EVALUATION OF ALUMINIUM HYBRID METAL MATRIX COMPOSITES BY ANALYTICAL HIERARCHY PROCESS (AHP) METHOD

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Abstract: *Selection of most appropriate matrix materials plays a pivotal role in the fabrication of aluminium based hybrid metal matrix composites. In order to satisfy the demands offered by engineering fraternity, aluminium based hybrid metal matrix composites (AHMMCs) has become a most promising material with superior mechanical properties, low density, good corrosion resistance and tribological properties. This paper mainly focused on an evaluation of a most suitable matrix material for fabrication of AHMMCs using an Analytical Hierarchy Process (AHP). In this research, selection of a suitable matrix material from AA 6XXX series has been investigated by considering the five criteria such as Density, Tensile strength, Hardness, Melting Point and Cost of available matrix materials in the market. Finally, the result shows that AA 6082 aluminium alloy is the optimum matrix materials for the production of AHMMCs.*

Keywords: *Material Selection, Analytic Hierarchy Process, Alternatives, Criteria, Multi-Criteria Decision-Making.*

1. INTRODUCTION

In today's high-tech manufacturing world, engineers are often looking forward new materials to increase their performances in specific applications. From past few decades, many engineering materials were developed to meet the customer demands with high standards, but few materials were couldn't meet the strength to weight ratio demands in manufacturing world. Therefore, Aluminium based Hybrid metal matrix composites were developed to overcome the many engineering problems along with strength to weight ratio issue in manufacturing era.

Aluminium based hybrid metal matrix composites (AHMMCs) are a new generation composite materials that have a potential to satisfy the demands of modern engineering applications with their enhanced mechanical characteristics, answerability to the traditional processing methods and a chance of decreasing the manufacturing cost [Michael Oluwatosin Bodunrin et al (2015)]. These material performances are mainly dependent on the selection of appropriate matrix material.Hence matrix material selection is one of the most prominent activities in the manufacturing industry. Since the lowest price is not only the promising approaches to achieving the optimum matrix material. The properties such as strength, density, melting point and hardness along with price are needed to be considerable for achieving optimum materials. A wrong selection of materials may result in damage or failure of a system and drastically decreases the performances [Ali Jahan et al (2011)].

When selecting a matrix material, the knowledge on material properties (i.e., mechanical and physical prosperities), its cost and their influences are required to chosen the most appropriate material and the mechanical properties of these materials were given the top priorities. In the process of material selection, the properties usually entwined are the strength, stiffness, toughness, hardness, density and creep resistance [Prasenjit Chatterjee et al (2009)]. To assist the decision maker in a selection of most appropriate matrix material for fabrication of AHMMCs requires procedural approach. The Analytic Hierarchy Process (AHP) is a general measurement theory or procedural approach that depends on the expert judgments. Moreover, AHP is a multi-criteria decision-making support tool that can solve daunting problems and was introduced by Thomas Saaty [Evangelos Triantaphyllou et al (1995)].

To endure the present global business scenario, AHP and TOPSIS approach were used for selection of suitable machine to prompt production levels and revenue generation [Rubayet Karim et al (2016)]. [Rajnish Kumar et al (2014)] Proposed a multi-criterion decision making method i.e., Entropy-TOPSIS method to select the most suitable material in engineering design by considering the criteria such as surface hardness, core hardness, surface fatigue limit, ultimate tensile strength and cost of ductile iron, cast iron, cast alloy steel and surface hardened alloy steels like carburized steels, nitride steels materials for exhaust manifold. [Eva chalúpková et al (2014)] Proposed MCDM methods i.e., Analytic Hierarchy Process (AHP) and sensitivity analysis for solving the multi-criteria decision-making problems in all business processes. Finally, they stated that by means of the sensitivity analysis, the best alternative is not responsive to a change in the weights estimated by the AHP.

Many methods had been proposed for material selection to improving the material properties and performances of materials but no research has been carried out to select the suitable matrix material for preparation of AHMMCs. So in order to address the lack research on matrix material selection, the present research evaluates an optimum matrix material using Analytic Hierarchy Process (AHP).

2. MATRIX MATERIAL SELECTION

Aluminium and its alloys are broadly used in many engineering applications due to their versatile properties such as lightweight, ductility, good malleability and formability, high oxidation and corrosion resistance, high electrical and thermal conductivity [Ashutosh Sharma et al (2015)].

