FABRICATION AND ANALYSIS OF STIR CASTED HEXAGONAL BORON NITRIDE AND NANO ALUMINA REINFORCED ALUMINUM MATRIX COMPOSITE

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Abstract

Aluminium alloy as a matrix of the composite is quite attractive among researchers because of the light weight, high ductility and exceptional corrosion resistance. In this research paper, a stir casting furnace setup is prepared for the fabrication of hexagonal boron nitride and alumina reinforced aluminium matrix composite. A ccomparative evaluation of the mechanical properties of aluminium based single and hybrid reinforced aluminium matrix composites are carried out. Two specimens of single reinforced aluminium matrix composites are fabricated using 5% and 10% hexagonal boron nit-ride in the matrix of AA7075 aluminium alloy by stir casting method. Other two specimen of the hybrid composites are fabricated with the addition of 2% and 4% Nano alumina in excess to 10% hexagonal boron nit-ride. The reinforcement is preheated up to 3000 c. Subsequently, Mechanical characterization such as hardness testing, and impact testing are done on all the four specimen and a comparative study of the testing has been done.

Keywords: Reinforced, Hexagonal boron nitride, Nano Alumina, Hardness, Impact AA7075.

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1. INTRODUCTION

Metal matrix composite is made of fibres or particles as the reinforcement in the matrix of metal. The metal matrix composite has the potential of producing a composite with very high stiffness and strength as well as very high temperature resistance. Metal matrix composite has the advantage of better abrasion resistance, creep resistance, resistance to degradation by fluids, dimensional stability and non-in flammability than the polymer matrix composite but they are limited by their higher weight and high cost of production associated with it. Al, Mg, Ti and Cu are most commonly used as the matrix material whereas silicon carbide and alumina are the most utilized as the reinforcement materials Composite having aluminium as the matrix phase of the material is called Aluminium matrix composite. Light weight, high ductility and corrosion resistance of aluminium makes it a very attractive material as a matrix of the composite. Alloying improves the mechanical properties of Al significantly. There are eight series of aluminium alloy from 1000 series to 8000 series. The tensile strength and yield strength of the AA7075 aluminium alloy is the largest among all the aluminium alloys. Light weight and high tensile strength make this one of the good materials to be used in aerospace industry [14]. The disadvantage of AA7075 is its low hardness and stiffness. The research on improving its hardness and stiffness has been going on for decades.

Use of the metal matrix composite in the field of automotive and aerospace industry has been increasing at a rapid rate because of the exceptional properties provided by metal matrix composites [14, 17, 19]. Some of the exceptional requirement of properties cannot be met by conventional material. Hence, In the ductile matrix of metal, Brittle ceramics are added to achieve high specific modulus, high specific strength, good corrosion resistance, High thermal shock resistance, Superior wear resistance, better hardness and tensile strength while maintaining the ductility and fracture toughness of the material [13, 17]. Usually conventional ceramics like SiC, Al_2O_3, TiB_2, Si_3N_4, B_4C etc. are added in the ductile matrix of light weight metals like Al, Mg, Ti to fabricate metal matrix composites. Apart from conventional ceramics, Industrial wastes like fly-ash, red-mud etc. And agricultural wastes like sugar cane bagasse, burnt rice husk, Bamboo leaf ash etc. can also be used to get the optimized micro-structural and mechanical properties of composites [19]. AA7075 Aluminium alloy has the highest tensile strength among all thealuminium alloy and its ductility is 11%. Its light weight and high ductility and good corrosion resistance make this alloy very attractive material for the matrix of the composite.

