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Fabrication of Al 7068 Reinforced with Tur Husk Ash (THA) and Alumina Hybrid Metal Matrix Composite by Powder Metallurgy and Evaluating Its Microstructure and Mechanical Properties

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Abstract - **The applications of metal matrix composites are increasing day by day due to high strength to weight ratio. The hybrid aluminum composites can be considered as an outstanding material where high strength and wear-resistant components are of major importance, predominantly in the aerospace and automotive engineering sectors. In the present work , Al7068 reinforced with tur husk ash(THA) and Al2O3 hybrid metal matrix composite is prepared from sintering of mechanically alloyed powder (ball milling) in powder metallurgy process. Different combinations of compositions (Al7068 reinforced with 0%,4%,8%,12% 0F THA and Al2O3) were taken with total 16 combinations. Hardness was found to be increasing with increasing percentage of Al2O3 but was decreasing with increasing percentage of THA. The microstructure of the composites was studied.**

Keywords- **Al7068; tur husk ash(THA);Al2O3; Powder metallurgy; Metal matrix composites.**

I. INTRODUCTION

Aluminium is the most abundant metal and the third most abundant chemical element in the earth's crust comprising over 8% of its weight. The unique combinations of properties provided by Aluminium and its alloys make Aluminium one of the most versatile, economical, and attractive metallic materials for a broad range of uses—from soft, highly ductile wrapping foil to the most demanding engineering applications. Because of its affinity for oxygen, aluminium is always found combined with other elements mainly as aluminium oxide.

Composite materials are defined as "A material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual.". An Aluminium 7068 alloy provides the highest mechanical strength of all aluminium alloys and matching that of certain steels. This outstanding alloy combines yield strength of up to 700 MPa (up to over 30% greater than that of 7075 alloy) and good ductility with corrosion resistance. Aluminium oxide is also known as Alumina. It is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. Alumina is one of the most cost effective and widely used material in the family of engineering ceramics. India is generating huge amount of low cost by-product and waste in the form of tur husk. Presently the use of this husk is only for the cattle feed and possessing very less value. However as this by-product is biomass and naturally carries carbon content with it so that we can use it in industrial application and hence can be used as reinforcement in MMCs. Methods available for the production of Hybrid composites are powder metallurgy, spray deposition, liquid metal in filtration, squeeze-casting, stir casting. Here powder metallurgy is used in this study The objective of present work is to fabricate hybrid composites of Al7068/ Al_2O_3 /tur husk ash by powder metallurgy and determine the effect of addition of tur husk ash on mechanical properties of Al7068 MMCs.

II.LITERATURE SURVEY

T.W.Clyne, has described in this article that The term Metal Matrix Composite (MMC) covers various types of system, and also a wide range of scales and microstructures. Common to them all is a metallic matrix, which is normally contiguous. The reinforcing constituent is in most cases a ceramic, although there are exceptions to this and MMCs can be taken to include materials "reinforced" with relatively soft and/or compliant phases, such as graphitic flakes, lead particles or even gases. It is also possible to use refractory metals,

interimetallics or semiconductors, rather than true ceramics. MMC types are commonly subdivided according to whether the reinforcement is in the form of (a) particles, which are at least approximately equiaxed, (b) short fibbers (with or without a degree of alignment) (c) Long aligned fibers. Choice of matrix and reinforcement, specification of the way in which the composite material is to be synthesised, and the manner in which a stock item or component is to be fabricated.

M K Surappa,in the work on aluminium matrix composites: challenges and opportunities, stated that AMCs have been utilized in high-tech structural and functional applications including aerospace, defence, automotive, and thermal management areas, as well as in sports and recreation. It is interesting to note that research on particle-reinforced cast AMCs took root in India during the 70's, attained industrial maturity in the developed world and is currently in the process of joining the mainstream of materials. This research survey presents an overview of AMC material systems on aspects relating to processing, microstructure, properties and applications.

