Characterization of Aluminium Hybrid Metal Matrix Composites

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Research Article

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Abstract

Hybrid Metal Matrix composites have emerged as an epicentre of material research due to their vast applications and a wide array of reinforcement combinations. In this experiment, a hybrid Aluminum metal matrix composite has been fabricated by the double (two steps) stir casting method. The present study evaluates the mechanical properties of AA6061 in varying concentrations of silicon carbide with 5, 10, 15 and 20 weight percent (wt.%), in addition to Rice Husk Ash, Tungsten Carbide and Alumina Powder which are in a fixed quantity. Mechanical properties have been evaluated by conducting an Impact test, Hardness test, Flexural test and Tensile Strength. In addition, micrograph Images have been incorporated for analysing the microstructural characteristics of the Hybrid AMMC. It was observed that MMC properties such as Tensile Strength, Yield Strength, Hardness, Impact Strength were highest at 20 wt.% SiC. Hence, it was inferred that 20wt% SiC was an appropriate concentration for applications in automobile and aerospace pertaining to its augmented mechanical properties. In conclusion, prospects of future research are also explored.

1. Introduction

Materials for automobile and aerospace applications require good mechanical and thermal properties. Pertaining to this ever increasing demand for materials with enhanced Hardness, tensile strength, along with few more properties, Metal Matrix Composites have evoked a keen interest in recent times for potential applications in aerospace and automotive industries owing to their superior strength to weight ratio and high temperature resistance. Metal matric composites can be defined as base metals or matrix materials which are reinforced with other material primarily ceramic, organic material or another metal [1]. Reinforcements are incorporated into the metal matrix in the form of fibres or particulates to augment mechanical properties such as conductivity, and tensile strength of the base material.

Owing to its high thermal conductivity and light weight, Aluminium alloy is highly preferred for manufacturing automobile components such as parts of chassis, cylindrical block, and also in applications requiring high endurance such as car brakes; car clutches to name a few [2]. In addition, Aluminium alloys are also widely used in aerospace components and aerial vehicle bodies. Attributing to their vast manufacturing possibilities, metal matrix composites with aluminium as the base metal are widely being fabricated and tested. These composites, called Aluminium Metal matrix composites (AMMC) have gained unprecedented popularity amongst researchers. Aluminium Hybrid Matrix composites encompass Aluminium metal matrix composites with two or more reinforcements. Hybrid refers to the higher number of reinforced materials in varying or constant proportions [3]. The hybrid phase is fabricated to achieve augmented mechanical properties and/or thermal properties that were previously impossible with single reinforcement [4–7]. The reinforcement selection is based on its work temperature stability in conjugation with its non-reactive tendency towards the base metal. By virtue of these properties, SiC and Al_2O_3 are the most widely utilised reinforcement in conjugation with their ability to enhance wear resistance, hardness and tensile strength [8]. In addition to the reinforcement used, dimensional parameters of the reinforced material such as size, shape, and distribution in the phase matrix, their volume fraction and homogeneity consequently govern the mechanical properties of the fabricated composite [9]. Literature review further elucidated the utilisation of ash reinforcements such as Fly Ash [10–13], Coconut coir Ash [10], Bamboo leaf ash [14], Bagasse ash [15]. It was concluded through these researches that the addition of ash affected significant mechanical characteristics such as density, hardness and porosity.

As Hybrid Aluminium metal composites constitute of more than one reinforcement material, a significantly wide range of secondary reinforcements can be used to elevate the mechanical properties of the base matrix [16–19]. In their experiment, Reddy et al. (2017) utilised Boron Carbide in varying proportions in conjugation with Silicon Carbide. They observed an increase in Tensile strength with B_4C although the flexural and impact strength decreased with the increasing percentage of Boron Carbide [20]. Other researchers like Kumar et al. (2020) [21], Babu et al. (2020) [22], Kumar et al. (2020) [23] and Venkatesh (2021) [24] used MoS_2 (Molybdenum Disulphide), Graphite (Gr), Titanium Carbide (TiC) and Kaoline respectively in conjugation with Silicon Carbide in Aluminium base matrix to fabricate Hybrid AMMC. It was observed that Hybrid AMMC showcased augmented mechanical performance in comparison with AMMC with single reinforcement.

The intermolecular interaction of the reinforcement with the phase metal is a crucial parameter to be considered while proposing a composite. Achieving a uniform distribution of reinforcement within the matrix is one such challenge, which directly affects the properties and quality of composite material [25]. Pertaining to this factor, the process used to fabricate the composite plays a crucial role in determining it mechanical and thermal performance. Stir casting is a widely used commercially to fabricate Metal Matrix composites by virtue of its ease and cost effectiveness [26]. Addressing the concerns of proper distribution of reinforced material in the matrix along with efficient bonding of different phases of the composite, stir casting has been accepted as a particularly promising route. During fabrication of a MMC by the stir casting method, prominent factors such as uniform distribution of the reinforced material, wettability between the different materials, porosity in the cast matrix composites, and chemical reactions between the reinforcement material and the matrix alloy require considerable attention [27–30]. To achieve optimised fabrication by successfully controlling these factors, advancement to the conventional Stir Casting method, known as the Two-Step/ Double Step Stir casting method, is extensively explored and used. Two step stir casting enhances the fabrication process by preheating the reinforcements and introducing them in semi-solid matrix which is later re-heated till melting point [31, 32]. Figure 1 elucidates flow chart comparing the conventional Stir casting method (a) and Two Step Stir casting method (b).

After an extensive literature review, it was observed that not much literature is present on Aluminium hybrid metal matrix incorporating Rice Husk Ash. In the present work, two step stir casting method has been employed for dispersion of SiC, Al_2O_3, Rice Husk Ash and Tungsten carbide (WC) particles in Al matrix. Literature is present on Aluminium Hybrid Metal Matrix with Alumina and Carbon [33] and Tungsten Carbide with Silicon Carbide [34], but not much has been explored with both Alumina and

Tungsten Carbide with Silicon Carbide. In addition, mechanical and microstructural analysis has been conducted to establish a relationship between Hardness, impact strength and weight fraction of SiC.

2. Materials And Methodology

The experimental methodology aims at developing a Hybrid Aluminium Metal Matrix Composite. This was achieved by reinforcing silicon carbide particles at varying concentrations. A two-step mixing method of stir casting technique was employed for the development of MMC. This was done to develop a conventional low-cost method of producing MMCs and obtain homogenous dispersion of ceramic material. Aluminum Alloy 6061 and Silicon Carbide with grit size of 320 in conjugation with Rice Husk Ash, Tungsten Carbide (WC) and Alumina Powder has been chosen. Experiment was conducted by varying weight fraction of Silicon Carbide (SiC) at 5%, 10%, 15% and 20% for samples 1, 2, 3 and 4, respectively, while keeping other concentrations constant. Table 1 elucidates the chemical composition for Aluminium AA6061.

Table 1
Chemical Composition of Aluminium Alloy AA6061

Element	Mg	Si	Fe	Cu	Cr	Ti	Zn	Mn	Al
Weight (%)	0.89	0.73	0.23	0.21	0.1	0.08	0.48	0.45	Bal.

3. Experiments

The experiment was designed for Aluminium AA6061 with Silicon Carbide particulates at varying concentration (wt. %). Table 2 describes the composition of individual particulates in the metal matrix for all 4 Samples. The samples were cut in form of rectangles with cross sectional area of $108mm^2$. Figure 2 represents the schematic diagram for the apparatus used.

