0.3333	1.0000	2.0000	3.0000
D	0.1429	0.2000	0.2000	0.3333	0.5000	1.0000	1.0000
C	0.1429	0.2000	0.2000	0.3333	0.3333	1.0000	1.0000

Based on data considered above and calculating further steps, the following results were obtained The eigenvalue of above relative matrix is $\lambda max=7.1203$ Consistency ratio, CR = CI/RI = 0.01604 < 0.1, hence the relative importance matrix is acceptable. Hence the weightage to individual attributes are given in Table-8 [2] [12]

Table 8. Weights to each Attribute

Attributes	Attributes1	Attributes2	Attributes3	Attributes4	Attributes5	Attributes6	Attributes7
Weights	0.3846	0.1965	0.1885	0.0946	0.0626	0.0377	0.0355

The alternatives are compared pairwise for the better understanding of each attribute w.r.t other. Distributed (or) Relative mode is used to assess the order of preference of alternatives. Sample data on pairwise comparison of first alternate are shown below in table

Table 9. Attribute 1 pair wise comparison with other attributes

Attribute	1	2	3	4	5	I	R
1	1.0000	0.7067	0.2723	0.1906	0.1590	0.1590	0.4795
2	1.4151	1.0000	0.3853	0.2698	0.2250	0.2250	0.6145
3	3.6730	2.5956	1.0000	0.7002	0.5840	0.5840	1.2145
4	5.2453	3.7067	1.4281	1.0000	0.8340	0.8340	1.5666
5	6.2893	4.4444	1.7123	1.1990	1.0000	1.0000	1.7835

Where I is idealized matrix and R is randomized matrix.

Table 10. Ranking of material by AHP method

Sr No	Materials	Preference index	Rank
1	Lead base babbit	0.1222	5
2	Tin base babbit	0.1294	4
3	Znal	0.1995	3
4	Cusn10	0.2545	2
5	Cuzn30	0.2944	1

IV. THE SIMPLE ADDITIVE WEIGHTING (SAW) METHOD

The SAW Method (Simple Additive Weighting) is one of the more popular and easy to understand and use. Simple Additive Weighting (SAW) which is also known as weighted linear combination or scoring methods is a simple and most often used multi attribute decision technique. The method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by decision maker followed by summing of the products for all criteria.

$$S(a_j) = \sum_{i=1}^{m} w_i v_{ij}$$

where w_i is the scale constant of the i-th criterion and v_{ij} is the value of alternative a_j evaluated by the i-th criterion.

Table 11. Ranking of material by SAW method

Sr No	Materials	Preference index	Rank
1	Lead base babbit	0.3469	5
2	Tin base babbit	0.3844	4
3	Znal	0.6172	3
4	Cusn10	0.8002	2
5	Cuzn30	0.9823	1

V.WEIGHTED PRODUCT METHOD (WPM)

This method is similar to SAW. The main difference is that instead of addition in the model there is multiplication. Each normalized value of an alternative with respect to an attribute, i.e., (m_{ij}) normal, is raised to the power of the relative weight of the corresponding attribute. The alternative with the highest P_i value is considered the best alternative the overall or composite performance score of an alternative is given by

$$P_i = [\prod_{j=1}^{M} (Mij)normal]^{w_j}$$

Where w_j is weight matrix M_{ij} is normal is a normalized matrix.

Table 12. Ranking of material by WPM method

Sr No	Materials	Preference index	Rank
1	Lead base babbit	0.2679	5
2	Tin base babbit	0.2857	4
3	Znal	0.5640	3
4	Cusn10	0.7926	2
5	Cuzn30	0.9799	1

VI. CONCLUSION

In this Paper, Preference Index of the different materials has been computed using Analytic hierarchy process (AHP) method, The Simple Additive Weighting (SAW) method And Weighted product method (WPM). The Ranked high among other is Cnzn30 and least preferred is lead base babbit. (ie Ranking sequence is 5-4-3-2-1).The same problem can be extended not only to this problem but also can implement to any organization any industry so on by varying alternatives and attributes. For more attributes, it is suggested to adopt excel program and MATLAB coding system.

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