M.A. Baghchesara et al. investigated on Microstructure and Mechanical Properties of Aluminium Alloy Matrix Composite Reinforced with Nano MgO Particles. In this work pure atomized aluminium powder with an average particle size of 1 µm and MgO particulate with an average particle size between 60-80 nm were used. Composites containing 1.5, 2.5 and 5.0 % of volume fraction of MgO were prepared by powder metallurgy method. The specimens were pressurized by cold isostatic pressure machine. The consolidation temperatures were 575, 600 and 625°C. After sintering and preparing the samples, mechanical properties were measured. The results of microstructure, compression and hardness tests showed that addition of MgO particulates to aluminum matrix composites improve the mechanical properties.

Shaikh Sharjeel Zeeshan et al., has studied on mechanical and tribological properties of aluminum-7068 alloy reinforced with sic and Al2O3 In this work Aluminium 7068 as matrix and Silicon Carbide and Alumina as reinforcement has been used. The %wt of reinforcement are varied to study the difference in aluminium property. Following are the samples are first sample is Al7068 with 2% SiC and 8% Al2O3, second sample consist of Al7068 with 4% SiC and 6% Al2O3 , third sample consist of Al7068 with 6% SiC and 4% Al2O3, and the fourth sample is of Al7068 with 8%SiC and 2% Al2O3. The materials are obtained by stir casting technique. The casted composite specimens were machined as per ASTM standards. The aim is to study the mechanical and tribological properties of Al-7068 alloy reinforced with SiC and Al2O3 composite with various weight fractions were prepared by stir casting method.

Prasanna Gubbi, et al,. on a study on mechanical and tribological properties of Aluminium 7068 MMC'S reinforced with silicon carbide (sic) and tur husk, the results showed that two phases namely a matrix and a reinforce-ment phase constitute composite materials. Most of studies shows that the material used for components should posses better mechanical and tribological properties. In this paper five samples were prepared by using stir casting. First sample is Al7068, second sample consist of Al7068 with 2% SiC and 8%Tur Husk, third sample consist of Al7068 with 4% SiC and 6% Tur Husk the fourth sample consist of Al7068 with 6% SiC and 4% Tur Husk and the fifth sample is of Al7068 with 8%SiC and 2%Tur Husk. It was found that tensile strength and impact is increased when SiC and Tur Husk is added to Al7068. Wear is decreased when SiC and Tur Husk is added to Al7068composition available of tur husk ash (THA).

1. Problem statement & objective

The extensive review of literature carried out for present study reveals that lot of work has been reported to enhance properties of Aluminium metal matrix composites through stir casting.

After the review of literature the following gaps were found:

- Very limited amount of work has been done which explains the factor effecting properties of Aluminium metal matrix composite by powder metallurgy.
- There is no detailed chemical composition available of tur husk ash (THA).
- No amount of work has been done on combined effect of Aluminium Oxide(Al2O3) and Tur Husk Ash (THA) with Aluminium metal matrix by powder metallurgy.

Due to the following gaps this work is done to develop the new material using Aluminium alloy composites, so that it should be lighter in its weight and with improved properties which can be used for industrial purpose such as automobile and aircraft industries.

II. METHODOLOGY

1. Preparation of samples by powder metallurgy

The base matrix material used in the present experimental investigation is Al7068 (fig 2.4) and Tur Husk Ash (THA) (fig 2.6) and Alumina (Al2O3) (fig 2.5) as the reinforcement to form a hybrid metal matrix composite. Tur husk was burnt in furnace at 600oC for about 2-3 hours in the presence of oxygen the ash content of tur husk is 3.2% of raw husk. the particle size of tur husk ash(THA) taken for this work is of 30 microns size, with the help of 30 microns sieve. The Al7068 hybrid composites with tur husk ash (THA) and Alumina (Al2O3) as reinforcement were produced using powder metallurgy. Table 1 shows the AL7068 powders that were weighed accurately and mechanical alloying was done for 10 hours in a pot mill (fig 2.1).

Table 1 Chemical composition of Al-7068

Elements of Al7068	Weight %
Si	0.12
Fe	0.15
Cu	2
Mn	0.1
Mg	3
Cr	0.05
Zn	8
Ti	0.01
Zr	0.1
Al	86.47

The hybrid composite was milled in 500ml polypropylene bottle with the alumina balls of sizs 10mm and 3mm as a grinding media. The powder to grinding media ratio used is 1:4 where 50% of total grinding media includes 10 mm alumina balls and other 50% of grinding media includes 3mm of alumina balls. The particles were added with 2% stearic acid to have proper bonding. A separate die and punch was made for compaction of metal powders.