Figure 2: Schematic diagram of Two-Step Stir method

Table 2
Chemical Composition of Hybrid Metal Matrix Composite

Sample	Matrix	Al_2O_3 (%)	RHA (%)	WC (%)	SiC (%)
1	88	3	2	2	5
2	83	3	2	2	10
3	78	3	2	2	15
4	73	3	2	2	20

As it can be seen from Table 2, the concentrations of Alumina (Al_2O_3), Rice Husk Ash (RHA) and Tungsten Carbide were kept constant for all 4 samples at 3%, 2% and 2% respectively. The experimental results were analyzed using Impact test, Tension test, Hardness test and Flexural test. The tensile test was performed on Universal testing machine to investigate the mechanical behaviour of the MMCs as per the ASTM E8 standards. The impact tests were done on the samples using the Charpy test as per IS 1757 standards. Finally, a hardness test was performed on composite specimens. The hardness values of the specimen were measured using Rockwell hardness testing system with 10mm diameter diamond indention at a load of 60kgf.

4. Results And Discussion

4.1. Density measurement test:

Density measurement was conducted for the prepared samples of Aluminium Hybrid Metal matrix composite as elucidates in Table 3.

Table 3
Density measurement of AA6061/Al_2O_3/ RHA/ WC/ SiC Composites

Sample	SiC (wt. %)	Density (Kg/m^3)
1	5	2835
2	10	2642
3	15	2373
4	20	2278

It can be seen from table as the Silicon carbide percentage increases, the density of the prepared sample decreases. It was explained on the basis that as the percentage of particulate reinforcement increased, the percentage of metal matrix decreased. Due to this, as the total mass decreased (for same volume of samples), a decrease in density was observed. Highest density (2835Kg/m^3) was observed at 5 Wt% of SiC sample, whereas the lowest (2278 Kg/m^3) was observed at 20 wt. % of SiC. There was a constant decline in density as represented in Fig. 3.

Figure 3: Variation of Density with varied SiC

This can be explained as the presence of other particulates, primarily Alumina, Rice Husk ash and Tungsten carbide, which had already occupied vacant spaces in the matrix lattice. Hence, no increase in the density was observed due to high density SiC particulates.

A similar density trend was as observed in this experiment was also observed by Gireesh et al. (2018) [35]. Their experiment with Al6061 matrix with SiC, $Al_2O_{3,}$ and fly ash reinforcement (with varying concentrations of SiC and Al_2O_3) observed a decrease in density when concentration was varied from 0–15% and 20–25%. Kanth et al. [36], post addition of fly ash (FA) and SiC particulate reinforcements in

AA7075 aluminium matrix observed a decrease in density as the wt% of the reinforcements increased. In the experiment conducted by Venugopal and Karikalan, the decrease in density with increase in TiO_2 and SiC particulates was observed up till a minimum value, after which the density increased [37]. It was explained that density is predominantly controlled by interaction of hard SiC particles and porosity. Therefore, development of pores into the structure may attribute to a decrease in the density. In addition, the two-step stir method involves rapid heating and cooling in two stages which may enhance the escape of gas bubbles. Formation of gas bubbles and their escape may cause pores formation, consequently reducing the density of the fabricated Hybrid Aluminium metal matrix. In addition to this, it was observed that Al_2O_3 and Rice husk ash is lower in density than SiC and Aluminium alloy. However, as their concentration is constant in all 4 samples, the appropriate explanation of the decrease in density is the formation of pores.

A very few studies showed a variation in this trend. Daniel et al. (2018) observed an opposite trend, where an increase in the density with an increase in SiC particle concentration was observed [38]. There is very much similar, in the experiment conducted by Patel et al. (2020), the AA5052 metal matrix density increased as the concentration (wt. %) of SiC particulates increased [39]. The increase in density was attributed to the increasing concentration of SiC particles. As the porosity of the fabricated composite was low due to the better stirring process, the influence of porosity was superseded by higher density SiC particles.

4.2. Impact Test:

Table 4
Impact test of AA6061/Al_2O_3/ RHA/ WC/ SiC Composites

Sample	SiC (wt. %)	Energy absorbed (Joules)
1	5	3.8
2	10	4
3	15	4.4
4	20	6

Table 4 represents the values of Energy absorbed for the 4 samples with varying Silicon Carbide Concentration. It was observed that for 5 wt%, 10 wt. % and 15wt. %, the values of absorbed energy remained closer to one another as compared to 20 wt. %. There was an increase in absorbed energy by 57% (approx.) from 5 wt. % (3.8J) to 20 wt. % (6J).

A linear increase in the Energy absorbed was observed as the reinforcement (SiC) wt. % was increased (Fig. 4). A similar trend was observed by Nathan et al. (2020) where with the increase in the concentration of the SiC particles, an increase in impact energy was observed [40]. In the experiment conducted by

Hillary et al. on Al6061 matrix reinforced with SiC and varying concentrations of TiB_2, it was observed that Impact strength increased as TiB_2 concentration in the matrix increased from 2 wt. % to 10 wt. % [41]. Similarly, an increase in Impact strength with TiO_2 and SiC particulates was concluded by Venugopal and Karikalan in their experiment [37]. The increase in the impact energy was attributed to the hard SiC particulate reinforcement. The increase in the impact energy is a consequence of augmentation in the resistance towards fracture and toughness. The increase in impact strength (inferred from increasing impact energy) was explained by the increase in the weight percentage of SiC reinforcements.

4.3. Tensile Test:

Table 5
Tensile Test of AA6061/Al_2O_3/ RHA/ WC/ SiC Composites

Sample	SiC (wt.%)	UTS (N/mm^2)	Yield Stress (N/mm^2)	Elongation (%)
1	5	113.83	61.61	2
2	10	118.33	82.76	1.64
3	15	120	91.13	1.4
4	20	130.15	96.4	1.2

Table 5 elucidates the results of Tensile Test. For Ultimate Tensile Strength, Highest tensile stress (130.15 N/mm^2) was observed at 20 Wt% and the lowest (113.83N/mm^2) was observed at 5 wt. %. There was an increase of 14% in UTS.

Figure 5: UTS and Yield Stress of AA6061 hybrid composite

As seen in Fig. 5, the Yield stress increases from 61.61N/mm^2 to 96.4 N/mm^2 for 5 wt% to 20 wt. % SiC reinforced particles. By increasing SiC concentration further, a linear increase in Yield Stress was observed. From 15 to 20 wt. %, a 5.4% increase in yield stress (from 91.13 to 96.4) was observed. The highest Yield stress was observed at 20 wt % SiC and lowest at 5 wt. % (56% increases in Yield Strength).The increase in UTS with increase in reinforcement concentration was also observed by other researchers [34–37, 40–42]. A variation to this was observed by Devaganesh et al. (2020) [43]. In their experiment with Al7075, SiC reinforcement and varying concentrations of Graphite, hBN (hexagonal boron carbide) and Molybdenum Disulfide, it was observed that ultimate tensile strength increased up to a maximum value and then decreased.

The increase in tensile strength was explained on the basis of hard material SiC. It was observed that the ultimate tensile strength of a hybrid composite was dependent upon the percentage contribution of the reinforcement. It was further observed that attributing to homogenous distribution of reinforced particulates; the interfacial bond strength increased which consequently enhanced the ultimate tensile strength of the composite. The Yield strength trend observed in this experiment was similar to researches conducted by other researchers. As observed from Fig. 5, Yield strength values increased when particle concentration increased from 5 to 20 wt. %. Similarly, in previously conducted experiments, a linear trend was observed, where the Yield strength increased with the increase in reinforcement particle concentration [34, 36, 42].

