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Research paper

Study of hardness and tensile strength of Aluminium-7075 percentage varying reinforced with graphite and bagasse-ash composites

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Abstract

Waste sugarcane bagasse-ash and graphite utilizing as reinforcement in fabricating of an aluminium alloy (Al-7075) based matrix hybrid composites. The aluminium matrix hybrid composites have been fabricated by stir-casting method at 750 °C. Casting was developed in circular metal mould having 5 circular slots of diameter of 21 mm and length of 250 mm. Adding bagasse-ash with varying reinforcement of three cases, in first case 2% constant with varying graphite 1%, 3%, and 5%, in second case 4%, and in third case 6% constant with varying same graphite percentage. The effect of the reinforcement has been performed through various mechanical tests. The mechanical properties measuring such as Brinell hardness and tensile strength of both the samples have been prepared as per the ASTM E23 and E8 standards. Results give out that there will be greater effect of reinforcing different bagasse-ash in aluminium alloy matrix hybrid composites. In the third case more enhanced mechanical properties have been achieved as compared to case one and two of bagasse–ash combination. It shows that the selection of bagasse-ash as reinforcement has one of the most significant criteria for the fabrication of aluminium matrix hybrid composites.

Keywords: Al matrix composites; Bagasse-ash; Graphite; Mechanical properties

1. Introduction

Recently hybrid composites are more popular and cover more than one material property. Attempts were made to explore the possible use of composites having hard and soft reinforcements in several technological applications. The addition of the reinforcement enhances the mechanical properties of aluminium based composite, when compared to the matrix alloy. However, addition of any hard reinforcement to aluminium reduces the corrosion resistance, electrical conductivity and surface finish, etc. Bagasse ash (BA) is rich in SiC, which helps to increasing the strength of aluminium such as high hardness, low coefficient of thermal expansion, high wear resistant and also good mechanical properties including high strength, thermal conductivity, etc. [1]. Graphite is considered as the most important constituent for solid lubrication of the ceramic reinforcement composites [2,3].

2. Literature review

The mechanical and physical behaviour for metal matrix composites (MMCs) shows variation of dislocations in composites in different states, such as liquid, solid and solid–liquid state [4]. Studies were carried out to understand the micro structural behaviour of the proposed composite material based on interface energy estimation process. It was observed that porosity in the cast composites damages the mechanical properties and suitable mould design was found efficient in controlling the damage [5]. Tribological and mechanical properties of Al-7075 alloy with graphite (Gr) reinforcement composites were investigated. Self lubricating properties and dry sliding condition were analysed on added reinforcement content of graphite with varying wt.% as 5, 10, 15 and 20. It was observed that the average coefficient of friction is decreases with increasing of graphite content and mechanical properties of composites decrease with increasing graphite percentage as compared with conventional alloy. 5% of graphite reinforcement shows most prominent results. [2]. Further investigation on

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influence of Gr for wear behaviour of Al 7075/Al_2O_3/5 wt.% Gr hybrid composite (2, 4, 6 and 8 wt.% of Al_2O_3) found that the ceramic phase weight percentage increased and finally suggested the wear behaviour of hybrid composites contains graphite that show superior resistance to wear [3]. After Synthesization and mechanical behaviour of Al–7Si reinforced with situ TiB_2, they have analysed the worn out surface and suggested that at lower loads ploughing and adhesion are predominant and at higher loads delamination is predominant [5]. Characterization of Al-7075 unreinforced and reinforced (7wt% of SiC and 3wt% Gr hybrid composite) were used to understand the tribological properties of the proposed materials. Unlubricated pin -on -disc wear testing machine at loads 20-60N, speed 2–6 m/s and sliding distances 2000–4000 m was used to know the specific wear rate and observed that the value of the hybrid composite is lower than that of the unreinforced Al-7075 alloy. Worn out surface is observed by using scanning electron microscope and was found that the effect of load on specific wear rate is most significant factor followed by sliding speed and sliding distance [6]. The modified mechanical and tribological properties of Al–SiC–Gr hybrid composites by using both reinforcement with equal weight fraction are explained as per the design of experimental technique wear were increased beyond the 7.5 wt% of reinforcement [7]. Study emphasized that dry sliding wear behaviour of Al reinforced with SiC and B_4C both at 5wt% hybrid composite by using pin on disc tribo-meter. They used Focused on Ion Beam (FIB) technique to characterize the tribological layers that formed at the worn out surfaces of composites and discussed in Results section the hybrid composites that enhanced wear resistance with small quantity of SiC and B_4C is achieved by the particles effect of reinforcement [8]. Studies on technical difficulties of uniform reinforcement distribution for SiC/Al alloy MMCs were discussed. Wettability between substances was found good and low porosity of material was achieved [9].

3. Experimental details

3.1. Material selection

3.1.1. Matrix material

Al7075 alloy is chosen as matrix material owing to its wide application in many engineering sectors including automotive and aerospace sectors. Further, this alloy exhibits good strength and formability. Table 1 shows the chemical composition of Al7075 alloy used in this study.

Table 1
Material composition in percentage.

