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Selection of Material for Connecting rod using MADM Approach

Prof. H. G. Chothani
Government Engineering College Rajkot
Prof. B. B. Kuchhadiya
Government Engineering College Rajkot
Prof. J. R. Solanki
Government Engineering College Rajkot

ABSTRACT

In Technical Institute/Mechanical Workshop, Decision maker always faces the problem to select the perfect connecting rod and bolt material for students as well as trainee to reduce the failure rate of rod and avoid the accident. Numbers of methods are available for selection of an optimal material for an engineering design from among two or more alternative materials on the basis of two or more attributes. In analytic hierarchy process (AHP) and simple additive weighting (SAW) method have been applied to rank out the material of connecting rod and bolt among of six materials.

KEYWORDS

AHP, MADM, Connecting rod, Material selection.

INTRODUCTION

Connecting rods are highly dynamically loaded components used for power transmission in combustion engines. A Connecting rod is the link between the reciprocating piston and rotating crank shaft. Small end of the connecting rod is connected to the piston by means of gudgeon pin. The big end of the connecting rod is connected to the crankshaft. The function of the connecting rod is to convert the reciprocating motion of the piston into the rotary motion of the crankshaft. Connecting rods for automotive applications are typically manufactured by forging from either wrought steel or powdered metal. [1]

The connecting rod is subjected to a complex state of loading. It undergoes high cyclic loads, which range from high compressive loads due to combustion, to high tensile loads due to inertia. Therefore, durability of this component is of critical importance.[2]

The selection of suitable material plays fundamental and vital role in product development, as each material processes individual characteristics that contribute many aspects to suit the particular application. A wrong selection of material favors large cost contribution as well as product failure. Hence among the various available materials the selections of particular become difficult. A better methodology is more and more needed for the selection of material.

The selection of an optimal material for an engineering design from among two or more Alternative materials on the basis of two or more attributes is a multiple attribute decision making (MADM) problem.[3] The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. AHP is known as a practical versatile approach.[4] 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 [6].

PROBLEM FORMULATION

On the basis of our application, Six materials such as C-70, AISI-4340, 35Mn5, Al-360, T-2024 and Al-7068 have been selected for the selection of material for connecting rod. Many properties effect to the efficiency and failure rate of rod ,main six properties such as Hardness (BH) in HB , Young's Modulus of elasticity (YM) in GPa, Yield strength (YS) in MPa ,Tensile strength (TS) in MPa, density (D) in kg/m3, and Poisson's ratio in % (PR) has been considered in the material selection work. Detail properties of this material are given in table.1

Table 1. Data of material selection

Material	BH	YM	YS	TS	PR	D
C-70	183	211.5	573.11	965.8	0.3	7850
AISI-4340	217	210	445	745	0.28	7800
35Mn5	167	200	450	765	0.33	7700
Al-360	217	71	363	422	0.33	2680
T-2024	125	80	370	495	0.33	2760
Al-7068	190	73.1	655	683	0.33	2850

BH, Brinnel Hardness; YM, Young Modulus; YS, Yield Strength; TS, Tensile Strength; PR, Poisson's Ratio, D, Density.

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.[3] [13][19]

The AHP Approach [3][13]

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

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

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

(c)Calculate A_3 and A_4 matrices such that

$A_3 = A_1 \times A_2$

$A_4 = A_3 / A_2$

Where A_1 is relative importance of matrix, A_2 is weight matrix [$w_1, w_2, \ldots w_j$ upto j attributes]

(d)Determine the maximum Eigen value λ_{max}, by taking the average of A4 matrix

(e)Determine Consistency index CI = λ_{max} – M / M-1.

(a)Obtain the Random index value from Table 2 , 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 2. 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 (wj)

Step:-5 Ranking will be given to each alternative based on the score

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 Hardness (BH) in HB , Young's Modulus of elasticity (YM) in GPa, Yield strength (YS) in MPa ,Tensile strength (TS) in MPa, density (D) in kg/m3, and Poisson's ratio in % (PR) on second levels and finally alternatives like C-70, AISI-4340, 35Mn5, Al-360, T-2024 and Al-7068 at the third level. The figure 1 shows such a Three level hierarchy model. [20]