Elongation percentage analysis (Fig. 6) showcased that elongation decreased by 66.66% as SiC concentration increased from 5–20%. The highest elongation (2%) was observed at 5% SiC and lowest (1.2%) at 20% SiC particulate concentration. A similar trend was observed Fenghang et al. in their experiment with Al6061 with SiC and WC reinforcement particles [34]. It was observed that with the increase in the wt. % of reinforcements, the elongation decreased. An opposite trend was observed by Hillary et al. (2019) in their experiment where the elongation increased with an increase in SiC and TiB_2 particle concentration [41]. The increase and then decrease in the elongation were explained by comparing factors such as strain hardening and increase in Hardness.

4.4. Hardness Test:

The loading time for hardness test was 30 seconds. Three readings were taken on each specimen to eliminate possibility of segregation and mean value was taken as the Hardness of the composite. The 20% SiC sample was observed to provide the best result.

Table 6
Hardness of AA6061/Al_2O_3/ RHA/ WC/ SiC Composites

Sample	SiC (wt.%)	Hardness (HRA)
1	5	29
2	10	30
3	15	33
4	20	35

The Hardness values were observed to increase from 29 to 35 HRA as the particle concentration increased. A similar trend was observed by Daniel et al. in their experiment with aluminium (Al5059) with SiC reinforced in the matrix. The Hardness of the MMC increased with increase in the SiC concentration. It was concluded that the enhanced Hardness was due to the high density reinforced SiC particles [38]. It was further explained that two factors majorly controlled the hardness trend, (i) Density was observed to enhance with increase in the mass fraction of the reinforced particulates, (ii) Hardness decreased with particle size.

As seen in Fig. 7, highest HRA value was observed at 20 wt% SiC concentration and lowest at 5 wt. % SiC concentration. From 5% SiC concentration to 20 % SiC, a 20.6% increase in Hardness was observed.

Many researches elucidated a linear relation with particle concentration and Hardness. These researches reported an increase in Hardness as the reinforced particulate wt. % increased [34, 36, 37, 40–42, 44]. In the experiment conducted by Devaganesh et al. (2020) an increase in Hardness till 5% Gr and then a decline in hardness value were observed [43]. Similarly, in the experiment conducted by Gireesh et al. (2018), the hardness value increased as the wt% increased from 0–20%, after which a decline in the hardness value was observed up to 25 wt. % [35]. This variation was attributed to the porosity of the fabricated composite. It was stated that porosity decreased the Hardness of the composite. It was further stated in experiments [45, 46] that addition of ceramic reinforcements decreased the Hardness of the fabricated composite whereas on increasing the reinforcement size, the porosity decreased hence increasing the Hardness. The juxtaposition of two explanations can explain the trend observed in this experiment. The increase in the Hardness as the SiC varied from 5–20% can be explained on the basis that as the SiC particulate matter increased, the porosity increased, but the effect of porosity was trivial in comparison with the Hardness of SiC. It can further be inferred that hardness and material characteristics have a higher influence on Hardness of composite than porosity. On further increasing the SiC content, the Hardness increased due to the predominantly hard SiC particle. Hence the greater magnitude increase in hardness value was observed. Here, the effect of porosity was superseded by the Hardness of the SiC particles hence the Hardness overall increased. In addition, WC also contributed in the enhanced Hardness of the composite. WC in conjugation with SiC overcame the porosity restriction by virtue of their stiffer characteristic.

4.5. Flexural Test:

Flexural test was conducted for 4 samples with varying concentration of SiC particles. The results of the test are elucidated in Table7.

Table 7
Flexural test of AA6061/Al_2O_3/ RHA/ WC/ SiC Composites

Sample	SiC (wt. %)	Load (N)
S1	5	5920
S2	10	6140
S3	15	6440
S4	20	6720

It can be observed from Fig. 8, that load value for 20% SiC concentration was 6720 which was the highest load value. Lowest load value was observed at 5% (5920N). An increase of 13% flexural bearing capacity was observed. In addition to this, a linear relation between particulate wt% and flexural strength was observed. It is patent from Fig. 8 that there is an increase in flexural strength with increase in the reinforced particle concentration. A similar conclusion was drawn by Hillary et al. in their experiment with Al6061, SiC and varying concentration of TiB_2. It was observed that as the concentration of TiB_2 increased from 2–10%, flexural strength simultaneously increased [41].

5. Microstructural Analysis

The structural analysis was conducted utilising Dino-Lite Edge Digital Microscope model AM7115MT at 220X. Figure 9 represents the micrographs for the 4 samples.

Micro-structural analysis possesses great significance as it explains the underlining characteristics and traits associated with mechanical analysis. Figure 9 (a) illuminates that at lower SiC weight percentage, lesser SiC is on the surface as compared to Fig. 9(c) and Fig. 9(d) which possess higher SiC weight percentage. It can be inferred that the two-step stir casting method successfully distributed the particulate reinforcements uniformly throughout the Aluminium metal matrix, which further explains the enhancement in the mechanical properties. In addition, it is patent from Fig. 9, that large craters are present throughout the surface of the fabricated composite. The crater formed is irrefutably associated with air (gas) bubbles which were liberated during double stir casting method. The observed gas holes were due to liberation of environmental gases. As this method encapsulates rapid heating and cooling of metal matrix twice, the formation and liberation of air bubble may be more as compared to conventional stir casting method. In comparison with Fig. 9(a) and Fig. 9(b), Fig. 9(c) and Fig. 9(d) witness higher reinforced material agglomeration. Through the use of a microscope, it is evident that more agglomeration takes place at higher reinforced particle concentration. The micrographs articulate the presence of different reinforced particles present in the Hybrid AMMC. Figure 9 (a) shows Alumina (Al_2O_3) represented with silvery white. The prominent agglomeration of Alumina can be due it low solubility. In addition, uniform distribution of Rice Husk Ash (greyish) can be observed in all the micrographs. Similarly, Tungsten Carbide (WC) (goldish) can be seen in form of a cluster in Fig. 9(b).

Surface analysis also illuminated the presence of crack which was prominently seen in Fig. 9(b). The presence of characteristic dendrite structures can be seen at higher Silicon carbide concentrations which further explain the presence of cracks at higher silicon carbide concentrations. The relation between increase in particle concentration and formation of cracks can be explained. As the particle concentration increases, more nucleation sites come into existence, which augments the crack propagation [41]. It can be inferred that the distribution of the reinforced particles is greatly influenced by the process of solidification [47]. After microscopic analysis, it was observed that the presence of crater cause by gas liberation causes an increase in porosity which was also confirmed by the decrease in density with increase in particulate concentration. Further, the equally distance SiC particle in the metal matrix in addition with lesser cracks in comparison with other composites confirm the efficiency and acceptable result of fabrication of composite with two step stir method.