Sl. No.	AL 7075	Graphite	Bagasse ash
1	97	1	2
2	95	1	4
3	93	1	6
4	95	3	2
5	93	3	4
6	91	3	6
7	93	5	2
8	91	5	4

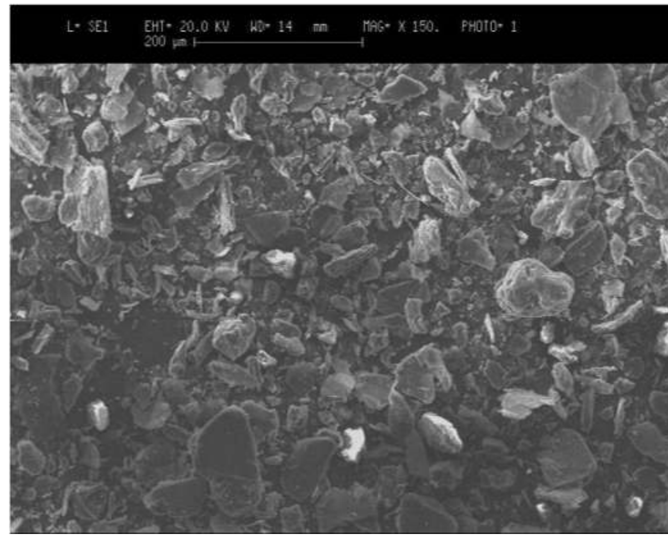


Fig. 1. SEM of graphite particles.

3.2. Reinforcement

3.2.1. Mater alloys for synthesis of bagasse ash and graphite particles

Commercially available bagasse ash (partial size 0.1–100 μm [1]) and graphite reinforcements were used for preparing the composites with Al7075 matrix material. The chemical composition of master alloys used in the present study is reported in Table 1. Both graphite and Al7075 alloys were procured from M/s Fen fee Metallurgicals, Bangalore, India, and bagasse ash is found in Pandavapura sugar cane factory.

3.2.2. Graphite

Fig. 1 shows the scanning electron micrograph of graphite particles used in this study. The particles are irregular in shape and size and is in the range of 20–60 μm. Graphite possesses the properties such as high tensile strength, low density, low friction and wear resistance, and high thermal conductivity.

3.3. Composite preparation

Hybrid Al7075-Gr-bagasse ash composites were fabricated by stir casting technique using 6 kw electrical resistance furnace. Fig. 2 shows photograph of casting furnace used in the present study. Table 2 shows the specifications of meting furnace. Three types of composites were prepared as reported below.

1. Al7075 alloy + 2%BA + 1%Gr
2. Al7075 alloy + 4%BA + 1%Gr
3. Al7075 alloy + 6%BA + 1%Gr
4. Al7075 alloy + 2%BA + 3%Gr
5. Al7075 alloy + 4%BA + 3%Gr
6. Al7075 alloy + 6%BA + 3%Gr
7. Al7075 alloy + 2%BA + 5%Gr
8. Al7075 alloy + 4%BA + 5%Gr
9. Al7075 alloy + 6%BA + 5%Gr

These compositions were melted in the furnace at temperature of 750 °C. The molten alloy was agitated by use of mechanical stirrer rotating at a speed of 200–300 rpm for

Fig. 2. Photograph of aluminium melting furnace.

duration of 15 minutes. The composites were maintained at a temperature of 750 °C to melt and were then poured into metallic moulds.

3.4. *Brinell hardness test*

Brinell hardness tests were carried out on samples of both unreinforced alloy and its composites, by applying 50 grams of load for a period of 10 seconds using Brinell hardness tester as per ASTM E10 standard test method. Meta test Model SE-B3000-O was employed for hardness test in Advanced Metallurgical Laboratory, Peenya, Bangalore.

Table 2
Specifications of aluminium meting furnace.

Particulate	Description
Temperature	12 000 °C
Melting capacity	5 kg
Heating element	Silicon carbide (6Nos)
Controller	Thyristerized PID Temperature – 6 Kw with power pack
Crucible	Graphite
Power	230 volts 6 kw.
Stirrer	50–1000 rpm Remi made

Fig. 3. Universal testing machine.

3.5. *Tensile test*

Tensile tests of developed hybrid composites were evaluated using TUE-C-400 tensile testing machine as per ASTM A370 standards at m/s; the test was conducted in Advanced Metallurgical Laboratory, Peenya, Bangalore. The photograph of TUE-C-400 tensile testing equipment is shown in Fig. 3 and its salient features of the equipment are Capacity IS 40T and IS-1828-991. Constant strain rate of 0.5 mm/min was adopted during all the tests. Ultimate tensile strength and percentage elongation were evaluated.