Aluminum matrix composite are classified [1-2] into four different types on the basis of reinforcements(Particle reinforcedAMCs,Whisker or short fibre reinforced AMCsContinuous fibre reinforced AMCs,Monofilament reinforced AMCs) .The effect of particle clustering on the mechanical behaviour of SiC particulate reinforced aluminium matrix composite using FEM simulation tool and reported its significant effect on the ductility of the composite[3]. T.P.D Rajan, R.M.Pillai,B.C.Pai, K.G.Satyanarayna and P.K.Rohtagi [4] evaluated the effect of the casting method on the homogeneity of the reinforced particle and reported that compocasting method followed by squeeze casting was the best method for it. A.Rabiei, L. Vendra, T.Kishi [5] studied and experimented Fracture behavior of particle reinforced metal matrix composites and the experimental value was compared with Hahn–Rosenfifield model. It was found in good agreement upto 5-10 um particle size.For the larger particle size, a modified Hahn–Rosenfifield model was developed and the new modified model was in good agreement with the experimental fracture toughness of the particle reniforced MMCs.Manojsingla, D.DeepakDwivedi, Lakhwirsingh and VikashChawla [6] stir casted Aluminum based SiC (5%, 10%, 15%, 20%, 25%, 30%) particulate matrix composite and investigated hardness, toughness and found increasing trend of homogeneity in particle distribution in 2step stirring than manual stirring.Hardness and toughness was at its peak at 25% SiC.G.Gopalakrishnan and N.Murugan [7] fabricated AA6061 matrix TiC particulate reinforced composite by enhanced stir casting method and investigated mechanical properties(Tensile strength , Percentage elongation) and wear behaviour .They reported improvement in the specific strength while maintaining percentage elongation appreciably. He also noted that the volume wear loss in Al-TiCp composite produced by stir casting method was less than that In Situ process.Mahindra Bhupathi, K.P Arulshri and N.Iyandurai [8] reported the increment in the tensile strength, yield strength and hardness of the Al matrix hybrid composite using SiC and fly-ash as reinforcement in the matrix of AA2024 with a decrement trend in the ductility and density of the composite. BeleteSirahbizuYigezu, Manas Mohan Mahapatra and Pradeep Kumar Jha [9] observed that alumina reinforced composite was more ductile than SiC reinforced composite by 31%.T.Rajmohan, K.Palanikumar and S.Rangnathan [10] investigated the effect of the mica and SiC as reinforcement in the matrix of AA356 and inferred that the tensile strength and hardness of the hybrid composite is maximum at 3% of the mica and further increase in the percentage of mica decreases the properties.Puvazhagan L, Kalaichelvan.K, Rajadurai.A and Senthilvelan.B [11] fabricated B4C (0.5% fixed) and SiC (0.5%, 1.0%, 1.5%) nanoparticles reinforced AA6061 aluminium matrix composite successfully by ultrasonic cavitation-based solidification process and confirmed it through SEM analysis and reported increase in hardness and tensile strength as the percentage of SiC particles increases except tensile strength which further decreased after 1% SiC. The impact strength and ductility was found to be decreasing continuously as the percentage of reinforcement (B4C and SiC) increased.Dora Shiva prasad,ChintadaShoba and NalluRamanaiah [12] investigated the rice husk ash and SiC as a reinforcement in the matrix of AA356.2 with their equal proportions as 2%, 4%, 6% and 8% and reported increment in the tensile strength, yield strength, hardness and porosity of the composite whereas a -decrement trend in the density was found. Dr. Anil birru and B.Praveenkumar [13] studied the effect of bamboo leaf ash as reinforcement(0%, 2%, 4%, 6%) in the matrix of Al-4.5%Cu alloy and reported an increment in the tensile strength and hardness up to 4% and noted further decrease in the strength and hardness. Density of the composite and its ductility decreased up to 6% and opposite trend was observed with porosity of the composite which was 2.512% at 6% of BLA.VeeravaliRamkateswRao, NalluRamanaiah and Mohammad MaulanaMohiuddinSircar [14] fabricated aluminium matrix (AA7075) composite reinforced with TiC particulates(2um) in varying proportion of 2%, 4%, 6%, 8%, 10% using stir casting method and reported better mechanical properties (hardness, tensile strength and wear resistance) with heat treated condition than the cast condition. Hardness, tensile strength and wear resistance increased up to 8% and then a further increment in its percentage decreased the properties at 10% whereas ductility of the composite was observed to be following opposite trend having the lowest ductility at 8%.

C.Kannan and R.Ramanujan [15] investigated the effect of preheating temperature 400, 500 and 6000 c on the mechanical properties of alumina (2%) reinforced al matrix composite and reported less porosity, higher hardness, better tensile strength and lower ductility at 500o c.Nishantvarma and S.C.Vettivel [16] fabricated the hybrid composite of AA7075 reinforced with 5% of B4C and varying proportion of rice husk ash (0%, 3%, 5%) and reported increment in hardness and compressive strength with increase in %age of RHA with their maximum values at 5% B4C and 5% RHA and also reported increment in tensile strength up to 5% B4C and a further decrease in it was observed with the addition of RHA. Mannivanan A and Sasikumar [17] fabricated cubic boron nitride reinforced aluminium matrix composite by two steps stir casting method and showed its suitability to be used as a fin material to enhance heat transfer rate.C.Saravana, S.Dinesh, P.Sakhtivel, V.Vijayan and B.Suresh Kumar [18] fabricated Silicon carbide and graphene reinforced AA7075 matrix composite and investigated the mechanical and micro-structural properties of the single reinforced and hybrid composite. He reported an increment in the impact strength of the composite. The maximum impact strength was found at 6% of the graphene and an increase in the tensile strength and hardness up to 3% and there was decrement with further addition of graphene.S. Rakshath, B.

Suresha, R.Sasi Kumar and I.Saravann [19] investigated the effect of alumina and h-BN as reinforcements in the matrix of AA7075 and reported increment in hardness and coefficient of friction and SWR of the composite.

2. DENSITY AND POROSITY CALCULATION

2.1 Theoretical density calculation

Theoretical density of a composite can be calculated using the following formula [2, 6].

$\rho_{th} = \rho_m \vartheta_m + \rho_r \vartheta_r + ...$(2a)

Where ρ_m =density of the matrix
ϑ_m=volume fraction of the matrix
ρ_r=density of the reinforcement
ϑ_r=volume fraction of the reinforcement
This formula can be extended to any number of reinforcements. Theoretical density for raw materials and all specimen are given in table 2.1 and table 2.3 respectively.

Table 2.1: Theoretical density of the reinforcement and the base metal

Materials	AA7075 [7]	h-BN	Alumina [7]
Density (g/cm^3)	2.81	2.29	3.97

Table 2.2: Percentage of reinforcement in the base metal

Specimen No.	h-BN (%Vol.)	Alumina (%Vol.)	AA7075 (%Vol.)
1	05	0	95
2	10	0	90
3	10	2	88
4	10	4	86

Table 2.3: Theoretical density of all the composite specimen

Specimen no.	Density calculation	Density (g/cc)
01	ρ_{th}=2.81*0.95+ 2.29*0.05	2.784
02	$\rho_{th} = 2.81 * 0.90 + 2.29 * 0.1$	2.758
03	$\rho_{th} = 2.81 * 0.88 + 2.29 * 0.10 + 3.97 * 0.02$	2.7812
04	$\rho_{th} = 2.81 * 0.86 + 2.29 * 0.10 + 3.97 * 0.04$	2.8044

2.2 Experimental density (Actual density) calculation.

Density of all the composite specimen and the base metal is carried out using Archimedes principle. In this method all the composite specimen and the base metal is weighed in the air and thereafter all the specimen again weighed in a fluid of known density. In this experiment, Fresh water was selected as a fluid of known density. Applying Archimedes principle, the following formula is used for actual density calculation [3]. Actual density all specimen is given in table 2.4.