5. Conclusion

An Aluminium Hybrid Metal Matrix composite was fabricated employing Two-Step Stir casting method. Silicon carbide in varying weight percentage (5%, 10%, 15% and 20%) was into the AMMC along with Tungsten Carbide (WC), Alumina (Al_2O_3) and Rice Husk ash in constant weight percentage of 2%, 3% and 2% respectively. Mechanical characteristics such as Tensile Strength, Hardness, Density, Impact Strength, and Flexural Strength along with Microstructural analysis were performed. The results are articulated in following points:

- Density measurement showed a linear relation with reinforcement concentration. A decrease in density was observed as SiC particles increased. Highest density was measured at 5 wt. % (2835 Kg/m^3) and lowest at 20 wt% (2278 Kg/m^3). A decrease of 24.4% in density was observed. This was attributed to the increase in porosity with increase in particulate reinforcements.
- Impact strength increased with increase in SiC concentration. This was due to the presence of Hard SiC particles in the matrix. Highest impact strength (6J) was observed at 20 wt. % SiC. An increase of 57% in impact strength was observed.
- Tensile strength of the fabricated composite was measured using UTM. A linear relation between Tensile strength and SiC contribution was observed. With the increase in particulate matter, tensile strength also increased. Lowest Tensile strength (113.83 N/mm^2) was observed at 5% SiC and highest tensile strength (130.15 N/mm^2) was observed at 20 wt. % SiC.
- Yield Strength and Elongation were also examined. Along with Tensile strength, Yield strength also increased with increase in SiC particle concentration. Highest Yield strength (96.4 N/mm^2) was measured at 20% SiC concentration whereas lowest (61.61) was measured at 5 wt. %. Similarly, elongation measurement followed a linear trend corresponding to the hardness values. Elongation decreased with increase in the SiC weight percentage. Highest elongation (2%) was measured at 5 wt. % whereas lowest elongation (1.2%) was measured at 20 wt. %.
- Hardness and Flexural strength increased with the increase in the SiC concentration. This was due to higher concentrations of SiC, which are inherently hard. Hardness of 35 HRA and Flexural strength at 6720 N was measured at 20 wt. % SiC.
- Microstructural analysis illuminated equally spaced and well distributed SiC particles in the Aluminium metal matrix. Due to proper distribution of SiC, an enhancement in mechanical properties of the fabricated composite was observed.
- This composite showcased promising results in Tensile Strength, Hardness and flexural strength. Therefore, application of the fabricated composite is proposed in aerospace and automobile field.
- Two-step stir method was successfully employed in fabricating Hybrid AMMC which had better mechanical characteristics.
- This experiment showcased characteristics of hybrid aluminium metal matrix with varying SiC concentration. Given to the fact that not much literature is present on utilisation of WC, Al_2O_3 and Rice Husk Ash as simultaneously reinforcements, new experiments could be designed with varying concentrations of these reinforcements. This is the proposed future scope in this field.

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Author contribution:

Siddharth Srivastava: Data Curation, Experimentation.

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Mudit K. Bhatnagar: Data Curation, Experimentation.

Neeraj Verma: Supervision.

Mamatha T. G.: Conceptualization, Supervision.

Mohit Vishnoi: Review & Editing, Investigation, Supervision.

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Figures

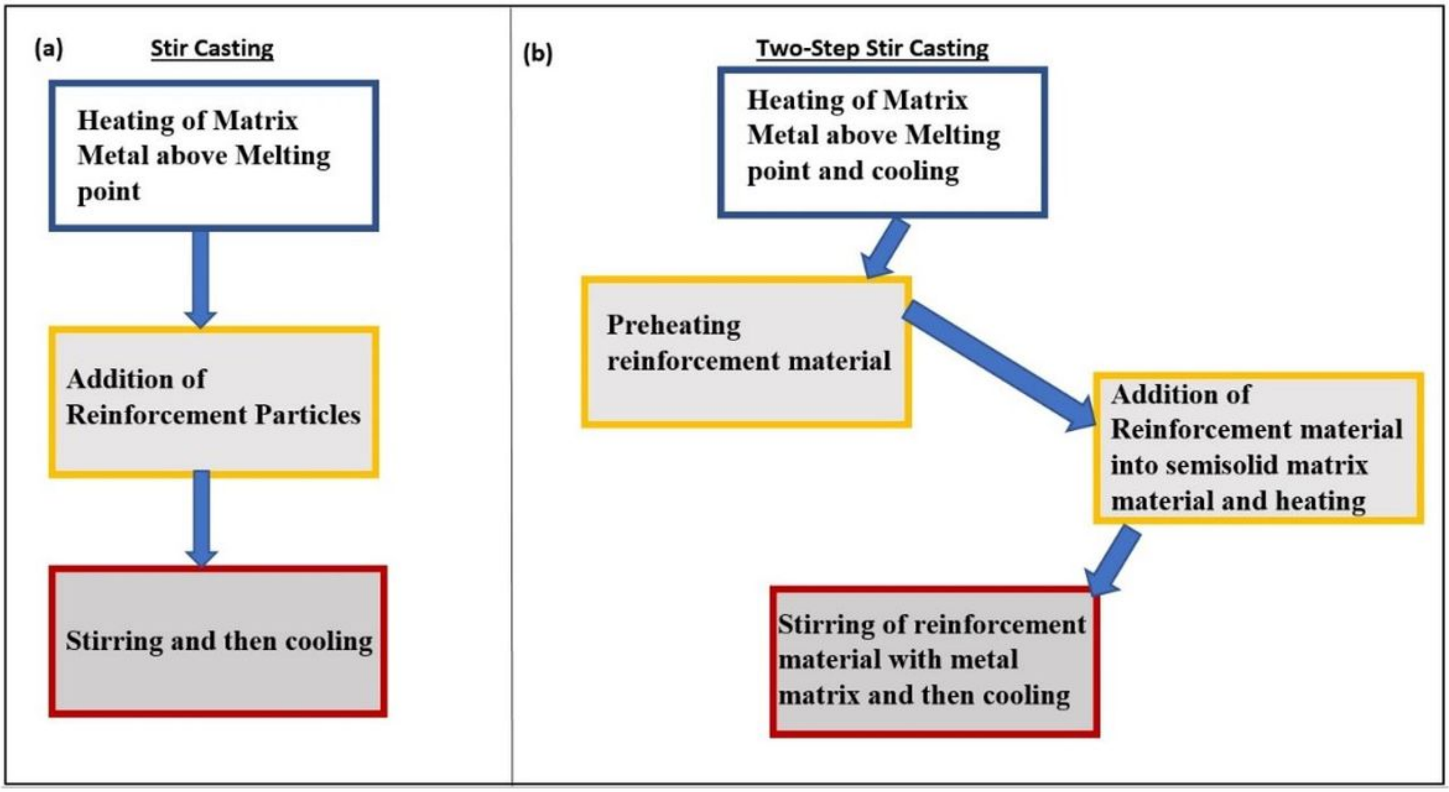

Figure 1

Comparative flowchart representation between (a) Conventional Stir casting and (b) Two-Step Stir casting