4. Results and discussion

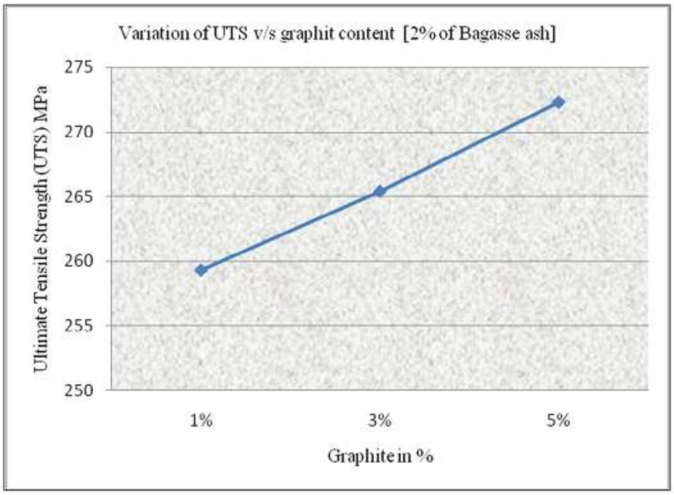
Experimental results of mechanical properties represented in Table 3 with respect to different compositions, ultimate tensile strength (UTS in MPa), Brinell hardness number (BHN), percentage of elongation (%) and yield strength (MPa).

4.1. *Ultimate tensile strength of* composites *with variation of* graphite

Fig. 4(a) shows as graphite is increased, UTS also increases gradually while 2% of bagasse ash is kept constant. Fig. 4(b) shows as graphite is increased, UTS also increases gradually as 4% of bagasse ash is kept constant. Fig. 4(c) shows as graphite

Table 3
Experimental results of mechanical properties.

Experiments	Composition		UTS (MPa)	BHN	Percentage of elongation (%)	Yield strength (MPa)
	Graphite	Bagasse ash				
1	1%	2%	259.3	87.3	6.7	176.84
2	3%	2%	265.4	92.4	6.4	183.83
3	5%	2%	272.3	94.3	5.8	197.05
4	1%	4%	267.3	87.7	6.3	180.68
5	3%	4%	283.4	94.2	5.9	188.56
6	5%	4%	290.3	95.4	5.2	199.29
7	1%	6%	294.2	88.3	5.9	184.93
8	3%	6%	296.3	95.4	5.4	190.53
9	5%	6%	299.4	99.6	4.9	200.86



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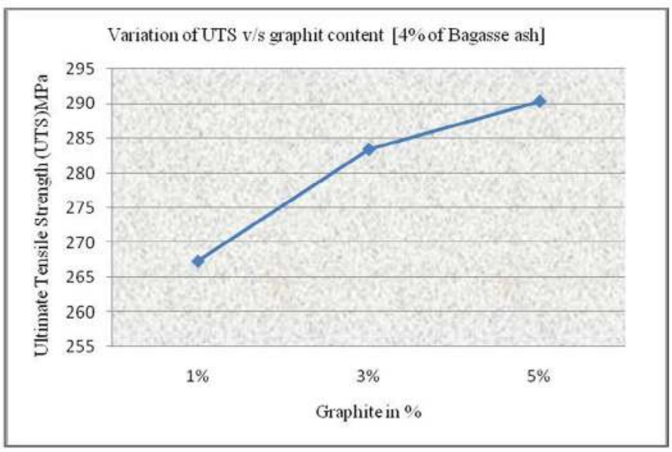

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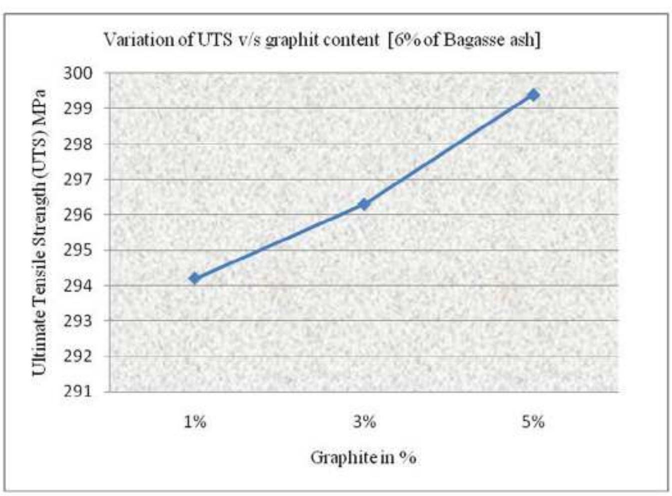

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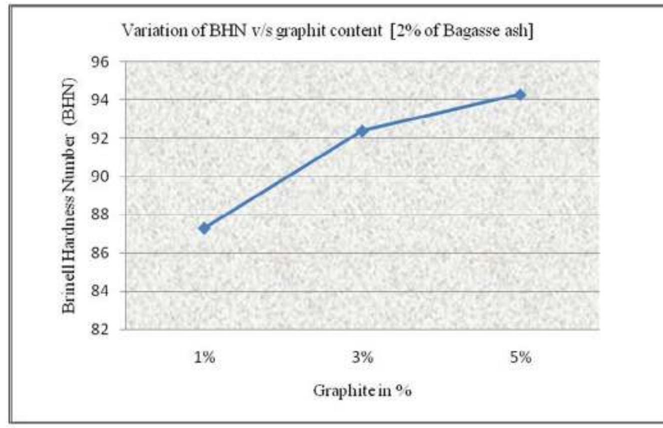
Fig. 4. Ultimate tensile strength of *composites* with variation of *graphite*. (a) Variation of UTS v/s graphite content (2% of bagasse ash), (b) variation of UTS v/s graphite content (4% of bagasse ash) and (c) variation of UTS v/s graphite content (6% of bagasse ash).