$$\rho_{mmc} = \frac{m}{m-m_1}\rho_w \text{...(2b)}$$

m=mass of the composite sample in the air
m_1=mass of the composite sample in the fresh water
ρ_w=density of fresh water

Table 2.4 Experimental (Actual) density of all the composite specimen

S. No.	Weight in air(m) (g)	Weight in water(m_1) (g)	Experimental density(g/cc) $\rho = \frac{m\rho_{th}}{m - m_1}$
1	15	9	2.436
2	30	19	2.658
3	35	22	2.62432
4	30	15	1.9495

2.3 Porosity calculation

After determining the theoretical density using rules of mixtures and actual density using Archimedes principle, Porosity was calculated using the formula given below. This porosity calculation gives us an indication of compactness of the composite fabricated. Less percentage porosity means less void space in the composite specimen and hence indicates defect free, void less and successful fabrication of the composite.

The percentage porosity for all the specimen can be calculated using the equation given below [10,14]. The percentage porosity for all four specimen is given in table 2.5.

$$\%\ \text{porosity} = \frac{\text{Theoretical density} - \text{actual density}}{\text{theoretical density}} * 100 \quad (2c)$$

Table 2.5Calculation of percentage porosity

Specimen No.	Theoretical density(g/cc)	Actual density (g/cc)	Percentage porosity
1	2.784	2.436	19.09
2	2.758	2.658	17.94
3	2.7812	2.62432	18.37
4	2.8044	1.9495	21.09

3. FABRICATION METHODOLOGY

3.1 Stir casting method

Stir casting is one of the least expensive methods of fabrication of composite. It consists of a crucible furnace, a stirrer, a variable speed motor and a reinforcement feeder. In the furnace, AA7075 is melted at around 6600c temperature. When aluminium alloy comes in the liquid state then single stage impeller is run at a certain rpm for a certain time during which, using reinforcement feeder, already preheated reinforcement in some other furnace is added to the liquid aluminium. Stirrer is kept rotating for a certain time to achieve uniform distribution of reinforcement particle in the Al matrix. The variable speed motor is used to vary the rpm of stirrer.

3.2 Preparation of pattern

Drawing of pattern is prepared in the part design workbench of CATIA V5R18 as per ASTM E10-07 (Brinell hardness test) & ASTM E23-07a (Impact test) [14], .It is saved as a .stl file and is imported to Curalink 3D printing software where the specimen is 3D printed using 3D Printer Model-3D Printer creality Ender 3 Pro.Drawings and Pattern are shown in Fig. 3.1, Fig 3.2 & Fig. 3.3.

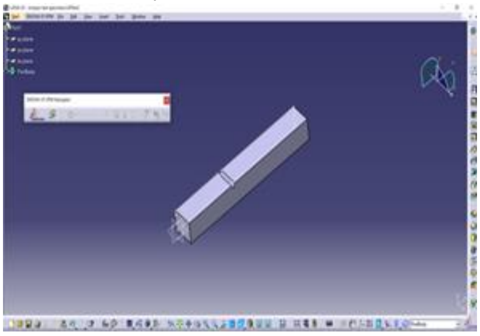


Fig. 3.1 Toughness test specimen(ASTM E23-07a) model in CATIA V5R18

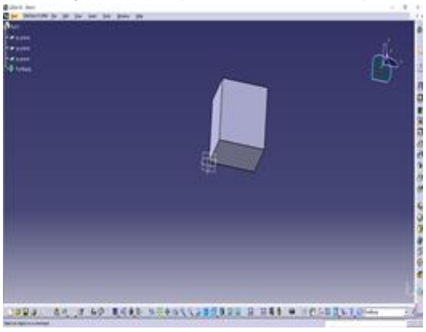


Fig. 3.2 Hardness test specimen (ASTM E10-07)

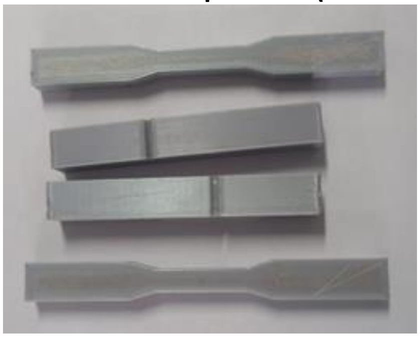


Fig. 3.3 3D Printed specimen pattern

3.

3 Preparation of mould

Mould cavity of the standard specimen is prepared using plaster of Paris.POP is chosen as a mould material because of its cost effectiveness,zero involvement of any machine and its high resistance to temperature.it can withstand temperature up to 1200^0 c.First POP is put into a container and some amount of water is added in it.Thereafter the slurry of POP and water is stirred thoroughly with hand.Now the properly stirred slurry is ready to be put into moulding box where 3D printed pattern of the standard specimen is already there.specimen pattern is taken out from the mould after 2 minutes of the mould cavity preparation When the pop mould has not hardened properly.Then after it is allowed in the air to dry.As it dries it gains its strength and get hardened and proper shape of the mould cavity is achieved as shown in figure 3.4 & 3.5.

Fig. 3.4 POP mould for toughness and hardness specimen.

Fig. 3.5 Inverted view of POP mould.