Table 2 The sample specification

Sample No.	Composition
1	Al7068 Pure
2	Al7068 + 0% THA + 4% Al_2O_3
3	Al7068 + 0% THA + 8% Al_2O_3
4	Al7068 + 0% THA + 12% Al_2O_3
5	Al7068 + 4% THA + 0% Al_2O_3
6	Al7068 + 4% THA + 4% Al_2O_3
7	Al7068 + 4% THA + 8% Al_2O_3
8	Al7068 + 4% THA + 12% Al_2O_3
9	Al7068 + 8% THA + 0% Al_2O_3
10	Al7068 + 8% THA + 4% Al_2O_3
11	Al7068 + 8% THA + 8% Al_2O_3
12	Al7068 + 8% THA + 12% Al_2O_3
13	Al7068 + 12% THA + 0% Al_2O_3
14	Al7068 + 12% THA + 4% Al_2O_3
15	Al7068 + 12% THA + 8% Al_2O_3
16	Al7068 + 12% THA + 12% Al_2O_3

Cold compaction at a low pressure of 400 MPa was done using a digital hydraulic press machine (fig 2.2) to produce green compacts of size 10 mm diameter and 12±0.5 mm height. The green compacts were sintered at 720oC for three hour in a raising hearth furnace (fig 2.3). The composites of Al7068 reinforced with THA and Al2O3 were produced according to the sample specification showed in Table II.

Fig.1. Pot mill.

Fig.2. Compacting of sample using Digital hydraulic press.

Fig .3. Raising Hearth Furnace.

Fig.4. AL7068 40µ size powder.

Fig.5. Alumina of 40µ size powder.

Fig.6. Tur husk ash 30µ size powder.

2. Tur Husk Ash (THA) analysis

2.1Thermogravometry analysis of tur husk ash:

The TG analysis of tur husk ash (THA) provides data of the presence of percentage of ash content in the sample. The analysis showed that the presence of total ash content observed in the graph is 3.2%. Thermalgravi-metric (TG) analysis is the process in which moisture and volatile matter changed according to the heat supplied which is plotted on a graph.

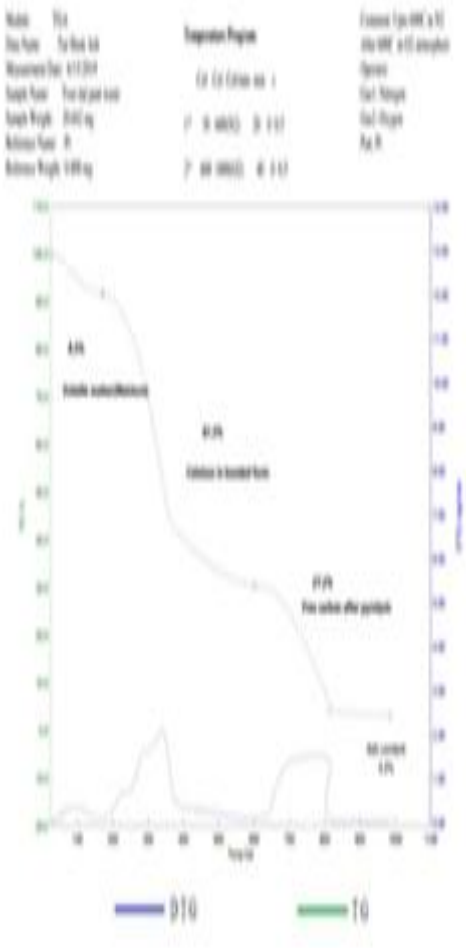

Fig .7. TG Analysis.

TG = thermal gravimetric
DTG = Derivative thermal gravimetric
Derivative thermal gravimatric (DTG) analysis gives us the data of the sample weight changed with respect to increase in temperature. This graph shows the reduction of moisture in the tur husk at 200C and upon further increase in the temperature the binder material i.e cellulose matter has been reduced at 600C.and upon further increase in the temperaure there is no matter to be reduced so the content left is only ash.