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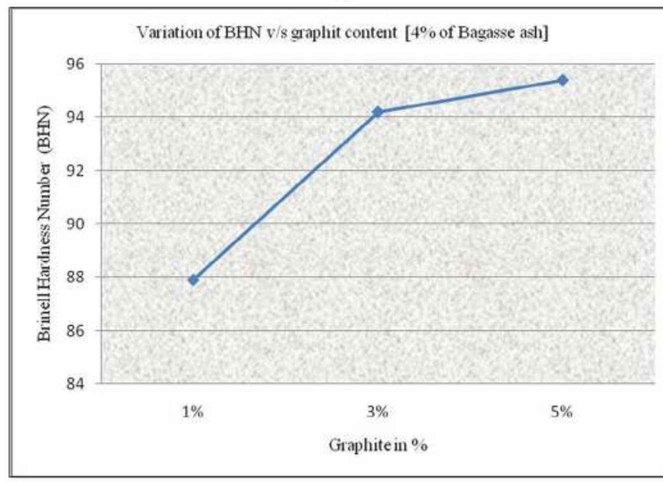

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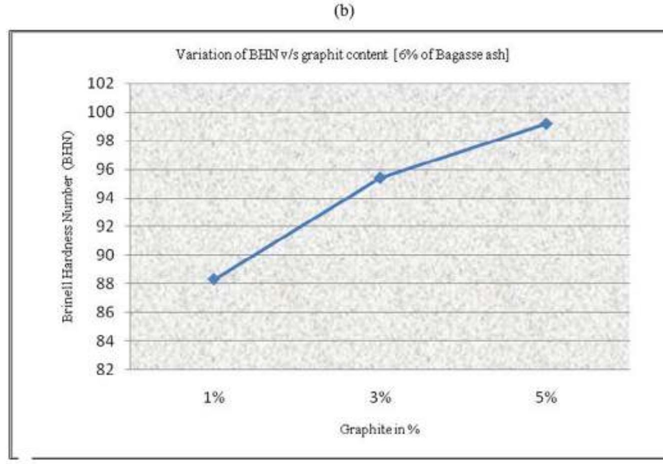

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Fig. 5. Effect of graphite on hardness of composites. (a) Variation of BHN v/s graphite content (2% of bagasse ash), (b) variation of BHN v/s graphite content (4% of bagasse ash) and (c) variation of BHN v/s graphite content (6% of bagasse ash).

is increased, UTS also increases gradually whereas 6% of bagasse ash is kept constant as represented in Table 4.

4.2. Effect of graphite on hardness of composites

Fig. 5(a) shows as graphite increases, BHN also increases gradually while 2% of bagasse ash is kept constant. Fig. 5(b)

Table 4
Ultimate tensile strength of *composites* with variation of *graphite*.

Experiments	Composition		UTS (MPa)
	Bagasse ash	Graphite	
1	2%	1%	259.3
2	2%	3%	265.4
3	2%	5%	272.3
4	4%	1%	267.3
5	4%	3%	283.4
6	4%	5%	290.3
7	6%	1%	294.2
8	6%	3%	296.3
9	6%	5%	299.4

Table 6
Yielding strength of *composites* with variation of *graphite*.

Experiments	Composition		Yield strength (MPa)
	Bagasse ash	Graphite	
1	2%	1%	176.84
2	2%	3%	183.83
3	2%	5%	197.05
4	4%	1%	180.68
5	4%	3%	188.56
6	4%	5%	199.29
7	6%	1%	184.93
8	6%	3%	190.53
9	6%	5%	200.86

shows as graphite is increased, BHN also increases gradually as 4% of bagasse ash is kept constant. Fig. 5(c) shows as graphite is increased BHN also increased gradually with 2% of bagasse ash is kept constant. Confidence interval represented in Table 5, the calculation carried as follows value of the *i*th sample (X_i), Mean [$M = (\Sigma X_i)/N$], N is Sample Size, Standard deviation [$SD = \{\Sigma(X_i - M)\}^2/(N-1)]^{1/2}$, Standard Error [$SE = SD/(N)^{1/2}$] and the upper and lower limits of confidence interval [95% $CI = M \pm (1.96 \times SE)$] for the hybrid composites [10]. The confidence interval has shown BHN increased with increasing in reinforcement.

4.3. *Yielding strength of* composites *with variation of* graphite

Fig. 6(a) shows as graphite is increased, yielding strength also increases gradually as 2% of bagasse ash is kept constant. Fig. 6(b) shows as graphite is increased, yielding strength also increases gradually whereas 4% of bagasse ash is kept constant. Fig. 6(c) shows as graphite is increased, yielding strength also increases gradually while 2% of bagasse ash is kept constant as represented in Table 6.