3.4 Fabrication of Aluminium matrix composite.

Aluminium matrix composite using h-BN and alumina as reinforcement is fabricated by stir casting method. The matrix material AA7075 has a melting temperature of 660°C first AA7075 is cut into smaller size to accommodate it into crucible. smaller size of AA7075 round bar is placed in the crucible and temperature is set at 850°c. After the aluminium metal has come into the semi-molten state,1.5% of Mg [1,14]is added in it to improve the wettability of the reinforcement in the metal and then the stirrer is placed in the crucible and it is started to run at 600 rpm. The moment when stirrer starts at the same time h-BN particles and alumina powder preheated up to 300° c is placed in the crucible. The stirring of molten mix is continued for 05 minutes. In the meantime, the plaster of Paris mould would be ready to pour into the molten mix. After the reinforcement particleshas mixed thoroughly for 05 minutes, the molten aluminium is poured into the plaster of Paris mould. After solidification the specimen is taken out from the plaster of Paris mould as shown in figure 3.14 and then it is subjected to various testing.

3.5 Details of raw materials and their properties.

AA7075, h-BN and Alumina was procured from special metals Mumbai,Intelligent materials pvt. Limited Derabassi Punjab and Saveer Matrix Nano Pvt. Limited, Greater Noida Uttar Pradaesh India respectively as shown in figure 3.6 and 3.7.AA70775 rod procured had a diameter of 20 mm and its density was 2.81 g/cc.Hence its length was calculated for the required weight and accordingly was cut using power hacksaw in the appropriate size.h-BN weighing was done on the precision digital balance and collected in transparent container.Alumina was also weighed on the digital balance and collected in a small transparent container.Magnesium was procured from Gaupad manufacturers and traders in metallic ribbon form from Chandausi Uttar Pradesh.

Table 3.1 Chemical Composition of AA7075

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.13	0.42	1.42	0.12	2.42	0.21	5.4	0.11	Rest

Fig. 3.6 Alumina nano powder

Fig. 3.7 Hexagonal boron nitride (h-BN)

Table 3.2 Properties of reinforcements and base metal

Properties	h-BN	Alumina	AA7075
Colour	white	white	-
APS	40-60um	50nm	-
Young's modulus (GPa)	20-64	375 [14]	71.7 [18]
Tensile strength (MPa)	-	-	572
Thermal conductivity(W/mK)	29-96	35 [20]	196
Melting temperature (^0C)	2973 [12]	2055 [14]	477-660^0 c
Chemical stability	Very high	high	
Coefficient of thermal expansion (um/m.K)	6.6 [18]	8.4 [14]	20-100[18]
Thermal stability	Very high	Very high	-
Density (g/cc)	2.29	3.97 [14]	2.81 [14]
Hardness on Mohs scale	low	9	-

Fig. 3.8 Precision digital balance

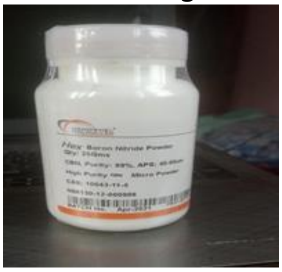


Fig. 3.9 h-BN Powder (40-60um)

3.6 Preparation of Stir casting setup

Toprepare stir casting setup, Horizontal muffle furnace available at the environmental engineering lab in the deptt of civil engineering and whirling shaft apparatus setup available at the dynamics of machine lab in the department of mechanical engineering,Muzaffarpur institute of technology, Muzaffarpur, Bihar-842003 was utilized.The device used from the Whirling shaft apparatus included speed controller ,variable speed 1/6 HP electric motor and rpm sensor (Proximity sensor).Horizontal muffle furnace was tilted by 90^o to make it vertical muffle furnace.Thereafter, 6 meter MS angle 50*50*6 procured from Agarwal's RR steel, Motihari road, Chandnichauk, Muzaffarpur, Bihar-842003 was utilized to make a suitable support for the electric motor so that to fit it just above the chamber of the muffle furnace.Special support for the electric motor was fabricated in the welding shop using SMAW portable welding m/c. During fabrication, drilling, welding cutting, machining etc. operation was performed on the special support.Support for the rpm sensor was also developed.Then special support was placed above the chamber of the muffle furnace and electric motor and rpm sensor was fitted in the support at their appropriate position. ENT rustproof 304 grade Stainless steel rod 10 mm diameter and the blade of the fruit juice mixer machine was utilized to make the stirrer. At one end of the SS rod a 6mm drilling and tapping was performed in which the SS blade tightened in the SS bolt was fitted and the other end of the SS rod was connected to the motor armature shaft via a rigid coupling. Stir casting setup is shown in figure 3.10,3.11& 3.12.

- **<u>Parts of stir casting setup</u>**

(1) Special support for electric motor
(2) 1/6 HP AC electric motor
(1) RPM sensor (Proximity sensor)
(2) Speed controller
(3) Stainless steel rod 10mm diameter
(4) Stainless steel impeller 30mm diameter
(5) Aluminium rigid coupling 10 mm bore
(6) Horizontal muffle furnace
(10) Graphite crucible (90*100)