These enhanced properties and strength to weight ratio offered by aluminium 6XXX series alloys have gained huge significance in lightweight military vehicles, rockets, missiles, aircraft, automotive, defence and civil applications [Prantik Mukhopadhyay (2012)].

Due to these properties and applications, the 6XXX series Aluminium Alloys (AA) has been used as matrix material for Hybrid Metal Matrix Composites (HMMCs). Generally, the annexation of high strength, high modulus ceramic particles to a ductile metal matrix will produce a spectacular material whose properties are intermediate between the matrix material and the ceramic reinforcement.

Therefore, in order to achieve these enhanced properties in AHMMCs, the right selection of matrix material plays a significant role along with reinforcement material in the fabrication of AHMMCs for improving its potentialities in a modern precise engineering field and to achieve such a spectacular material properties i.e., mechanical-physical and tribological properties.

The nearest aluminium suppliers to our research centre i.e., M/s. PMC Corporation, Bangalore, M/s. Arihant Aluminium Agencies, Chennai and M/s. Bharat Aerospace metals, Mumbai are considered to buy the aluminium alloys and selected the most favourable matrix material in available 6XXX series Aluminium alloys. The various available aluminium alloys, their cost, mechanical - physical properties and chemical compositions are tabulated in Table 1.

The major role of matrix material in AHMMCs is to transfer and distribute the load to the reinforcement materials and it will also act as the bonding element. This load transferring phenomenon is mainly dependent on the bonding between the matrix and the reinforcement and these bonding depend on the matrix material type and the reinforcement material as well as to the production method. For the matrix material selection, following factors are considered such as density, tensile strength maintained at elevated temperature, Hardness, melting point and cost [Huda, M., D. et al (1995)].

From these available aluminium alloys, the exemplary matrix material is evaluated with adminicle of Analytic Hierarchy Process (AHP) through formulating the pairwise comparison matrix with their importance ie., Cost, Mechanical (i.e., Tensile Strength (σTS) and Hardness (BHN)) and Physical properties (i.e., Density (ρ) and Melting Point (Mp)).

Generally the designation of wrought Aluminium alloys are the four-digit numerical designation to specify aluminium and its alloys, where the first digit signify the principal alloying element, the second digit is the specific modification or for the changes to impurity limits and the last two digits indicates the specific

Table 1: Cost, Mechanical - Physical Properties and Chemical Compositions

Alloying Elements (%)	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
AA 6061	0.40-0.80	0.70	0.15-0.40	0.15	0.80-1.2	0.04-0.35	0.25	0.15	Bal.
AA 6063	0.20-0.60	0.35	0.10	0.10	0.45-0.90	0.10	0.10	0.10	Bal.
AA 6082	0.70-1.3	0.50	0.10	0.40-1.00	0.60-1.20	0.25	0.20	0.10	Bal.
AA 6351	0.70-1.3	0.50	0.10	0.40-0.80	0.40-0.80	0.15	0.20	0.20	Bal.
Cost, Mechanical and Physical Properties									
	Cost (₹)	Density (gm/cc)	Tensile Strength (MPa)	Hardness (BHN)	Melting Point (^{0}C)				
AA 6061	300.00	2.7	310	95	651				
AA 6063	250.00	2.7	241	73	654				
AA 6082	300.00	2.7	330	91	650				
AA 6351	300.00	2.71	310	95	649				

Table 2: Designation of Aluminium Alloys [The Aluminum Association, Inc. (1998)]

Alloy Designation	Alloying Element
1XXX	99% pure aluminum
2XXX	Cu containing alloy
3XXX	Mn containing alloy
4XXX	Si containing alloy
5XXX	Mg containing alloy
6XXX	Mg and Si containing alloy
7XXX	Zn containing alloy
8XXX	Other alloys

aluminium percentages [Prantik Mukhopadhyay (2012)] and the alloy designations are depicted in Table 2.

3. ANALYTIC HIERARCHY PROCESS (AHP)

Simon's theories found a new approach for simplifying the complex problems in the decision-making process [Simon, Hebert A. (1960)] and these theories influenced the Saaty L. Thomas to develop the Analytical Hierarchy Process in the 1970s. Saaty developed AHP was concerned about the explicit elision of setting weights and facilitate the mental processes in decision making [Saaty, Thomas L. 1980].