4.4. *Ultimate tensile strength of* composites *with variation of bagasse ash*

Fig. 7(a) shows as bagasse ash is increased, UTS also increases gradually as 1% of graphite is kept constant. Fig. 7(b) shows as bagasse ash is increased, UTS also increases gradually whereas 3% of graphite is kept constant. Fig. 7(c) shows as bagasse ash is increased, UTS also increases gradually while 5% of graphite is kept constant as represented in Table 7.

Table 7
Ultimate tensile strength of *composites* with variation of bagasse Ash.

Experiments	Composition		UTS (MPa)
	Graphite	Bagasse ash	
1	1%	2%	259.3
2	1%	4%	267.3
3	1%	6%	294.2
4	3%	2%	265.4
5	3%	4%	283.4
6	3%	6%	296.3
7	5%	2%	272.3
8	5%	4%	290.3
9	5%	6%	299.4

4.5. *Effect of bagasse ash on hardness of composites*

Fig. 8(a) shows as bagasse ash is increased, BHN also increases gradually while 1% of graphite is kept constant. Fig. 8(b) shows as bagasse ash is increased, BHN also increases gradually whereas 3% of graphite is kept constant. Fig. 8(c) shows as bagasse ash is increased, BHN also increases gradually as 5% of graphite is kept constant. Confidence interval is represented in Table 8; the calculation carried as follows the value of the *i*th sample (X_i), Mean [$M = (\Sigma X_i)/N$], N is sample size, standard deviation [$SD = \{\Sigma(X_i - M)\}^2/(N-1)]^{1/2}$,

Table 5
Effect of graphite on hardness of composites.

Experiments	Composition		BHN-Hardness			BHN Mean (M)	Standard deviation (SD)	Standard error, SE	95% confidence interval	
	Bagasse ash	Graphite	1	2	3				Minimum	Maximum
1	2%	1%	87	89	86	87.3	0.494974	0.234514	86.8403	87.7596
2	2%	3%	93	91	93	92.4	0.141421	0.081661	92.2399	92.5600
3	2%	5%	95	94	94	94.3	0.070710	0.040824	94.2199	94.3800
4	4%	1%	88	89	86	87.7	0.070710	0.040824	87.6199	87.7800
5	4%	3%	94	95	94	94.3	0.070710	0.040824	94.2199	94.3800
6	4%	5%	96	95	95	95.4	0.141421	0.081661	95.2399	95.5600
7	6%	1%	88	88	89	88.3	0.070710	0.040824	88.2199	88.3800
8	6%	3%	95	95	96	95.4	0.141421	0.081661	95.2399	95.5600
9	6%	5%	99	101	99	99.6	0.141421	0.081661	99.4399	99.7600