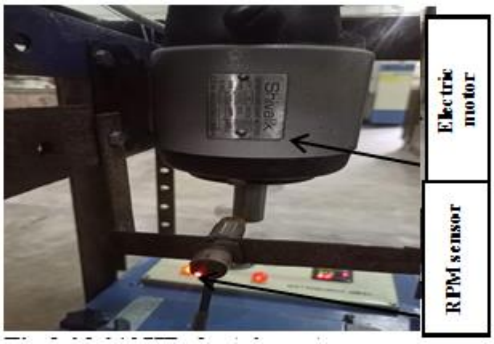


Fig. 3.10 1/6 HP electric motor and rpm sensor

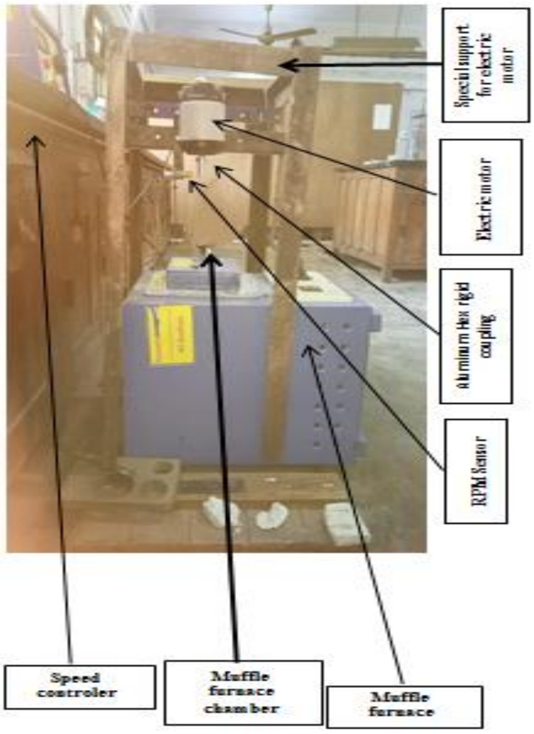


Fig 3.11 Stir casting setup assembly

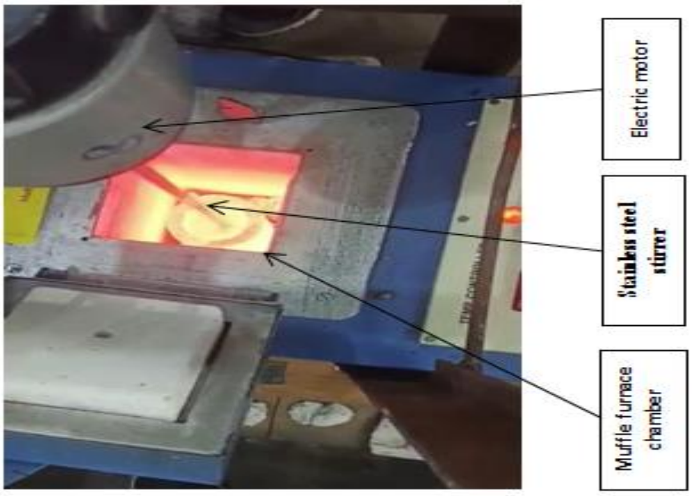


Fig. 3.12 Furnace and Temperature Indicator

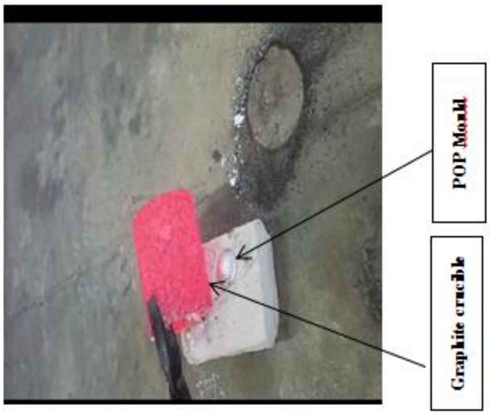
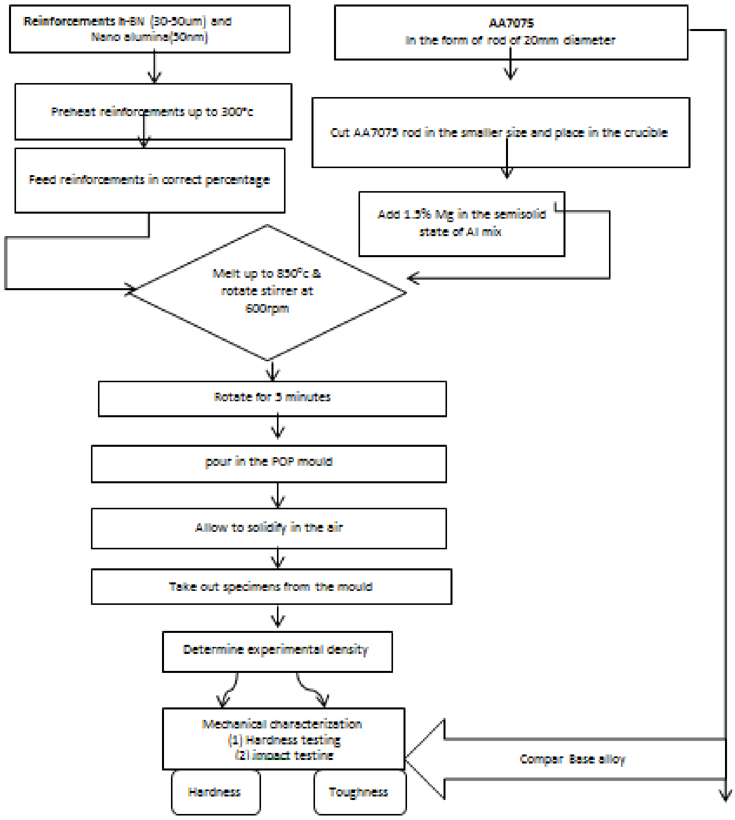


Fig. 3.13 Pouring of molten AMC

Fig. 3.14 Some Fabricated aluminium composite Sample

Fig. 3.15 Flowchart of Stir casting process.



4 RESULT AND DISCUSSION

4.1 Density and porosity

The theoretical and actual density of all the composite specimen was determined using rules of mixtures formula and Archimedes principle respectively. Theoretical density of the specimen 1 and 2 was found to be decreasing whereas theoretical density of specimen 3 and 4 was found to be increasing as shown in figure 4.2 and 4.3. Decrement in the density of specimen 1 and 2 is due to h-BN as its density is less than base metal and on the other hand increment in the density of specimen 3 and 4 is due to higher density of the Nano alumina reinforcement. Theoretical density of the specimen 4 was found to be the highest among all the specimen. Thereafter, Experimental density was determined using Archemediesprinciple(equation 3e).Overall the experimental density was found to be decreasing. Experimental density of the 4th specimen was the least.It may be due to higher porosity in it.Specimen 2 and 3 experimental density was in conformance to the theoretical density which indicates good fabrication of the composite.