Basically, AHP method began with the recognition of the objective i.e., select the suitable matrix material amongst various available materials and develop the priorities to alternatives with respect their criteria; which is used to identify the best alternative and it combines the tangible and intangible aspects [Salah Agha, R. et al (2012)]. The main advantage of AHP is that allows decomposing the overall problem in a systematic, detailed and structured manner into its fundamental components and interdependencies, with a large degree of flexibility. In general, the AHP method consists following levels:

3.1. Assessment of Optimum Matrix Material using AHP Model

The AHP model has been developed to select the most suited matrix material for AHMMCs and it is evaluated based on its mechanical and physical properties. This Hierarchy structure consists of five main criteria and four alternatives, Figure 1 illustrates the proposed hierarchy for

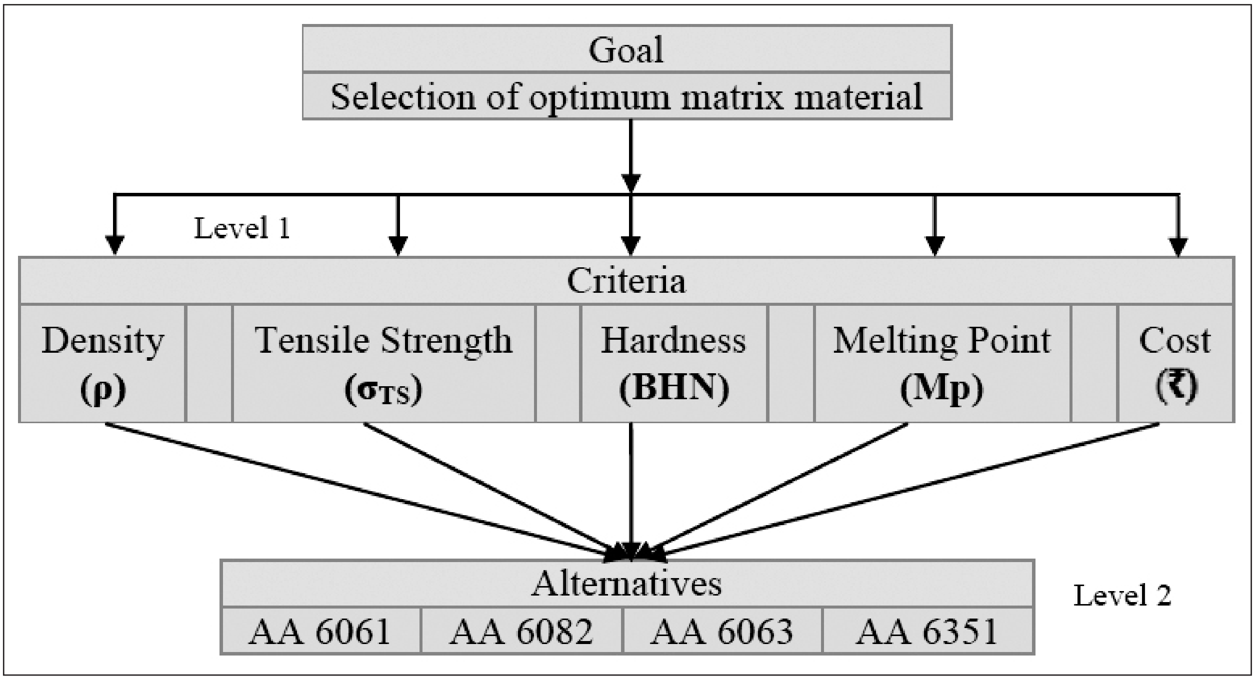

Fig 1. AHP Hierarchy Structure

matrix material evaluation. The important criteria selected for assessment are Tensile Strength (σ_{TS}), Hardness (BHN), Density (ρ), Melting Point (Mp) and Cost (₹). These factors are selected as matrix material evaluation criteria based on discussion with experts and referring to literature. In this hierarchy structure, the problem descends from a goal, down to criteria, down further to sub-criteria or finally to the alternatives from which the choice is to be made" [Saaty, R., W. (1987)].

3.2. Importance of Influential Factors in Selection of Matrix Material

The mechanical properties are those internal reactions of a material to an externally applied force to resist that force or action and these properties are directly interrelated to each other. In other words, one property of a material change causes to change in one or more properties of the same material are called mechanical properties. For example, if the Tensile Strength of material increases, the yielding strength, Toughness and ductility usually increased and the Hardness usually decreases. The material property that can be observed without changing its identity is called physical properties. The density and melting point are the examples of physical properties.