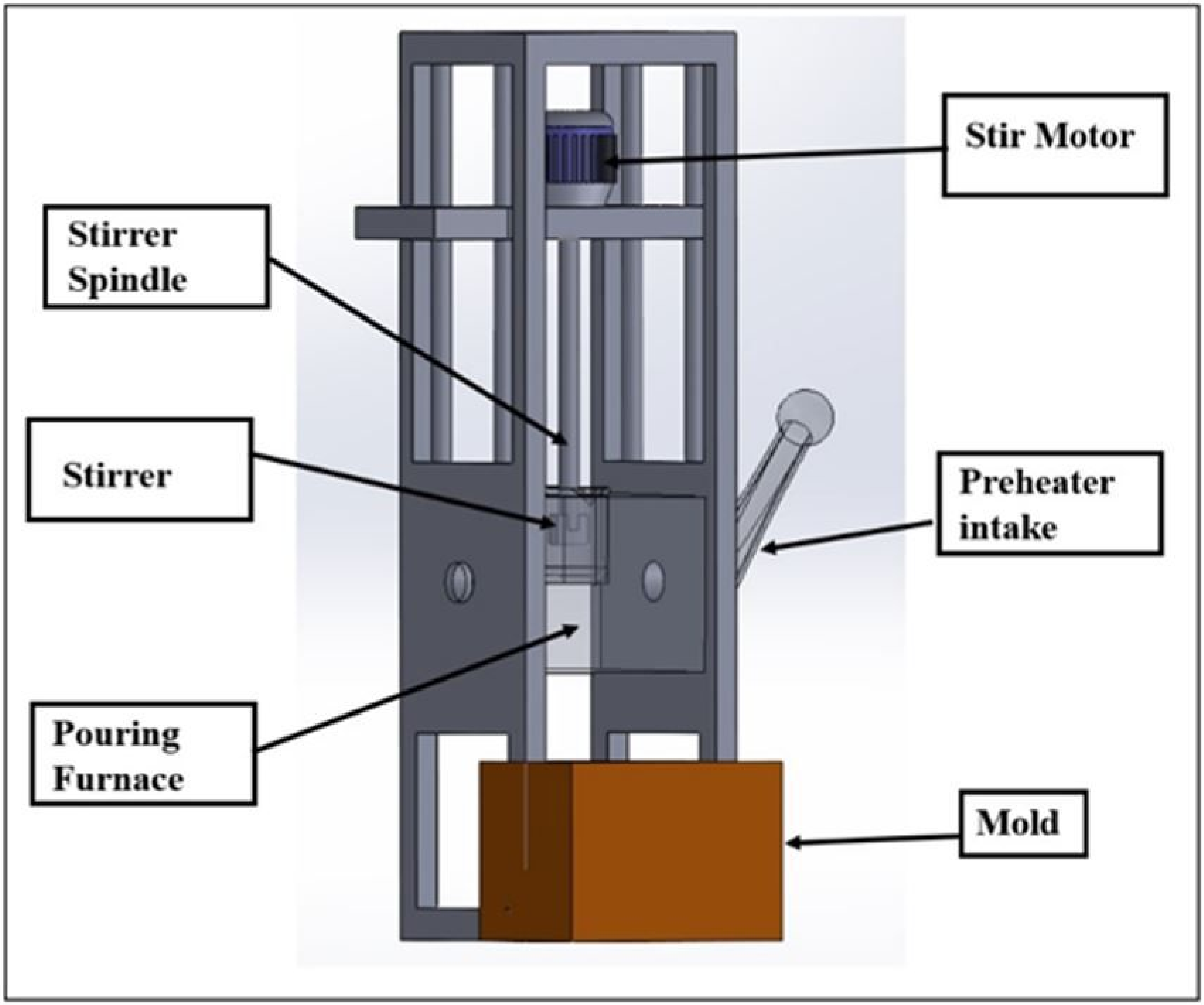

Figure 2

Schematic diagram of Two-Step Stir method

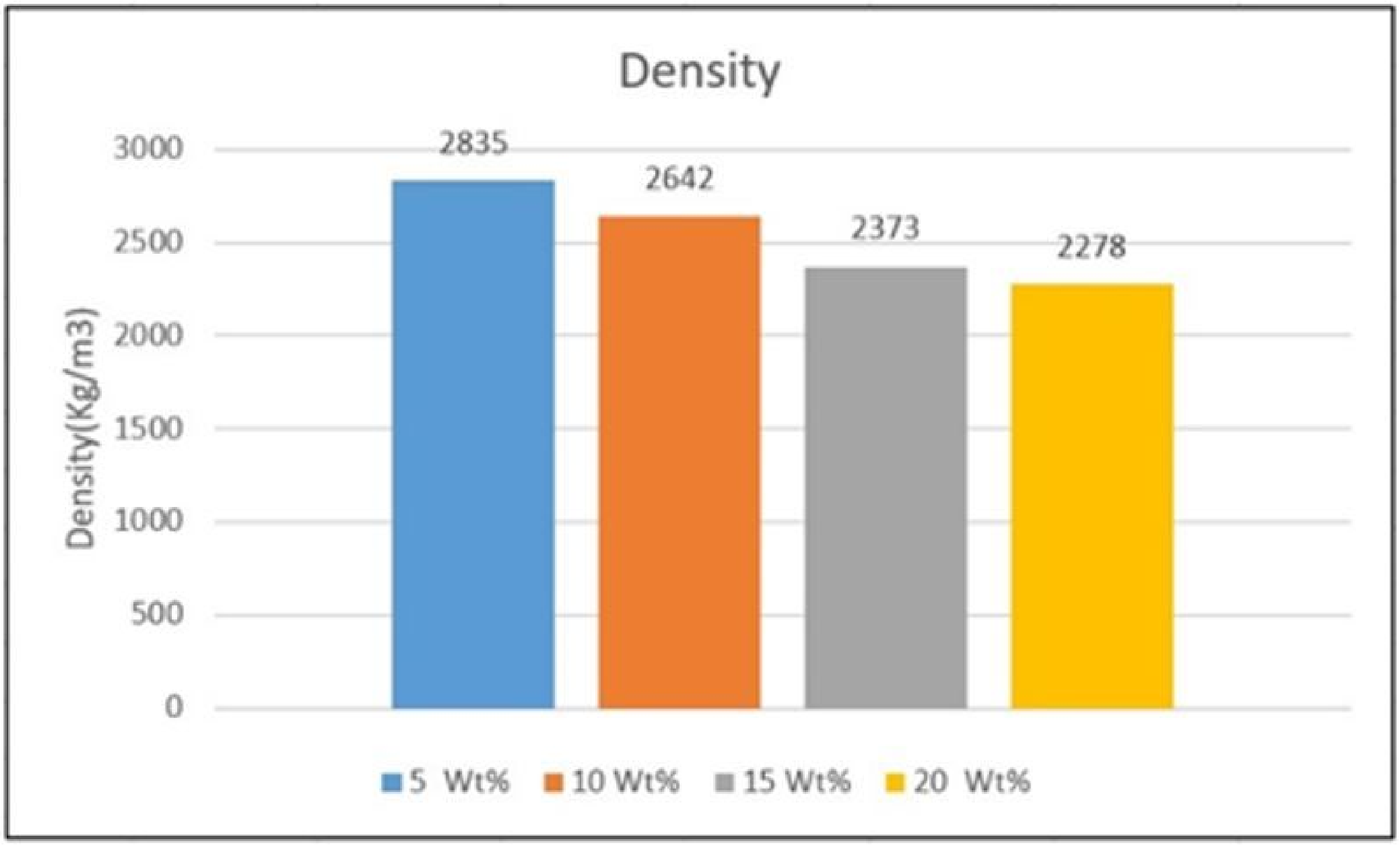

Figure 3

Variation of Density with varied SiC