Percentage porosity of thefabricated composite was computed using the equation (6a).

$$\%age\ porosity = \frac{\rho_{th-}\rho_{actual}}{\rho_{th}} * 100\ (4a)$$

Percentage porosity of the 4th specimen was found to be the highest as shown in figure 4.4 and 4.5. This may be because of the non-uniform distribution of the Nano and micron particle, poor wettability of the base metal and particle clustering and agglomeration. Poor adhesive inter-facial bond between the ceramic reinforcement and the base matrix causes the porosity in the metal matrix composite.Factors influencing the porosity are stirring speed, viscosity of the molten mix and the density difference between the reinforcement particle and the base metal melt. Preheating of the reinforcement before adding it in the melt reduces the porosity.

Fig 4.1 Digital spring balance

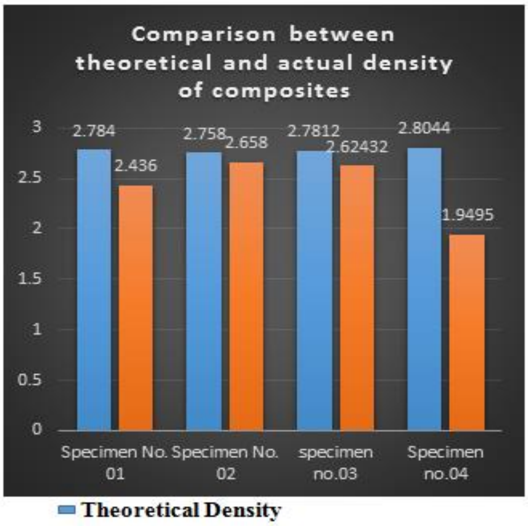


Fig. 4.2 Comparison between theoretical and experimental density of the single reinforced and hybrid reinforced composite.

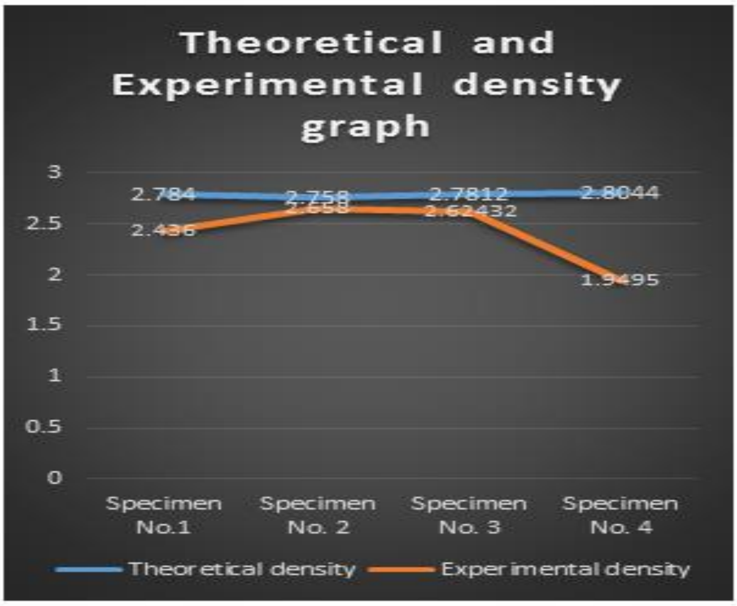


Fig. 4.3 Experimental and theoretical density graph

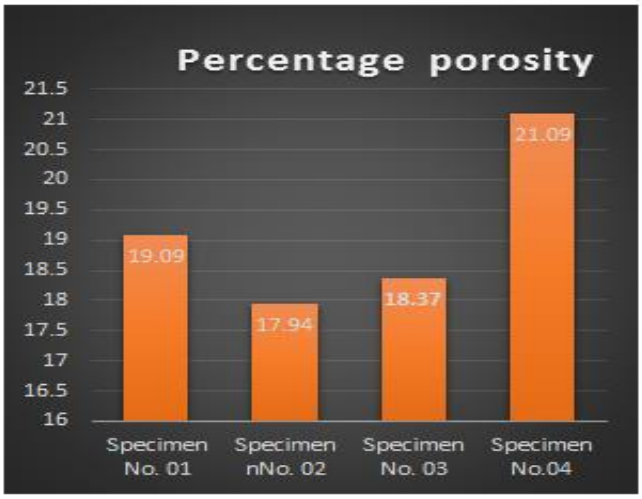


Fig. 4.4 Percentage porosity of composite specimen 1, 2, 3 and 4.

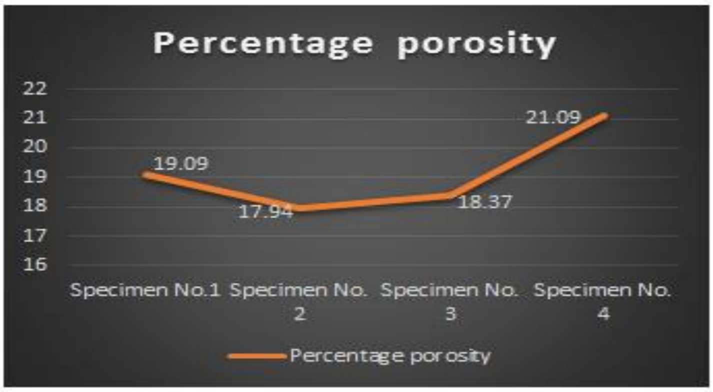


Fig. 4.5 Percentage porosity graph of specimen 1, 2, 3 and 4.