Generally, the engineers require high strengthened, high hardened, low density and low cost material working at elevated temperature for many engineering fields. So these factors have been chosen for evaluating the best matrix material to fabricate AHMMCs.

A. Tensile Strength

Tensile strength is an ability of the material to support the maximum stress or load. Tensile Strength of available aluminium alloys is tested by using UTM machines and compared the data with provided data of suppliers. Finally, both the values are obtained same and are tabulated in Table 1.

B. Hardness

Hardness is the ability of a material to resist the localised plastic deformation. The Hardness of the purchased Materials is tested by Brinell Hardness Test and compared with data obtained from suppliers. Finally, both the values are obtained same and tabulated in Table 1.

C. Density

The Density Property is one of the important criteria in matrix material selection for achieving low-density AHMMCs. The Density of these Matrix Materials is tested by Archimedes Principle. The obtained data from Archimedes Principle and aluminium suppliers are compared and concluded that both are same and these values are tabulated in Table 1.

D. Melting Point

To perform the AHMMCs at an elevated temperature melting point of matrix materials along with reinforcement material are need to be high because higher melting point material could sustain or performed under a high-temperature environment. So this factor also important to determine the optimum matrix material and it is considered as one of the criteria. The Melting point of these available alloys is gathered and collected from suppliers and is tabulated in Table 1.

E. Cost

The main motivation for using cost criteria is to reduce the cost of the Aluminium Hybrid Metal Matrix Composites by selecting the low-cost matrix material. The purchased rate per kg of these aluminium alloys from suppliers is tabulated in Table 1.

3.3. Determination of Priorities to Main Criteria

After constructing the hierarchy structure of matrix material evaluation, the prioritisation process commences to determining the comparative importance of the elements at each level. The importance of each criterion over other criterion is formulated using Saaty's scale to develop the pairwise comparison matrix for determining the priorities of main criteria in level 1. After doing all pairwise comparisons at level 1, the same procedure is extended to all factors with respect to the criteria [Dilli Babu, R. et al (2010)].

The aim of calculating the local priorities is to measure the comparative importance of the elements with respect to goal in the first level. In this matrix, the principle of comparative judgements is applied to set up the pairwise comparisons between main criteria by listing the elements to be compared to the left and on the top. Then an element on the left is compared with an element listed on top to judge the importance of a criterion using saaty scale (Table 3).

When an element is compared with itself, the ratio is one (i.e., the diagonal elements of the matrix are 1). When compared with another element, if it is more important, an integer value is assigns. If it is less important the reciprocal value is assigned. Thus only positive matrices are involved and only n*(n-1)/2 judgements are required if there are n criteria.

By observing the properties and principle alloying elements in Table 1, the properties such as Tensile strength, Density and Hardness are directly proportional and the Melting point is inversely proportional to the principle alloying elements.

Table 4 tabulates the pairwise comparisons matrix between the criteria and the last column

Table 3: The Saaty Scale of Absolute Numbers [Thomas Saaty, L. (1997)]

Relative Intensity	Definition	Explanation
1	Equally Preferred	Two requirements are of equal value
3	Moderately Preferred	Experience slightly favours one requirement over another
5	Strongly Preferred	Experience strongly favours one requirement over another
7	Very Strongly Preferred	A requirement is strongly favoured and its dominance is demonstrated in practice
9	Extremely Preferred	The evidence favouring one requirement over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between two judgements	When compromise is needed
Reciprocals of above	If activity 'i' has one of the above non-zero numbers assigned to it when compared with activity 'j', then 'j' has the reciprocal value when compared with 'i'	

Table 4: Pair Wise Comparison Matrix Between Criteria of 6XXX Series

Criteria	**P**	**σ_{TS}**	**BHN**	**Mp**	**₹**		
P	1	½	½	1	9		
σ_{TS}	2	1	1	5	9		
BHN	2	1	1	5	9		
Mp	1	1/5	1/5	1	9		
₹	1/9	1/9	1/9	1/9	1		
Total, T_i	6.111	2.811	2.811	12.111	37		
Normalised Matrix							
Criteria	**P**	**σ_{TS}**	**BHN**	**Mp**	**₹**	**Eigen Vectors**	**Priority Values**
P	0.163	0.177	0.177	0.082	0.243	0.159	0.166
σ_{TS}	0.327	0.355	0.355	0.412	0.243	0.334	0.347
BHN	0.327	0.355	0.355	0.412	0.243	0.334	0.347
Mp	0.163	0.071	0.071	0.082	0.243	0.110	0.115
₹	0.018	0.039	0.039	0.009	0.027	0.023	0.024
λ_{max}	0.07119						

of the table shows the priority values of criteria. From this Table, it is evident that Tensile Strength and Hardness are the most important and equal significance among the other main criteria. Likewise, the pairwise comparison is formulated between alternatives also based on the other criteria and alternatives with similar estimation of local priorities for all the elements.

