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Selection of Material for Hacksaw Blade using AHP-PROMETHEE Approach

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Abstract-In Technical Institute/Mechanical Workshop, Decision maker always faces the problem to select the perfect hacksaw blade material for students as well as trainee to reduce the failure rate of blade 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 this paper Preference Ranking Organization Methods for Enrichment Evaluations (PROMETHEE) and analytic hierarchy process (AHP) method have been applied to rank out the material of hacksaw blade among of five materials.

Key Word-Material Selection, PROMETHEE, AHP, MADM, Hacksaw Blade

1. INTRODUCTION

A hacksaw is a fine-tooth saw with a blade under tension in a frame, used for cutting materials such as metal. Hand-held hacksaws consist of a metal frame with a handle, and pins for attaching a narrow disposable blade. A screw or other mechanism is used to put the thin blade under tension. [1] The demand of hacksaw blade is considerably increasing day by day with the growth of industrilisation, engineering sector,real estate, automobile sector etc.It is used in almost every sector for cutting of materials like angle, channel, flat plates, rods and such other things, also required in auto repairing shops, general repairing workshops, fitting shops, welding shops and technical institutes.

In Technical Institutes the failure rates of blades are increased because of lack of experience, knowledge and improper selection of material. The Failure rate of Blade 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. The complexity of materials selection makes multi-criteria analysis an invaluable tool in the engineering design process. Literature review reveals that various methodologies have already been used by the past researchers for proper material selection. [2]. 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 [7] This paper discusses two well known and widely used methods, Preference Ranking Organization Methods for Enrichment Evaluations (PROMETHEE) and analytic hierarchy process (AHP) method.

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[7]. AHP is known as a practical versatile approach [12]. [13] PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) is also a quite simple ranking method in terms of concept and application compared with many other methods for multicriteria analysis [14]. [15] used a family of PROMETHEE MCDM methods to choose a proper structural system Some researchers tried to combine AHP and PROMETHEE to further enhance the capabilities of both techniques In these combined methods, AHP has been used to analyze the structure of the Problem and determine the weights of the criteria, whereas PROMETHEE has been used for the final ranking.

2. **Problem Formulation**

On the basis of our application, five materials such as S45C, Q235, ASTM A36, AISI 1038, C40 have been selected for the selection of material for hacksaw balde. Many properties effect to the efficiency and failure rate of blade ,main six properties such as Hardness (BH) in HB , Young's Modulus of elasticity (YM) in GPa, Yield strength (YS) ,Tensile strength (TS) in MPa, density (D) in kg/m3, in MPa, and Elongation in % (E) has been considered in the present research work. Detail properties of this material are given in table 1.

Table:-1 Data of Material Selection

	BH	**YM**	**YS**	**TS**	**D**	**E**
SA 45	180	200	343	569	8000	32
Q235	200	206	235	425	7850	26
ASTM A36	130	200	250	500	7850	22
AISI 1038	149	200	285	515	7845	18
C40	170	207	270	590	7857	30

BH, Brinnel Hardness; YM, Young Modulus; YS, Yield Stress; TS, Tensile Stress; D, Density; E, Elongation

3. **An Overview of the PROMETHEE and AHP**

3.1 The AHP Approach

This is the most popular Technique among all MADM methods. Saaty TL 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. [7][8]

3.1 The AHP Approach

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

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

$$Wj = GM / \sum_{j=1}^{M} GMj \tag{2}$$

c) Calculate A3 and A4 matrices such that

$$A_3 = A_1 \text{ x } A_2 \tag{3}$$

$$A4 = A_3/A_2 \tag{4}$$

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. (5)

f) Obtain the Random index value from Table 2 , for the required attributes

g) Calculate Consistency ratio CR = CI / RI (6)

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

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

3.2 The PROMETHEE Approach by using AHP

The PROMETHEE method was introduced by Brans et al. (1984) and belongs to the category of outranking methods. Like all outranking methods, PROMETHEE proceeds to a pairwise comparison of alternatives in each single criterion in order to determine partial binary relations denoting the strength of preference of an alternative 1 over alternative 2.[5][6]

The implementation of PROMETHEE requires two additional types of information: [5][6]

- Relative importance (weights) of the criteria considered
- Information on the decision-maker preference function, which he/she uses when comparing the contribution of the alternatives in terms of each separate criterion.

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

Step:-2: The weights of relative importance of the criteria may be assigned using analytic hierarchy process (AHP) explained in section 3.1

Step:-3: Information on the decision-maker preference function.

The preference function (Pj) translates the difference between the evaluations (i.e.,scores) obtained by two alternatives (a and b) in terms of a particular criterion,into a preference degree Ranging from 0 to 1.Let P_i (a,b) preference function associated to criterion Ci

$$\text{Let } P_i(a,b) = G_i[C_i(a)-C_i(b)] \quad (7)$$

$$0 \leq Pi(a,b) \leq 1$$

Where Gi is anon decreasing function of the observed deviation (d) between two alternatives a,b over the criterion Ci.