2.2 XRD Analysis:

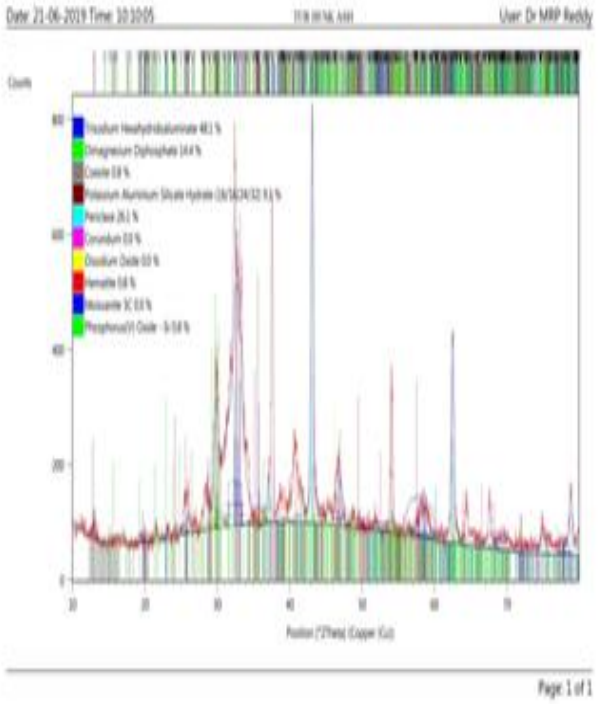

Fig.8. XRD Analysis.

Represents the XRD analysis of tur husk ash (THA) which provides knowledge of the presence of MgO in the sample.The analysis showed that the presence of crystalline structure as sharp peaks are observed in the graph. Table III shows the chemical composition of tur husk ash (THA).

Table 3 Composition of Tur Husk Ash (THA).

Sl. No.	Compound Name	Chemical Formula	Weightage Percentage
1	Phase Trisodium Hexahydridoaluminate	Na_3H_6Al	48.10%
2	Phase Periclase:	MgO	26.10%
3	Phase Dimagnesium Diphosphate	$Mg_2O_7P_2$	14.40%
4	Phase Potassium Aluminium Silicate Hydrate	$K_{16}Al_{16}Si_{24}O_{12}H_{64}$	9.00%
5	Phase Coesite	SiO_2	0.80%
6	Phase Hematite	Fe_2O_3	0.80%
7	Phase Phosphorus(V) Oxide	P_2O_5	0.80%

Fig .9. Green samples.

Fig .10 . Sintered samples.

III. RESULTS AND DISCUSSION

1.Density

The density of samples is determined by measuring the weight and volume of the specimens

Table 4 Density of samples

Sample No.	Green Density (grms/cc)	Sintered Density (grms/cc)
1	2.21	2.37
2	2.28	2.46
3	2.25	2.45
4	2.36	2.66
5	2.26	2.42
6	2.23	2.47
7	2.20	2.49
8	2.32	2.50
9	2.23	2.48
10	2.27	2.48
11	2.27	2.49
12	2.29	2.51
13	2.14	2.42
14	2.12	2.45
15	2.17	2.45
16	2.21	2.50

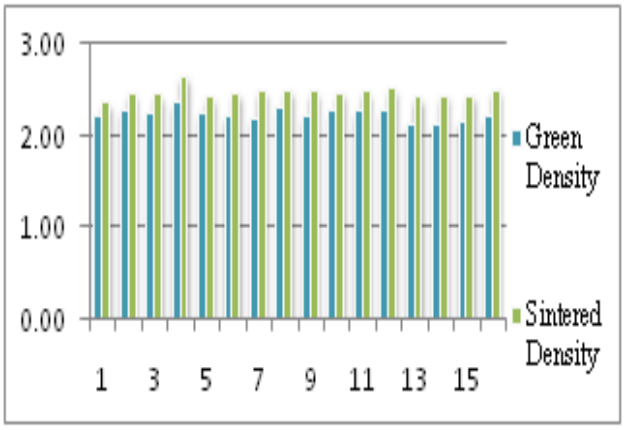

Fig .11. Graphical representation of Green and Sintered density in g/cc.