3.4. Validate the Consistency

After doing pairwise comparisons of main criteria, the consistency ratio (CR) is estimated to validate the credibility of expert judgments. If the CR value is less than or equal to 10%, then the pairwise comparisons matrices are considered as an acceptable consistency. In case the CR value is greater than 10%, pairwise comparison matrix indicates the inconsistent judgments.

[Anand Babu, K et al (2015)] used geometric mean method for estimating the consistency ratio (CR) of formulated pairwise comparison matrix and the same procedure is used to determine the CR values for all elements in constructed hierarchy of present problem and is tabulated in Table 4 and Table 6. They used following steps to validate the pairwise comparisons.

In the **first Step**, the Eigen vectors are calculated after normalising the formulated pairwise matrix using geometric mean method (i.e., the product of each element in a row and taking their nth root) and these calculations are shown below and are tabulated in Table 4.

Eigen values for Density

$$EV_{\boldsymbol{\rho}} = \sqrt[5]{0.163 * 0.177 * 0.177 * 0.082 * 0.243} = 0.159;$$

For Tensile Strength

$$EV_{\boldsymbol{\sigma TS}} = \sqrt[5]{0.327 * 0.355 * 0.355 * 0.412 * 0.243} = 0.347;$$

For Hardness

$$EV_{\mathbf{BHN}} = \sqrt[5]{0.327 * 0.355 * 0.355 * 0.412 * 0.243} = 0.347;$$

For Melting Point

$$EV_{Mp} = \sqrt[5]{0.163 * 0.071 * 0.071 * 0.082 * 0.243} = 0.115;$$

For Cost

$$EV_{₹} = \sqrt[5]{0.018 * 0.039 * 0.039 * 0.027 * 0.027} = 0.024;$$

In the **second step**, the Priorities or Weights of each criterion are determined by dividing the each Eigen value element by the total sum of Eigen values column and these calculations are shown below and are listed in Table 4.

Priority values for Density
PV_{ρ} = 0.159/0.961 = 0.166;

For Tensile Strength
$PV_{\sigma TS}$ = 0.347/0.961 = 0.347;

For Hardness
PV_{BHN} = 0.347/0.961 = 0.347;

For Melting Point
PV_{Mp} = 0.115/0.961 = 0.115

For Cost
PV₹= 0.024/0.961 = 0.024

As part of validating the pairwise comparison

In the **third step**, let the pairwise comparison matrix is denoted by A_1 and the Priority vector be denoted by A_2. Then define the A_3 by multiplying the A_1 matrix with A_2 elements and then again define the A_4 by dividing the A_3 elements with A_2 elements and these calculations are shown in below:

$$A_3 = \begin{pmatrix} 1 & \frac{1}{2} & \frac{1}{2} & 1 & 9 \\ 2 & 1 & 1 & 5 & 9 \\ 2 & 1 & 1 & 5 & 9 \\ 1 & \frac{1}{5} & \frac{1}{5} & 1 & 9 \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} & 1 \end{pmatrix} * \begin{pmatrix} 0.166 \\ 0.347 \\ 0.347 \\ 0.115 \\ 0.024 \end{pmatrix} = \begin{pmatrix} 0.847 \\ 1.821 \\ 1.821 \\ 0.638 \\ 0.132 \end{pmatrix}; \; A_4 = \begin{pmatrix} 0.847/0.166 \\ 1.821/0.347 \\ 1.821/0.347 \\ 0.638/0.115 \\ 0.132/0.024 \end{pmatrix} = \begin{pmatrix} 5.102 \\ 5.244 \\ 5.244 \\ 5.55 \\ 5.45 \end{pmatrix}$$

Finally, the Principal Eigen value (λ_{max}) is calculated by dividing the sum of all elements in A_4 with number of criteria ie. n.

$$\lambda_{max} = (5.102 + 5.244 + 5.244 + 5.55 + 5.45)/5 = 5.318933$$

In the **fourth step**, the consistency index (CI) is calculated using below shown equation, where n is number of criteria

$CI = (\lambda_{max} - n)/(n-1) = (5.318-5)/5-1 = 0.0795$

Finally, the Consistency Ratio (CR) is calculated by using below shown equation. The Random Index number is chosen from Table 5 based on their number of criterion. In this case, RI is 1.12 as the number of criteria n= 5. The pairwise matrix is acceptable when the CR should be around 10%.