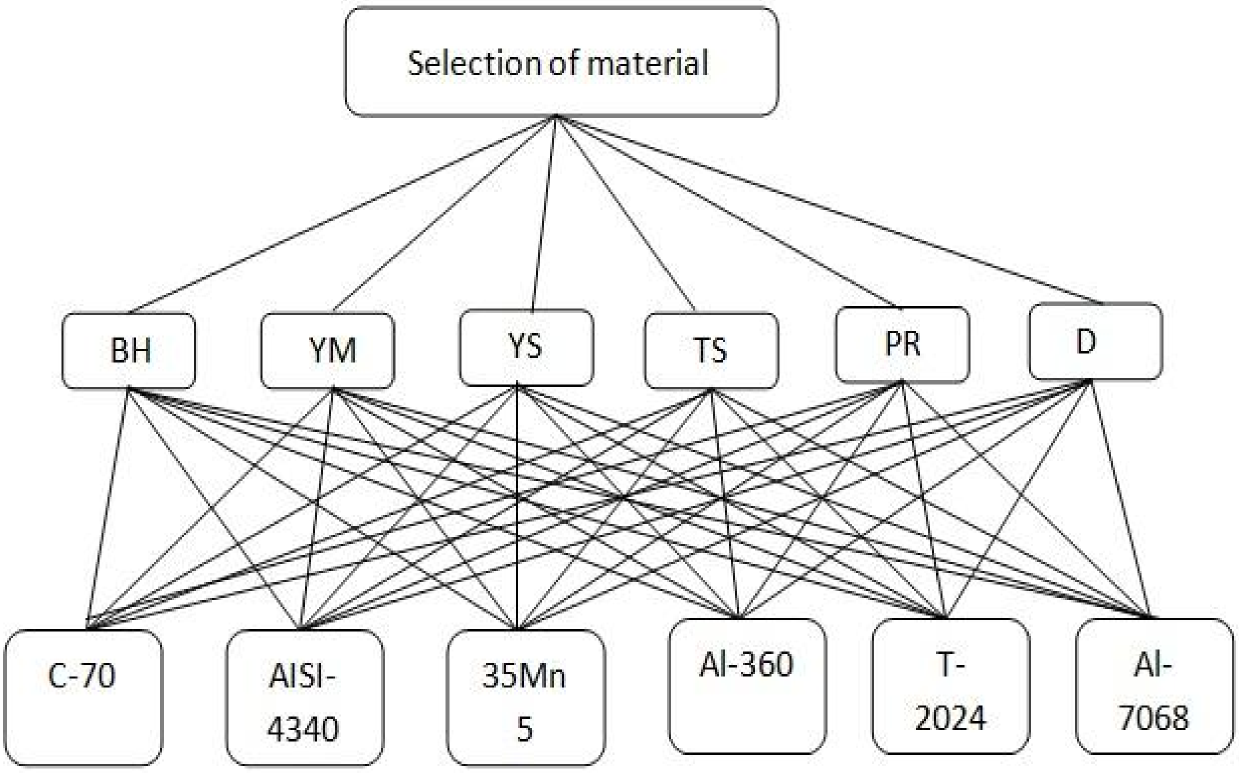

Fig.1: Three level hierarch diagram

In present problem all the attributes are beneficial except density (D). The normalized value of table 1 is tabulated in table 3.

Table 3. Normalized Data

Material	BH	YM	YS	TS	PR	D
C-70	0.843318	1	0.874977	1	0.909091	0.351592
AISI-4340	1	0.992908	0.679389	0.771381	0.848485	0.34359
35Mn5	0.769585	0.945626	0.687023	0.792089	1	0.348052
Al-360	1	0.335697	0.554198	0.436943	1	1
T-2024	0.576037	0.378251	0.564885	0.512528	1	0.971014
Al-7068	0.875576	0.345626	1	0.707186	1	0.940351

BH, Brinnel Hardness; YM, Young Modulus; YS, Yield Strength; TS, Tensile Strength; PR, Poisson's Ratio, D, Density.

An attributes compared with other attributes, the number 3,5,7,9 correspond to the 'moderate importance', 'strong importance', 'very strong importance', 'absolute importance' respectively. The pair wise comparison matrix and weights are shown in table 4.

Table 4. Pair wise comparison Matrix & Weights

	BH	YM	YS	TS	PR	D	WEIGHTAGE
BH	1	3	4	5	5	7	0.434469137
YM	0.333333	1	2	3	4	5	0.224525522
YS	0.25	0.5	1	2	3	5	0.151330892
TS	0.2	0.333333	0.5	1	1	3	0.082715909
PR	0.2	0.25	0.333333	1	1	2	0.068876146
D	0.142857	0.2	0.2	0.333333	0.5	1	0.038082387

BH, Brinnel Hardness; YM, Young Modulus; YS, Yield Strength; TS, Tensile Strength; PR, Poisson's Ratio, D, Density.

The **CR** value is **0.028885**which is less than 0.1, so that relative importance matrix is acceptable.[12][13]

RATING OF MATERIAL

Table 5. Rating of material

RATING OF MATERIAL		RANK
C-70	0.882052282	2nd
AISI-4340	0.895545454	1st
35Mn5	0.798295302	3rd
Al-360	0.736809829	5th
T-2024	0.568930732	6th
Al-7068	0.772526087	4th

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.[12][13][19][20]

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

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 6. Ranking of material by SAW method

Sr No	Materials	Preference index	Rank
1	C-70	0.882052272	2
2	AISI-4340	0.895545452	1
3	35Mn5	0.798295064	3
4	Al-360	0.736809629	5
5	T-2024	0.568930749	6
6	Al-7068	0.772525989	4

CONCLUSION

In this Paper, Preference Index of the different materials has been computed using analytic hierarchy process (AHP) method and The Simple Additive Weighting (SAW) method. For connecting rod the Ranked high among other is AISI-4340 and least preferred is T-2024. (ie. Ranking sequence is 2-1-3-5-6-4).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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