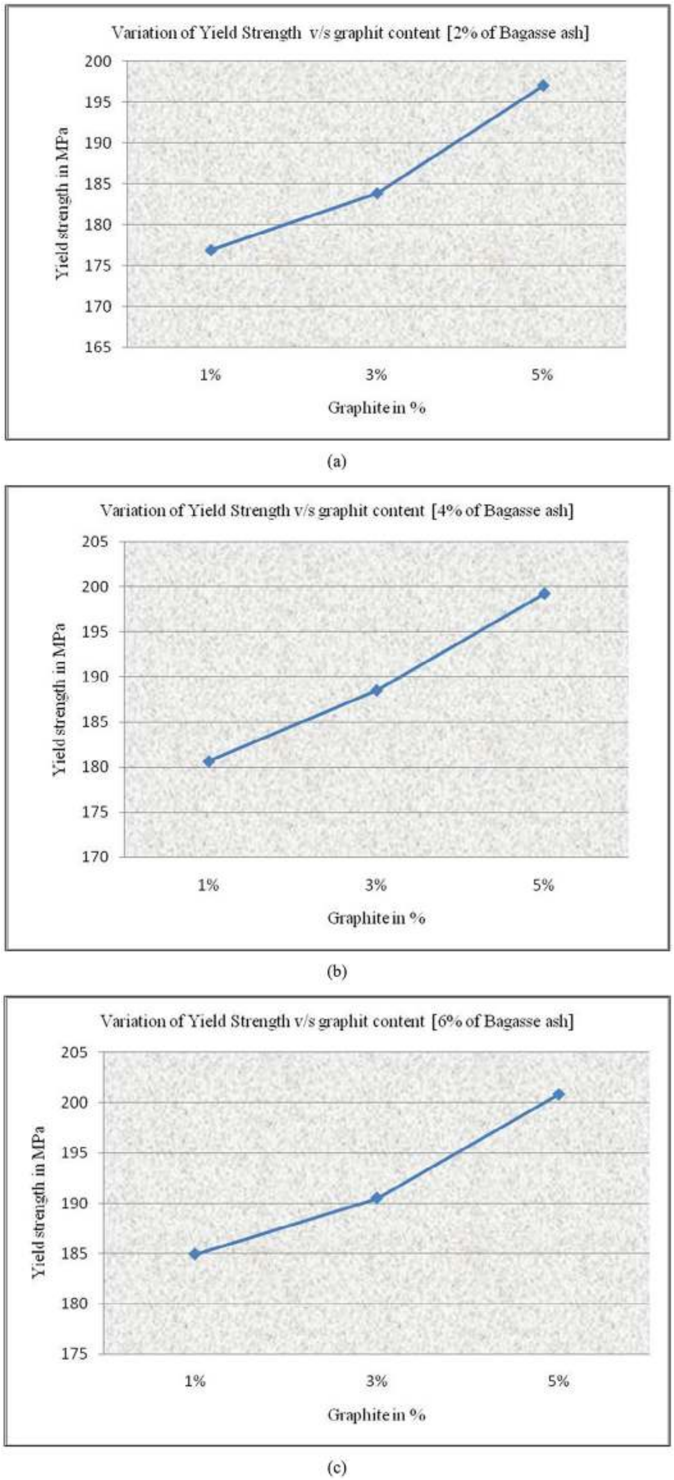


Fig. 6. Yielding strength of *composites* with variation of *graphite*. (a) Variation of yielding strength v/s graphite content (2% of bagasse ash), (b) variation of yielding strength v/s graphite content (4% of bagasse ash) and (c) variation of yielding strength v/s graphite content (6% of bagasse ash).

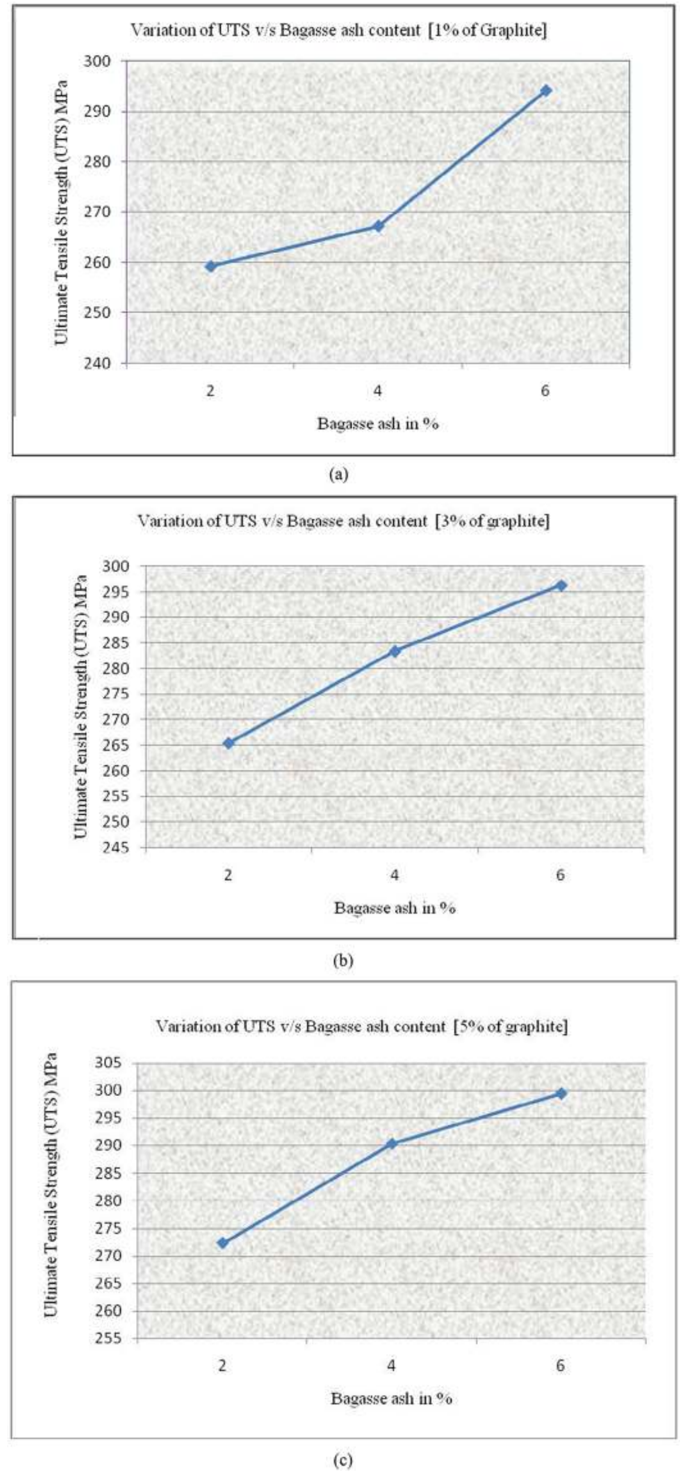
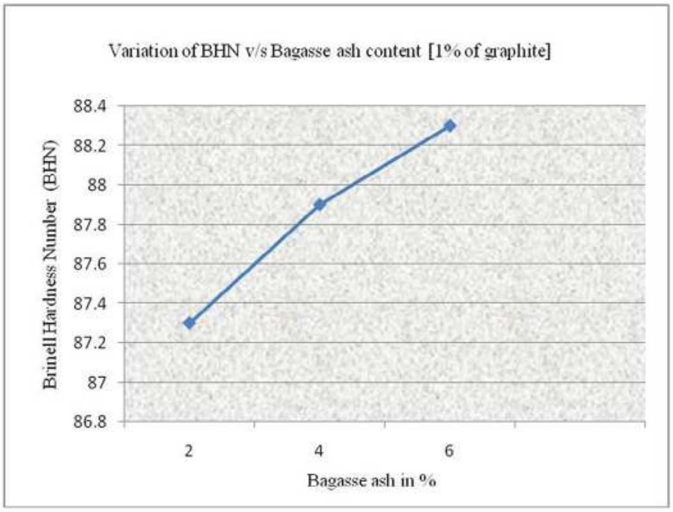