4.2 Hardness

ASTM standard ASTM E10-07 is used to determine the hardness of single reinforced composite specimen 1and 2 and hybrid reinforced composite specimen 3 and 4. It was done using Brinell hardness tester at room temperature 30^{o}c by a 10 mm steel ball indenter and a load of 500 kg was applied for 30 second.This testing was performed on Brinell hardness tester Model-DS575 at Nalanda college of engineering, Chandi, Nalanda, Bihar. For each specimen 3 readings were taken and then its average value was considered as final hardness value of the specimen.Specimen 3 was found to be having the highest hardness. This is likely to be attributed to the lower percentage porosity. In general, It is found that cooling of the stir casted composite at room temperature tend to strengthen the matrix phase because of the mismatch in the coefficient of thermal expansion of the reinforcement and the matrix. This mismatch in the CTE induces the mismatch strains at the reinforcement and the matrix interface which causes hindrance in the motion of dislocation and finally results in the higher hardness of the composite. Hardness of specimen 3 is highest as shown in figure 4.7 and 4.8.

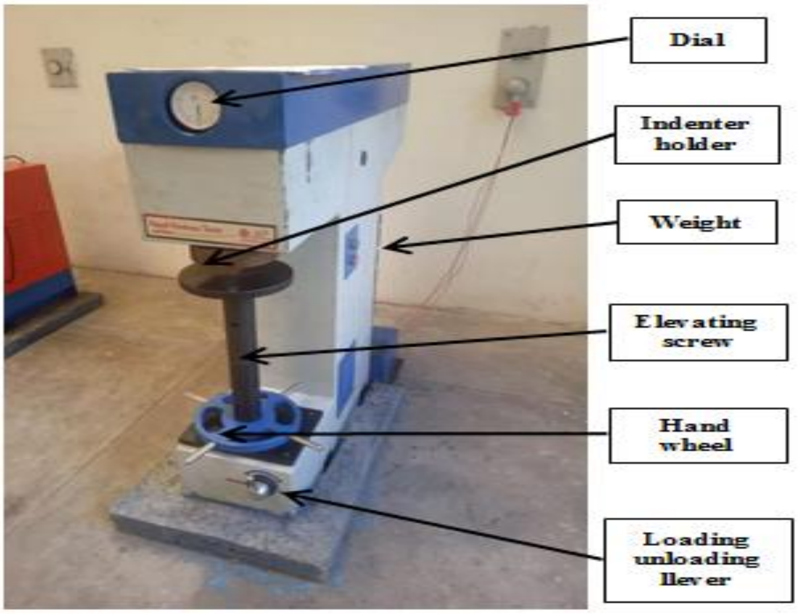


Fig. 4.6 Brinell hardness tester Model-DS575

Formula used for calculating the Brinell hardness number is

Specimen No.	Reading 1(mm)	Reading 2(mm)	Reading 3(mm)	Avg reading (mm)	BHN
1	3	4	4.8	3.93	39.6
2	3	4.5	4.8	4.1	36.2
3	3.9	3.9	3.9	3.9	40.2
4	4.5	4	4	4.167	34.9

$BHN = \frac{2P}{\pi D\{D-\sqrt{D^2-d^2}\}}$ ....(4b)

Here,
P = Applied load in kgf
D = Indenter diameter in mm
d = Indentation diameter in mm