The green density and sintered density of the samples showed varying values of densities with different percentage of reinforcement of THA and Al2O3. The calculation of density of sintered samples showed increased in density values as compared with the green density. The data is graphically represented in above graph in grams per centimeter square.

2.Compression test

The digital hydraulic press was suitable for the compression test as the size of the samples were small in dimension e.i 10 mm dia and 12 mm height.The samples were placed in hydraulic press and load was applied until fracture was observed on the sample and the respective readings were noted down.

Table 5 Compression test results

Sample No.	Compressive Stress in kg/mm2	Compressive Stress in Mpa
1	16.3	159.85
2	14.6	143.18
3	16.6	162.79
4	14.3	140.24
5	15.7	153.96
6	15.5	152.00
7	11	107.87
8	9.5	93.16
9	13.2	129.45
10	18.2	178.48
11	17.3	169.66
12	15.1	148.08
13	19.2	188.29
14	13.6	133.37
15	11.4	111.79
16	12.5	122.58

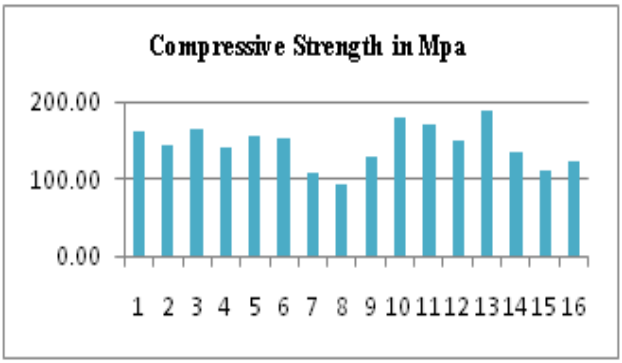

Fig.12. Representation of compression test results.

From the above graph it is seen that the highest value of compressive strength was observed for the composition Al7068 + 12% THA + 0% SiC i.e188.29 MPa.

3.Scanniing Electron Microscopy (SEM)

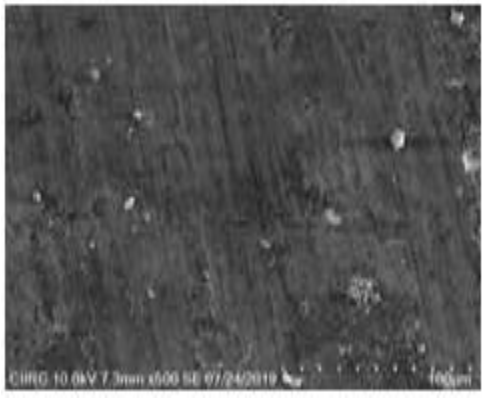

Fig .13. SEM image of Al7068.

The above image shows the sintered sample of AL-7068 with no reinforcement, by seeing this fig it was observed that the sample was sintered properly without any pores left and with no pores. So we cannot go further magnification inside the sample.the particles are binded excellently with each other.

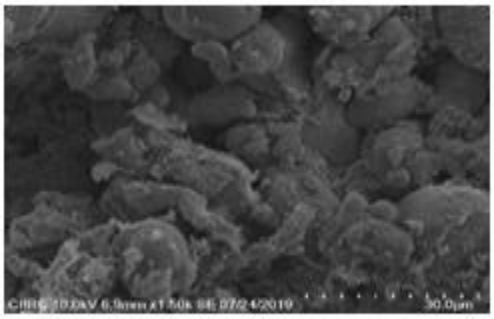

Fig .14. SEM of Al7068 +0% THA +12% Al_2O_3 sample.

The above fig shows the hybrid composite with Al2O3 as reinforcement to AL-7068, by which we can say that the particles are properly milled together in the milling process, but due to the large pore sizes seen after sintering we can say that it needs higher force for the compaction.

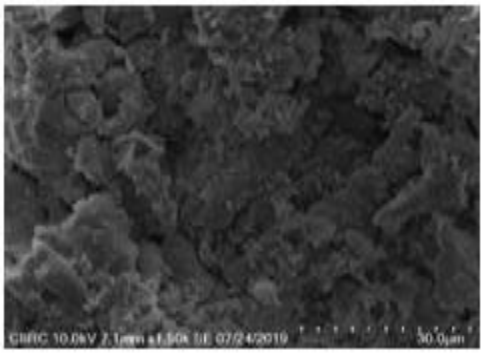

Fig.15. SEM of Al7068 +12% THA +0% Al_2O_3 sample.