Fig. 7. Ultimate tensile strength of *composites* with variation of bagasse ash. (a) Variation of UTS v/s bagasse ash content (1% of graphite), (b) variation of UTS v/s bagasse ash content (3% of graphite) and (c) variation of UTS v/s bagasse ash content (5% of graphite).

standard error [$SE = SD/(N)^{1/2}$] and the upper and lower limits of confidence interval [$95\%\ CI = M \pm (1.96 \times SE)$] for the hybrid composites [10]. The confidence interval has shown BHN increased with increasing in reinforcement.

4.6. *Yielding strength of* composites *with variation of bagasse ash*

Fig. 9(a) shows as bagasse ash is increased, yielding strength also increases gradually as 1% of graphite is kept constant.



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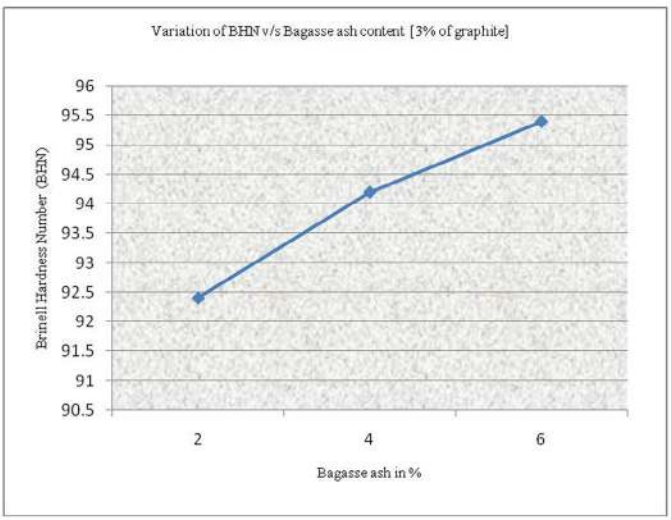

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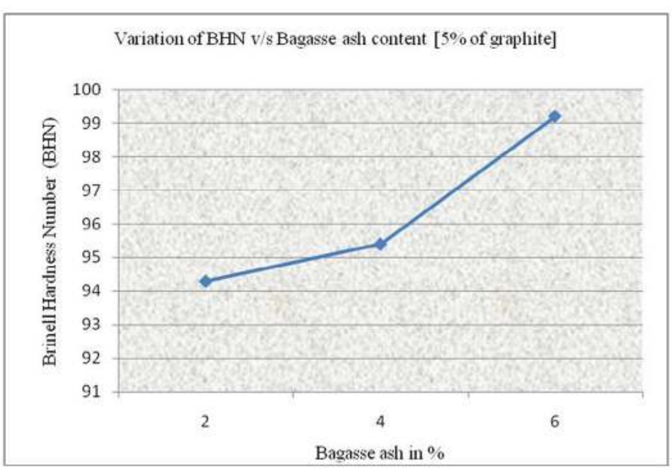

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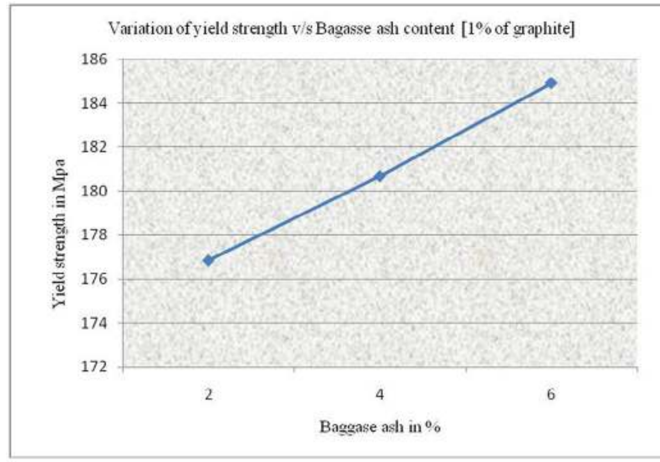
Fig. 8. Effect of bagasse ash on hardness of composites. (a) Variation of BHN v/s bagasse ash content (1% of graphite), (b) variation of BHN v/s bagasse ash content (3% of graphite) and (c) variation of BHN v/s bagasse ash content (5% of graphite).