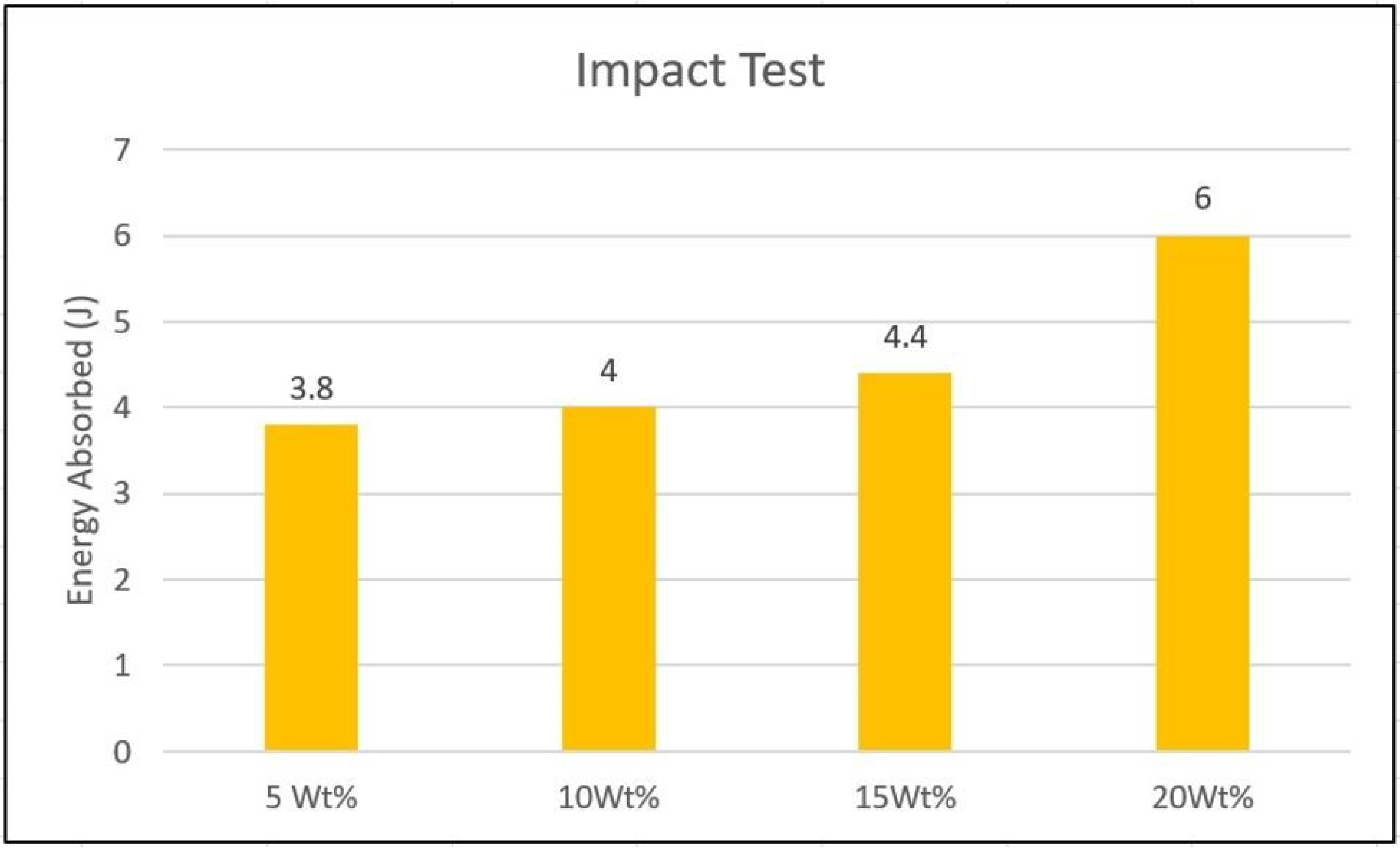

Figure 4

Impact Test of AA6061 hybrid composite

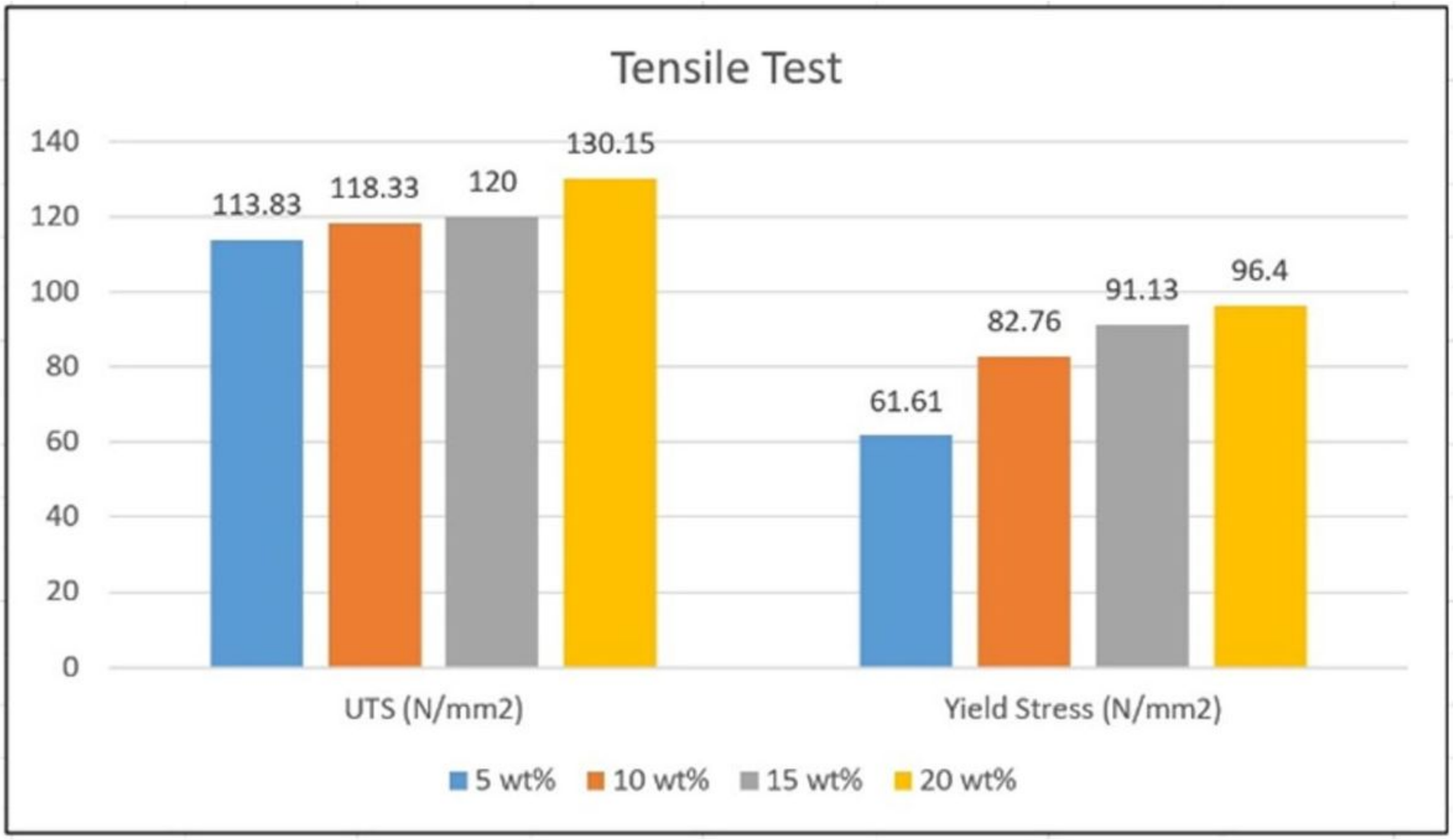

Figure 5

UTS and Yield Stress of AA6061 hybrid composite