Table 5: Random Index Table for Different Matrix Order (n) [Angelis Tsagdis (2008)]

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

C.R = (CI/RI) = (0.0795/1.12) = 0.07119

Hence the CR is less than 10%; therefore the pairwise comparison matrix is acceptable.

Accordingly, the acceptability of each and every element in all levels is checked and considered the respective priority values to evaluate the most suitable matrix materials for preparation of AHMMCs.

3.5. Calculating the Priority Weights to Alternatives

After calculating local priority values of main criteria, pairwise comparisons between alternatives was made to estimating the priority weights of alternatives with respect to each criterion and depicted in Table 6.

The last column of Table 6 shows the priority weights of all alternatives with respect to each criterion. From Table 6, it is evident that AA 6082 matrix material is the most significant alternative for Density, Tensile strength properties and Cost criterion. The AA 6061 and AA 6351 matrix materials are having equal importance for Hardness property and AA 6063 is the most significance matrix material for melting point criterion, whereas AA 6061 and AA 6082 are having similar importance to melting point criterion.

The consistency checking for formulated pairwise comparison matrices in Table 6 are calculated using consistence check procedure (above said). The CR value of all formulated pairwise comparisons for alternatives with respect to main criteria is accepted and these values for all elements are summarised in Table 6.

Table 6: Properties Based Pair Wise Priority Values of 6XXX Series

Pair wise comparison of 6XXX series in density						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**		
AA 6061	1	1	1/5	1		
AA 6063	1	1	1/5	1		
AA 6082	5	5	1	3		
AA 6351	1	1	1/3	1		
Total, T_i	8	8	1.73	6		
Normalised Matrix						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**	**Eigen values**	**priority values**
AA 6061	0.125	0.125	0.115	0.166	0.131	0.132
AA 6063	0.125	0.125	0.115	0.166	0.131	0.132
AA 6082	0.625	0.625	0.577	0.5	0.579	0.583
AA 6351	0.125	0.125	0.192	0.166	0.149	0.150
Total, T_i	1	1	1	1	0.992	---
λ_{max}	4.032406	CI=0.0108		CR=0.0120 < 0.1		
Pair wise comparison of 6XXX series in tensile strength						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**		
AA 6061	1	7	1/3	1		
AA 6063	1/7	1	1/9	1/7		
AA 6082	3	9	1	3		
AA 6351	1	7	1/3	1		
Total, T_i	5.1428	24	1.777	5.1428		
Normalised Matrix						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**	**Eigen values**	**priority values**
AA 6061	0.194	0.291	0.186	0.194	0.212	0.216

AA 6063	0.027	0.041	0.062	0.027	0.037	0.038
AA 6082	0.583	0.375	0.564	0.583	0.518	0.527
AA 6351	0.194	0.291	0.186	0.194	0.212	0.216
Total, T_i	1	1	1	1	0.981	---
λ_{max}	4.085991	CI=0.028664		CR=0.031848 <0.1		
Pair wise comparison of 6XXX series in Hardness						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**		
AA 6061	1	9	2	1		
AA 6063	1/9	1	1/9	1/9		
AA 6082	½	9	1	½		
AA 6351	1	9	2	1		
Total, T_i	2.611	28	5.111	2.611		
Normalised Matrix						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**	**Eigenvalues**	**priority values**
AA 6061	0.382	0.321	0.391	0.382	0.368	0.372
AA 6063	0.042	0.035	0.021	0.042	0.034	0.034
AA 6082	0.191	0.321	0.195	0.191	0.219	0.221
AA 6351	0.382	0.321	0.391	0.382	0.368	0.372
Total, T_i	1	1	1	1	0.990	----
λ_{max}	4.05966	CI=0.019887		CR=0.022096<0.1		
Pair wise comparison of 6XXX series in melting point						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**		
AA 6061	1	1/2	1	1		
AA 6063	2	1	2	1		
AA 6082	1	1/2	1	1		
AA 6351	1	1	1	1		
Total, T_i	5	3	5	4		
Normalised Matrix						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**	**Eigenvalue**	**Priority values**
AA 6061	0.2	0.166	0.2	0.25	0.202	0.205
AA 6063	0.4	0.333	0.4	0.25	0.339	0.345
AA 6082	0.2	0.166	0.2	0.25	0.202	0.205
AA 6351	0.2	0.333	0.2	0.25	0.240	0.244