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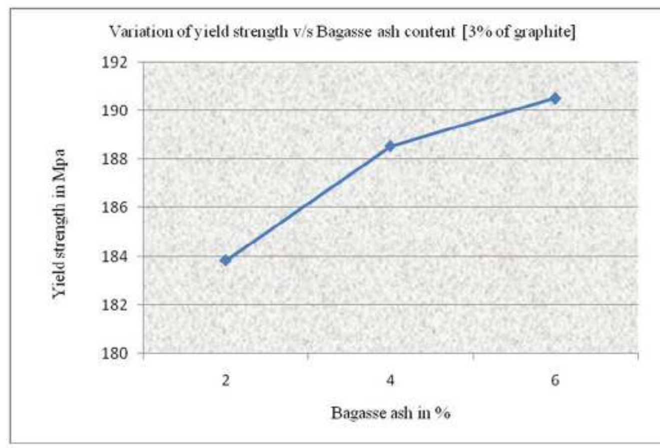

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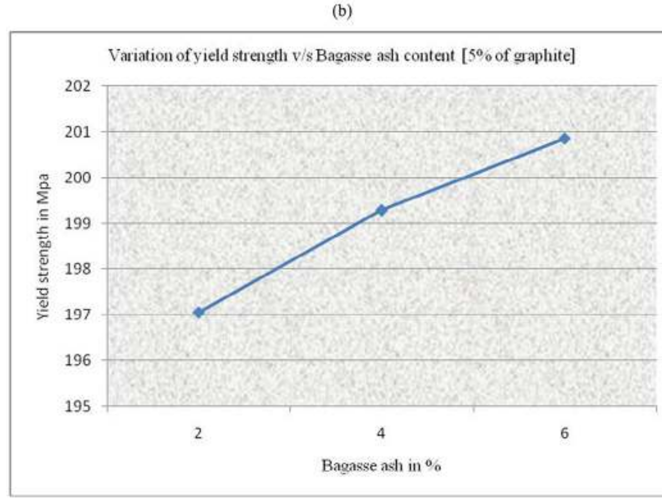

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Fig. 9. Yielding strength of *composites* with variation of bagasse ash. (a) Variation of yielding strength v/s bagasse ash content (1% of graphite), (b) variation of yielding strength v/s bagasse ash content (3% of graphite) and (c) variation of yielding strength v/s bagasse ash content (5% of graphite).

Fig. 9(b) shows as bagasse ash is increased, yielding strength also increases gradually whereas 3% of graphite is kept constant. Fig. 9(c) shows as bagasse ash is increased, yielding strength also increases gradually while 5% of graphite is kept constant as represented in Table 9.

Table 8
Effect of bagasse ash on hardness of composites.

Experiments	Composition		BHN-Hardness			BHN Mean (M)	Standard deviation (SD)	Standard error, SE	95% confidence interval	
	Graphite	Bagasse ash	1	2	3				Minimum	Maximum
1	1%	2%	87	89	86	87.3	0.494974	0.234514	86.8403	87.7596
2	1%	4%	88	89	86	87.7	0.070710	0.040824	87.6199	87.7800
3	1%	6%	88	88	89	88.3	0.070710	0.040824	88.2199	88.3800
4	3%	2%	93	91	93	92.4	0.141421	0.081661	92.2399	92.5600
5	3%	4%	94	95	94	94.3	0.070710	0.040824	94.2199	94.3800
6	3%	6%	95	95	96	95.4	0.141421	0.081661	95.2399	95.5600
7	5%	2%	95	94	94	94.3	0.070710	0.040824	94.2199	94.3800
8	5%	4%	96	95	95	95.4	0.141421	0.081661	95.2399	95.5600
9	5%	6%	99	101	99	99.6	0.141421	0.081661	99.4399	99.7600

4.7. Discussion

Al7075–bagasse ash–Gr composites were developed by using stir-casting method. The investigation results are tabulated (Table 3) and shows increase in mechanical properties when both graphite and bagasse ash reinforcements are increased. Hence gradually increasing in hardness, ultimate tensile strength and yielding strength when both reinforcements are increased. Also 95% confidence interval has shown increase in BHN with increasing in reinforcement. If only Bagasse ash reinforcement is used increase in properties is achieved but major loss of material takes place at the time of casting due to maximum slag formation (due to the presence of carbon and oxygen) [11], to reduce this desirable effect graphite is used for more enhancement in mechanical properties, which has resulted in reduced slag formation and less loss of material.

5. Conclusions

Al7075–bagasse ash–Gr hybrid composite specimens are prepared using stir casting technique. Hardness of composites is gradually increased with increasing the reinforcement in the base alloy. The 95% confidence interval has shown BHN increased with increasing in reinforcement. Ductility of the composites decreases with increasing content of reinforcement in the matrix alloy. Resultant Al7075–bagasse ash–graphite hybrid composite possess ultimate tensile strength and yielding strength increased gradually with increasing in reinforcement.

Table 9
Yielding strength of *composites* with variation of bagasse ash.

Experiments	Composition		Yield strength (MPa)
	Graphite	Bagasse ash	
1	1%	2%	176.84
2	1%	4%	180.68
3	1%	6%	184.93
4	3%	2%	183.83
5	3%	4%	188.56
6	3%	6%	190.53
7	5%	2%	197.05
8	5%	4%	199.29
9	5%	6%	200.86

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