Above fig represents SEM image of sintered sample with THA reinforcement. The image shows that the sample is not been sintered properly because the particles are loosely bond and have not formed grain boundaries.

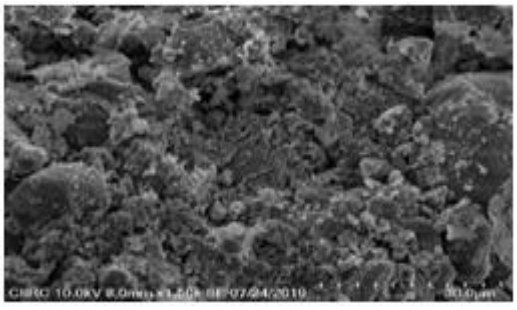

Fig .16. SEM of Al7068 +12% THA +12% Al_2O_3 sample.

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From the image of the hybrid composite above it was observed that the tur husk ash is completely submerged in the matrix but it can be seen that the pores size did not reduce this might be due to improper sintering.

4.Energy Dispersive X-Ray Study (Edx)

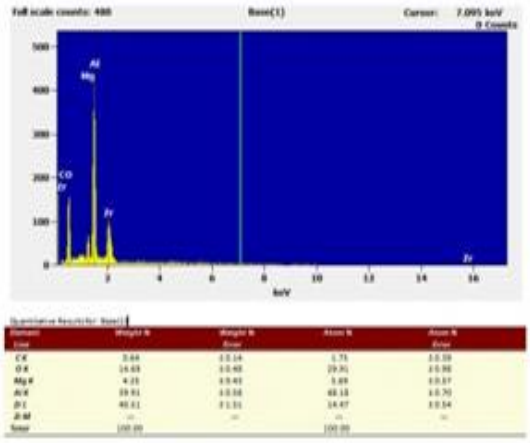

Fig .17. EDX of Al 7068 sample.

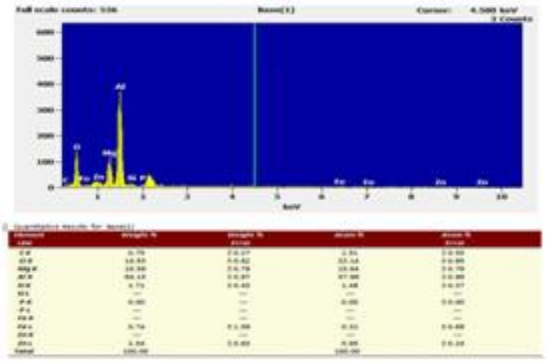

Fig .18: EDX of Al7068 +0% THA +12% Al_2O_3 sample.

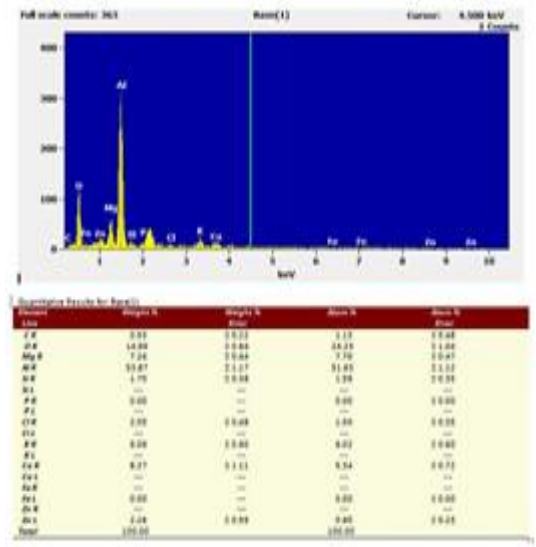

Fig .19. EDX of Al7068 +12% THA +0% Al_2O_3sample.