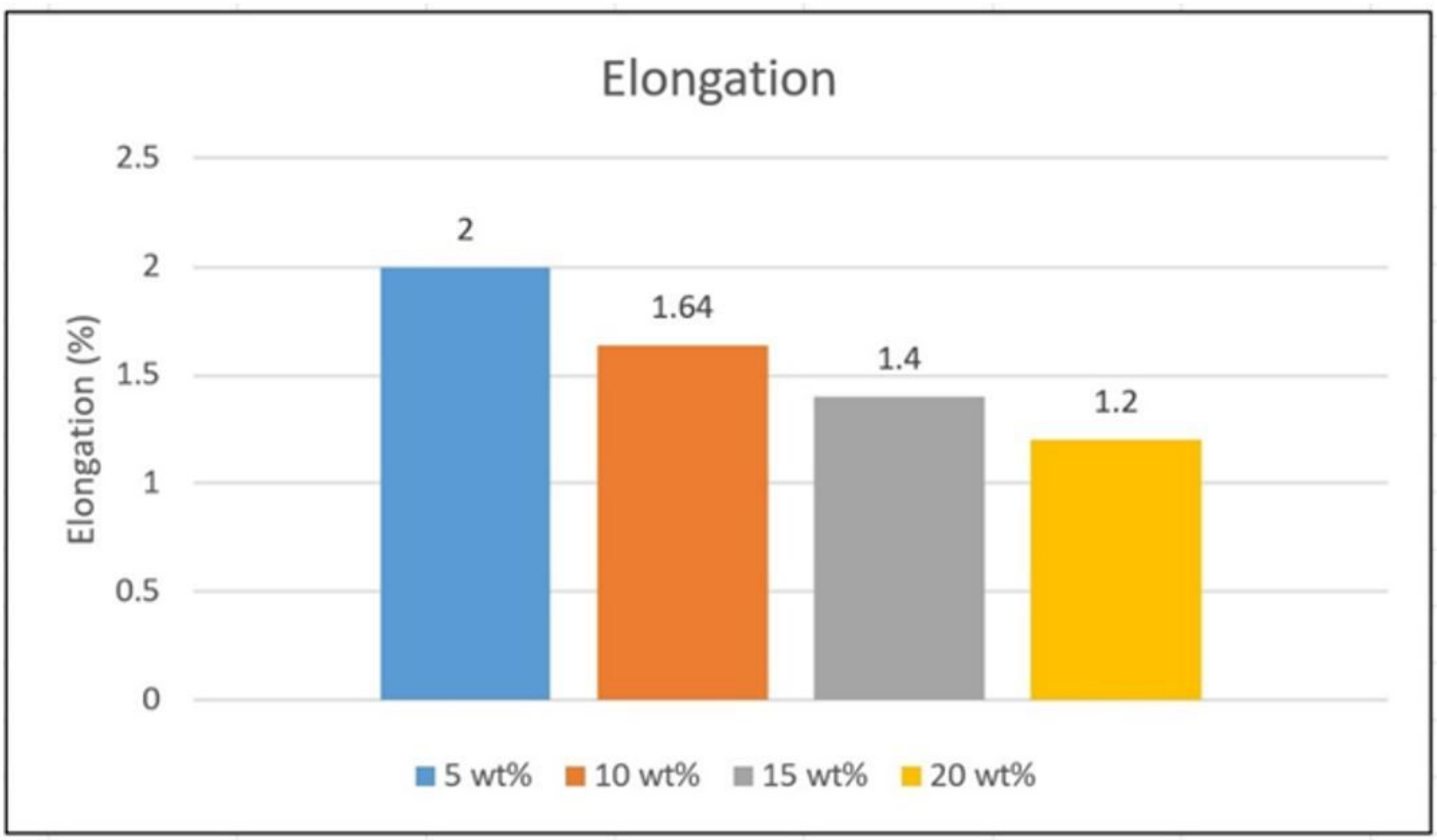

Figure 6

Elongation Percentage graph of AA6061 hybrid composites

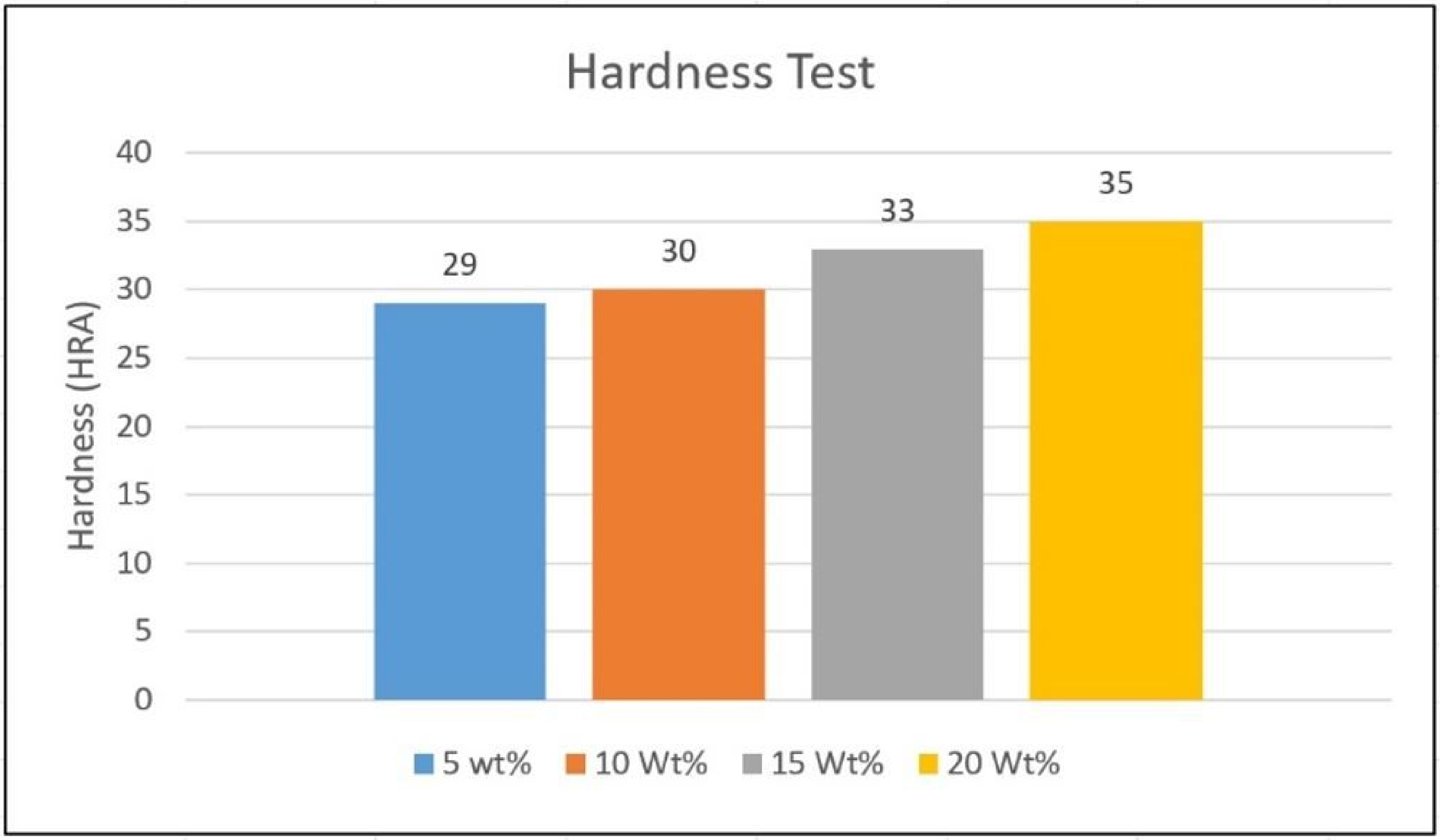

Figure 7

Hardness of AA6061 hybrid composites