Step:-4: Calculate the multiple criteria preference index $\Pi_{a,b}$

$$\Pi_{a,b}=\sum_{i=1}^{M} Pi, a\ b \quad (8)$$

Step:-5: For PROMETHEE outranking relations, the Leaving flow $\varphi^+(a)$, Entering flow $\varphi^-(a)$ and Net flow $\varphi(a)$ for an alternative a belongs to set of alternative A are defined by the following equations.

$$\varphi^+(a)=\sum_{x\in A} \Pi xa \quad (9)$$

$$\varphi\text{-}(a)= \sum_{x\in A} \Pi ax \quad (10)$$

$$\varphi(a)= \varphi+(a)- \varphi\text{-}(a) \quad (11)$$

Step:-6: Ranking will be given to each alternative based on the score

4. Results and Discussion

AHP Method:-

In table: - 1 alternative materials and attributes are given. Three level hierarchy diagrams have been used to evaluate the best material. Figure 1 show that level 1 refers to the goal, level 2 composes of the six objectives such as Hardness (BH) in HB , Young's Modulus of elasticity (YM) in GPa, Yield strength (YS) ,Tensile strength (TS) in MPa, density (D) in kg/m3, in MPa, and Elongation in % (E)and level 3 refers to different alternatives such as S45C, Q235, AISI 1038, ASTM A36 and C40. The objective of this research work is to find out the best alternative on the basis of six important properties. [2]

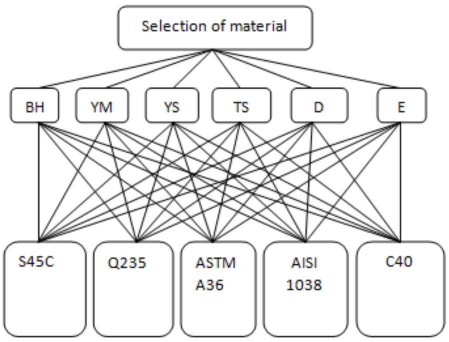

Fig 1 Three level hierarchy Diagram

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

	BH	YM	YS	TS	D	E
SA 45	0.9000	0.9662	1.0000	0.9644	0.9806	1.0000
Q235	1.0000	0.9952	0.6851	0.7203	0.9994	0.8125
ASTM A36	0.6500	0.9662	0.7289	0.8475	0.9994	0.6875
AISI 1038	0.7450	0.9662	0.8309	0.8729	1.0000	0.5625
C40	0.8500	1.0242	0.7872	1.0000	0.9985	0.9375

BH, Brinnel Hardness; YM, Young Modulus; YS, Yield Stress; TS, Tensile Stress; D, Density; E, Elongation;

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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	D	E	WEIGHTS
BH	1.0000	3.0000	3.0000	4.0000	6.0000	7.0000	0.3956
YM	0.3333	1.0000	1.0000	3.0000	4.0000	5.0000	0.1924
YS	0.3333	2.0000	1.0000	3.0000	5.0000	5.0000	0.2241
TS	0.2500	0.3333	0.3333	1.0000	5.0000	5.0000	0.1099
D	0.1667	0.2500	0.2000	0.2000	1.0000	1.0000	0.0402
E	0.1429	0.2000	0.2000	0.2000	1.0000	1.0000	0.0378

BH, Brinnel Hardness; YM, Young Modulus; YS, Yield Stress; TS, Tensile Stress; D, Density; E, Elongation

The CR value is 0.078 which is less than 0.1, so that relative importance matrix is acceptable.

The next step is to obtain the overall performance for alternative by multiplying the relative normalized weight of each attribute with its corresponding normalized weight value of each alternative and summing over the attributes for each alternative just like Simple Additive Weighting (SAW) method.The ranking of material are shown in table

Table:- 5 Ranking of material

Sr No	Material	Preference Index	Rank
1	SA 45	0.9492	1
2	Q235	0.8907	3
3	ASTM A36	0.7657	5
4	AISI 1038	0.8242	4
5	C40	0.8952	2

PROMETHEE Method:-

Objectives and attributes are given in table 1 and The weights of relative importance of the criteria may be assigned using analytic hierarchy process (AHP) as per table 3.After calculating weight by using AHP method, the next step is to have information on the decision maker preference function. If two alternative have a difference d is not equal to zero in criterion Ci, then preference value ranging between 0 and 1.1 is assigned to the better alternative whereas the worse alternative receives 0.If d=0, then they are indifferent which results in an assignment of 0 to both alternatives. The pair wise comparison of BH gives the matrix in given table -6.BH is the beneficial criterion and higher values are desired.[5][6]

Table-6 Pair wise comparison matrix of BH

	SA 45	Q 235	ASTM A36	AISI 1038	C40
SA 45	-	0	1	1	1
Q235	1	-	1	1	1
ASTM A36	0	0	-	0	0
AISI 1038	0	0	1	-	0
C40	0	0	1	1	-

BH, Brinnel Hardness;

The resulting preference indices as well as leaving, entering and Net flow values are given in table 6

Table-7 Overall performance score

Sr.No	Material	SA 45	Q 235	ASTM A36	AISI 1038	C40	φ+(a)	φ-(a)	φ(a)	Rank
1	SA 45	0.000	0.372	0.767	0.767	0.658	2.564	1.051	1.513	1
2	Q235	0.628	0.000	0.626	0.626	0.436	2.316	1.644	0.671	3
3	ASTM A36	0.040	0.334	0.000	0.038	0.040	0.452	3.123	-2.671	5
4	AISI 1038	0.040	0.374	0.770	0.000	0.264	1.449	2.167	-0.718	4
5	C40	0.343	0.564	0.960	0.736	0.000	2.602	1.398	1.204	2

5. **Conclusion**

In this Paper, Preference Index of the different materials has been computed using Preference Ranking Organization Methods for Enrichment Evaluations method (PROMETHEE) and analytic hierarchy process (AHP) method. The Ranked high among other is SA 45 and least preferred is ASTM A 36. (ie Ranking sequence is 1-3-5-4-2).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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