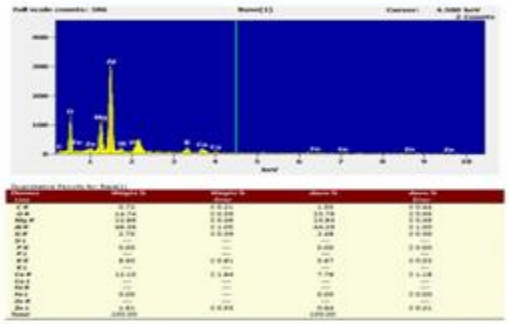

Fig .20: EDX of Al7068 +12% THA +2% Al_2O_3 sample.

From the fig 3.7 we can say that the EDX of sample containing only Al-7068 with no reinforcement ,shows all the compositional elements present in it and it matches with standard Al-7068 composition.

From the fig 3.8 EDX of sample containing Al7068 +0%THA+12%Al2O3 confirms the presence of alumina and the aluminium matrix as we can see through the peaks and data provided by table. It contains high percentage of aluminium.

From the fig 3.9 EDX of sample containing Al7068 +12%THA+0%Al2O3 confirms the presence of THA and the aluminium matrix as we can see through the peaks and data provided by table.It contains aluminium and more amount of MgO which is present in THA.

From the fig 3.10 EDX of sample containing Al7068 +12%THA+12%Al2O3 confirms the presence of THA, alumina and the aluminium matrix as we can see all the elements present in the composition are observed in the table.

5.Hardness test

Hardness of the samples were tested on Brinell Hardness Tester.

Table VI: Hardness test results

Sample No.	Brinell Hardness (HB)
1	94
2	95
3	93
4	97
5	88
6	82
7	85
8	89
9	72
10	74
11	75
12	81
13	58
14	65
15	67
16	70

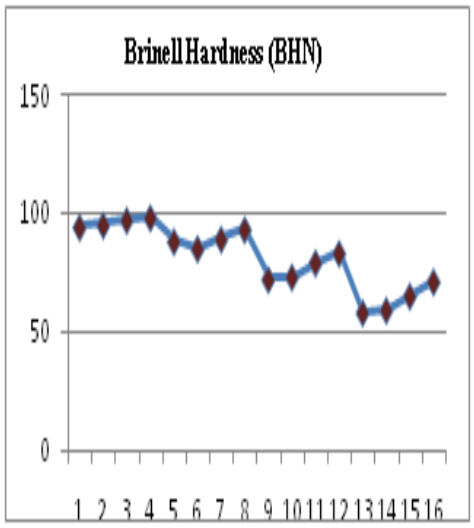

Fig .21. Representation of Hardness test results.

From the results, it is observed that the hardness of the samples decreases as percentage of tur husk ash increases. As well, the hardness increases as the weight percentage of Al2O3 increases. The maximum hardness value obtain is 97 BHN for the composition of Al7068 reinforced with 0% THA and 12% Al2O3.

IV. CONCLUSION

From the present work on the aluminium based hybrid MMC the following conclusions have been derived:

- The ash content of tur husk was obtained through TG analysis and was found to be 3.2% of raw husk.
- The chemical composition of the Tur husk ash was obtained by XRD.
- XRD report shows that the tur husk ash (THA) has 26.1% of MgO in it.
- The density was measured before and after sintering,and was found to be increasing.
- The EDX of samples confirmed the proper mixing of reinforcement in it.
- The microstructure analysis (SEM) of sintered sample showed that it was partially sintered as pores were identified.
- As sample reported to be partially sintered, it was observed that the compressive strength was found to be varying and were significantly low.
- The hardness test shows that the hardness increases as percentage of Alumina increases but it decreases with increasing percentage of tur husk ash.

V. SCOPE FOR FUTURE WORK

The above work has been completed in view based on the literature already available. By applying Design of experiments (Tagauchi Technique) the optimization of number of samples can be carried out, yielding better results. In this work only random composition (based on the literature available) was taken and the results were analyzed, discussed and documented. In the future work Design of experiments can be effectively used to study the mechanical properties of the hybrid composites. The mechanical properties can be further improved by increasing compacting load. Further to improve mechanical properties, the sintering can be done in presence of inert gases to avoid oxidation The other test like tensile test and wear test can be analysed. Different reinforcement such as ZrO2,TiO2, B_4 C, TiC etc can be used to fabricate the different hybrid composites and analysed.

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