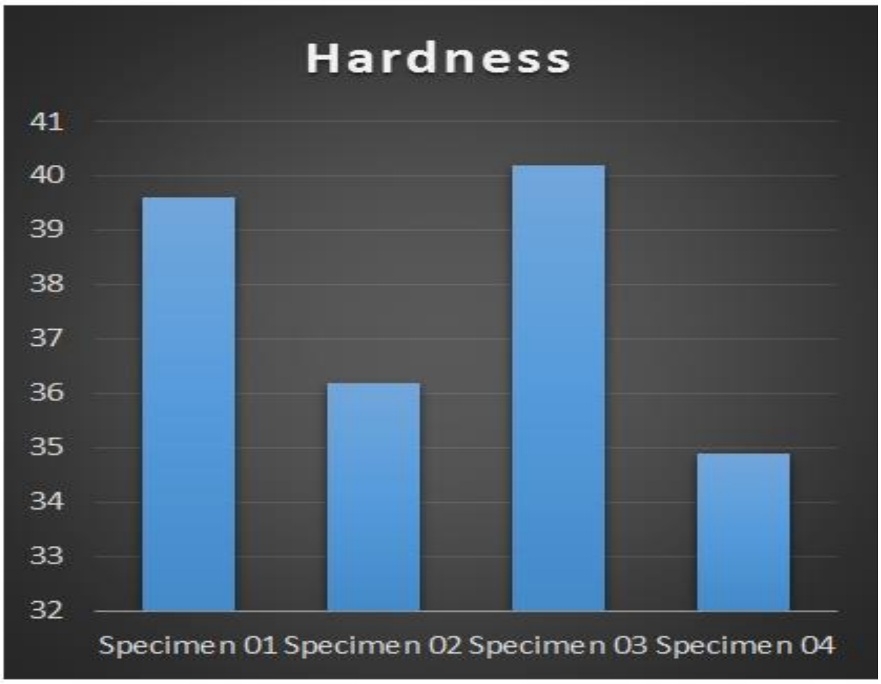


Fig. 4.7 Hardness of the composite specimen 1, 2, 3 and 4

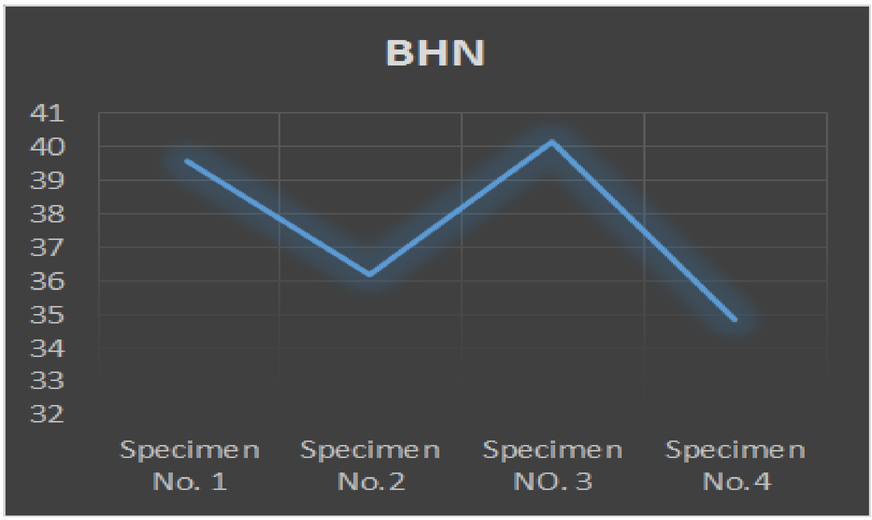


Fig. 4.8 Brinell hardness graph of the specimen 1, 2, 3 and 4

4.3 Impact strength

Impact strength of all the composite specimen was determined as per the ASTM standard ASTM E23-07a using Izod impact testing machine.The testing was performed at Nalandacollege of engineering,Chandi, Nalnda, Bihar.Standard shape and size of the specimen has been shown in the figure.The impact strength of the composite specimen was found to be increasing as compared to the base alloy AA7075.The lowest toughness was found to be for the specimen 1.The highest value of toughness was for specimen 4 as shown in figure 4.10 and 4.11.Impact strength of the material indicates the amount of energy the material can absorb dynamically.Often it is seen whenever you increase the tensile strength and the hardness impact strength automatically tends to decrease.

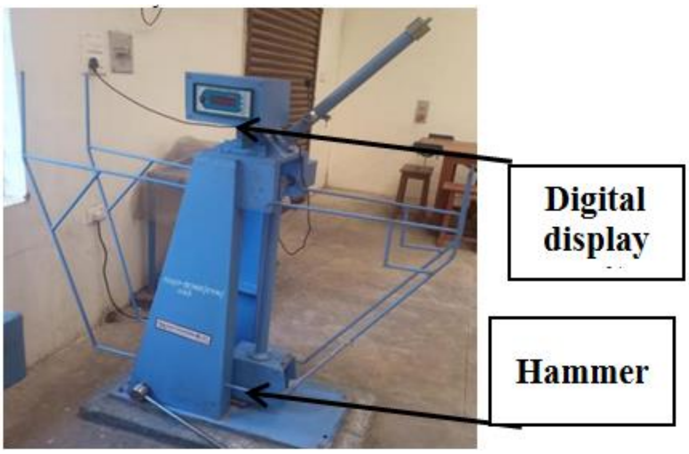


Fig. 4.9 Impact testing machine Model-DS 523

Fig. 4.10 Toughness value of all the four specimen

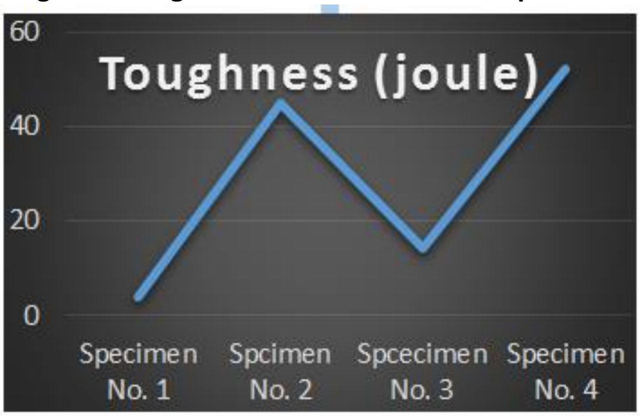


Fig. 4.11 Toughness value graph

5 CONCLUSION

1. Theoretical density of h-BN reinforced aluminum matrix composite decreased whereas that of hybrid reinforced Al composite increased as compared to base matrix density (2.81g/cc).Experimental density of all the composite specimen was found to be decreasing as compared to its theoretical density.Experimental density of the specimen 4 was observed to be the least whereas that of specimen 2 was observed to be the highest.Percentage porosity of the specimen 4 was the highest in all the specimen and it was the least for specimen 3.

2. Percentage porosity of specimen 4 is highest at 21.09 and lowest for specimen 2 at 17.94.
3. Hardness of the specimen 1, 2, 3 and 4 was 39.6 BHN, 36.2 BHN, 40.2 BHN, 34.9 BHN respectively.Hardness of the specimen 3 was the highest at 40.2 BHN whereas that of the specimen 4 was the least at 34.9 BHN.With the increment in the percentage of h-BN from 5% to 10% Brinell hardness decreased from 39.6 BHN to 36.2 BHN.The Brinell hardness of the specimen 3 with 10% h-BN and 2% alumina was the highest at 40.2 BHN.Increment in the percentage of alumina from 2% to 4% decreased the hardness value by 13.18%.
4. Toughness value of the specimen 1, 2, 3, 4 was tested to be 3.85 joule, 45 joule, 14.15 joule, 52.46 joule respectively.Toughness of the specimen 4 with 10% h-BN and 4 % alumina was found to be the highest at 52.46 joule whereas that of the specimen 1 with 5% h-BN was found to be the least at 3.85 joule.There was a general trend of increment in the toughness value except specimen 3 with 5% h-BN and 2% alumina whose toughness decreased.

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