Total, T_i	1	1	1	1	0.984	
λ_{max}	4.060434	CI=0.020145		CR=0.022383<0.1		
Pair wise comparison of 6XXX series in cost						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**		
AA 6061	1	1	½	1		
AA 6063	1	1	½	1		
AA 6082	2	2	1	5		
AA 6351	1	1	1/5	1		
Total, T_i	5	5	2.2	8		
Normalised Matrix						
Alternatives	**AA 6061**	**AA 6063**	**AA 6082**	**AA 6351**	**Eigenvalue**	**Priority values**
AA 6061	0.2	0.2	0.227	0.125	0.183	0.188
AA 6063	0.2	0.2	0.227	0.125	0.183	0.188
AA 6082	0.4	0.4	0.454	0.625	0.461	0.473
AA 6351	0.2	0.2	0.090	0.125	0.146	0.149
Total, T_i	1	1	1	1	0.974	
λ_{max}	4.106103	CI=0.035368		CR=0.039297<0.1		

Table 7: Global Priorities for each Alternative

Criteria / Alternatives	ρ (0.166)	σ_{TS} (0.347)	BHN (0.347)	Mp (0.115)	₹ (0.024)	Overall priority Values
AA 6061	0.132	0.216	0.372	0.205	0.188	0.254035
AA 6063	0.132	0.038	0.034	0.345	0.188	0.091083
AA 6082	0.583	0.527	0.221	0.205	0.473	0.391261
AA 6351	0.150	0.216	0.372	0.244	0.149	0.260572

3.6. Global Priority Weights

The final level of AHP is to estimate the global priority by multiplying the local priority weights of main criteria and alternatives. At this point, priorities are "synthesized from the second level down by multiplying local priorities by the priority of their corresponding criterion in the level above and adding them for each element listed in a level according to the criteria it affects" [Engin Acar et al (2016)]. These global weights are tabulated in Table 7 and the last column of this table indicates the composite priority of all elements (alternatives) with respect to their criteria. Based on these weights the ranking is done to judge the most suitable matrix material among all other alternatives or matrix materials.

Table 8: Overall Rankings of Alternatives

Alternatives	Overall priority level	Ranks
AA 6061	25.40%	3
AA 6063	9.10%	4
AA 6082	39.12%	1
AA 6351	26.05%	2

4. RESULTS

The final rankings of the most suitable matrix material selection are listed in Table 8. From this

Table, it is observed that the AA 6082 matrix material is having highest global or overall priority level and ranked it as first. Likewise, all other alternatives are ranked based on the global priorities.

5. CONCLUSIONS

In the present modern engineering scenario, the engineers must take a decision to select the most appropriate matrix material for fabrication of AHMMCs. Hence the process of selecting best-suited aluminium alloy among various available alloys makes more difficult due to its cost and changes in properties from one material to other material with respect their principle alloying elements. Material properties influence the potentialities and overall cost of a system in many engineering applications, so several factors plays a crucial role in material selection. In this regard, the main contribution of this paper was to select the most suitable matrix material for AHMMCs using analytic hierarchy process (AHP). Based on the importance of each criterion and results obtained by AHP, the following conclusions have been drawn:

1. From Table 4, it is concluded that the Tensile Strength and Hardness are most influential criteria or properties in material selection having 0.347 as priority value followed by others.
2. From the Table 8, it is concluded that the aluminium alloy AA 6082 becomes the most dominating alternative having the highest priority level of 39.18% which is followed by the others. So, AA 6082 is the most suitable alternative among four alternatives.
3. Moreover, by observing the Table 8 it is concluded that the AA 6082 having high strength, high hardness, low density and low cost and also it is most suitable to fabricate the AHMMCs
4. Finally concluded that analytic hierarchy process (AHP) is an effective multi-criteria decision-making tool for solving the complex problem.
5. A major reason for selecting the most suitable matrix material using AHP is that the properties and cost of matrix materials also critical along with reinforcement material in AHMMCs to enhance potentialities and properties for achieving the demands offered by modern engineering world.

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