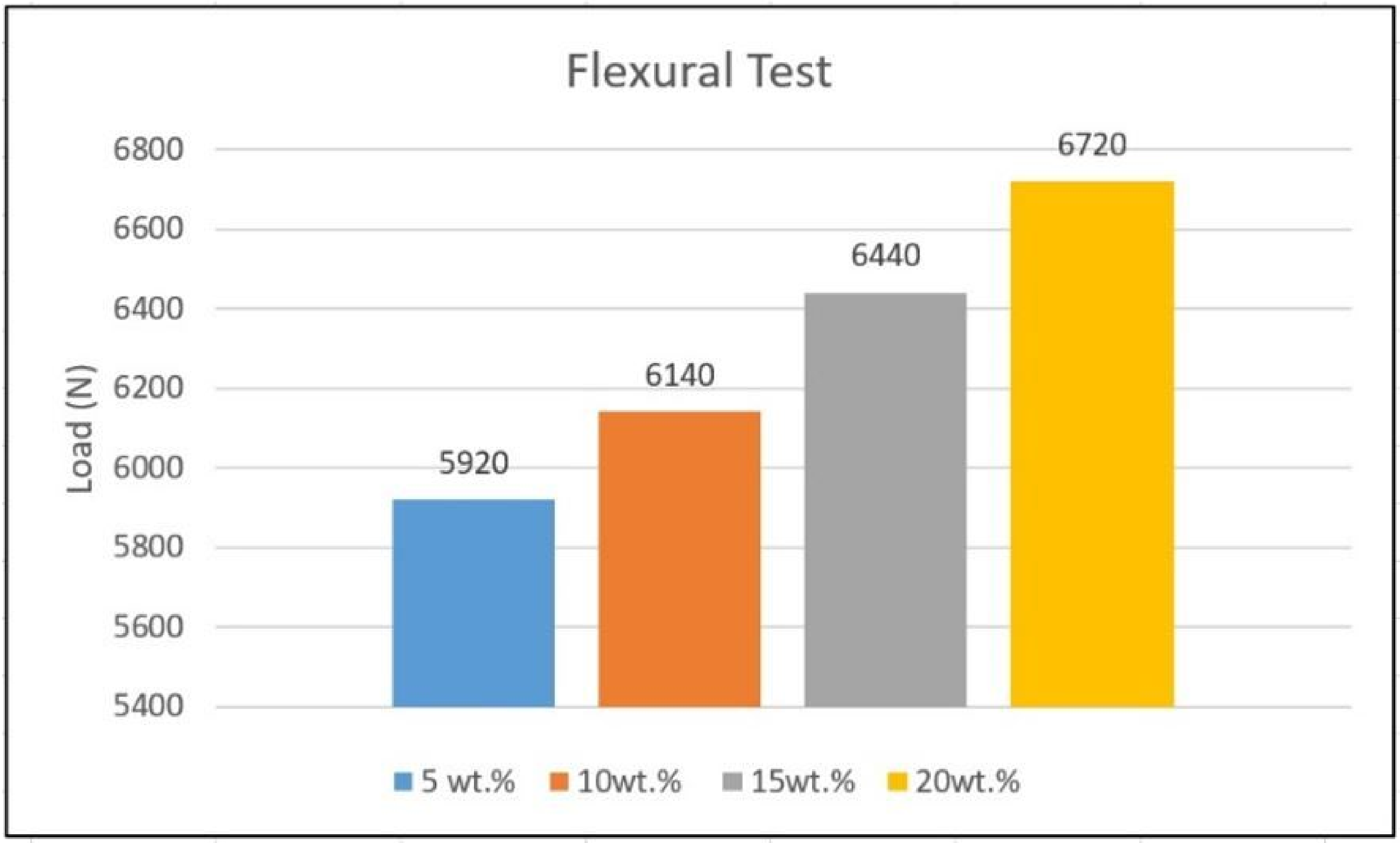

Figure 8

Flexural test graph of AA6061 hybrid composites

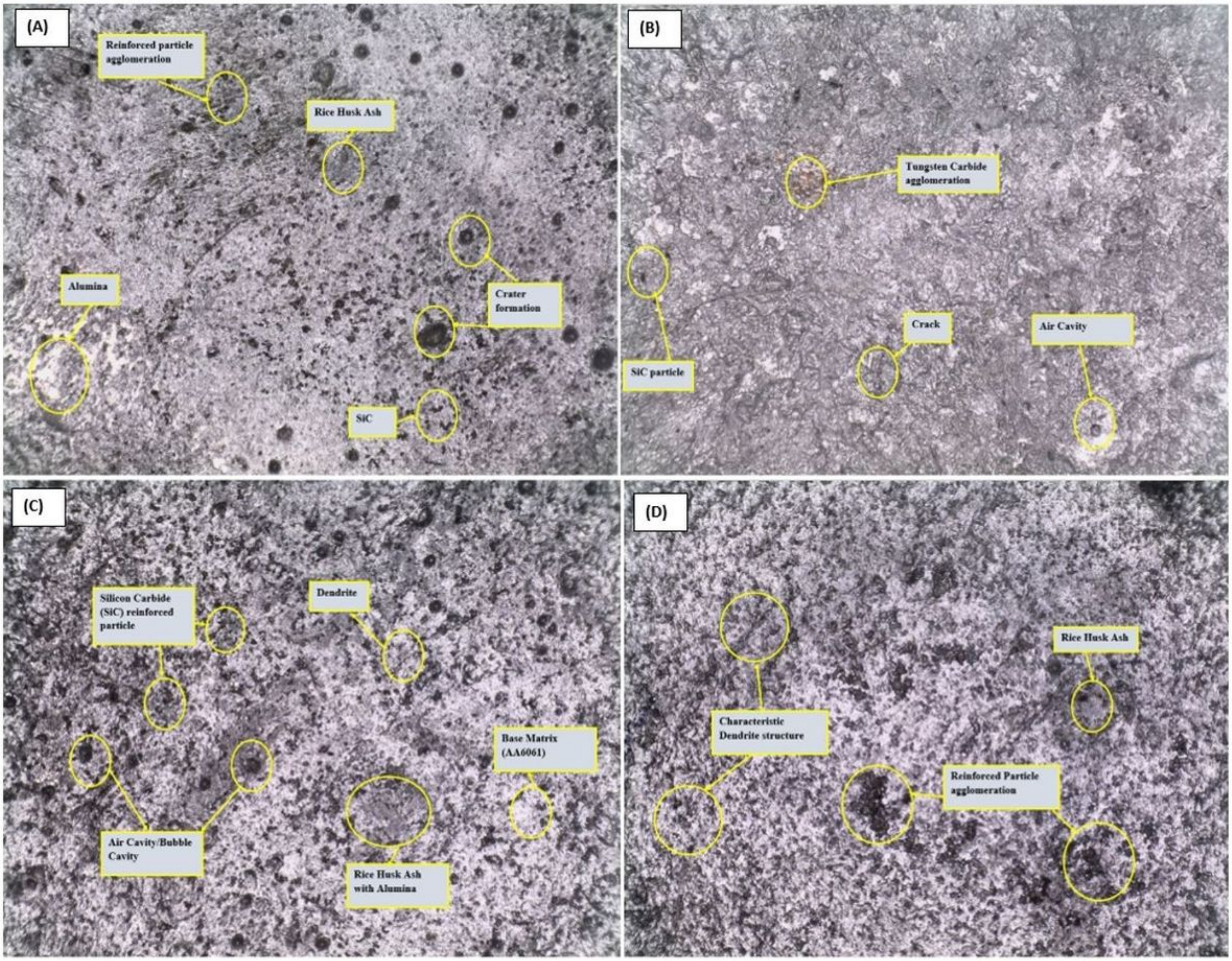

Figure 9

Micrographs for (a) 5, (b) 10, (c) 15 and (d) 20 wt. % SiC.