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Mechanical properties of Al-Si17Cu3.5Mg0.8 alloy fabricated by stir casting with UV and new CRSS casting process with and without T6 condition

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Abstract

Aluminum-Silicon metal matrix composites are the popular materials in the vast majority of the car and modern industries on account of their low weight, high mechanical properties, and incredible wear opposition properties. In the present study, Al-Si17Cu3.5Mg0.8 alloy is fabricated by two casting processes such as stir casting with ultrasonic vibrations (RSC) and merged-rheo-stir-squeeze (CRSS) casting with and without heat treated (T6) condition. Microstructural and material characterization was explored by advanced metallurgical microscope (AMM), SEM and EDS. Though, tensile and hardness tests were executed by Tensometer and hardness tester (Brinell). The casting process (CRSS) greatly improves the mechanical properties than rheo stir casting about 30%. The micrograph results display uniform distribution of Si-particles in CRSS cast workpieces than the regular casting. Furthermore, mechanical values revealed that the addition of heat treatment (T6) process led to the development of hardness and tensile strength.

Keywords: Al-Si alloy; Stir casting; Squeeze casting; EDS; SEM; Tensometer

Introduction

Al alloys are getting more attention due to high ductility and low weight. however, with the addition of particles like ceramics, the alloys attain good wear resistance and stiffness [1]. Moreover, the aluminum alloys extraordinary strengthen with the reinforcement of Si particles without losing ductility [2]. The metal matrix composites (MMC) (Hyper-eutectic Al-Si) made from most recent techniques are getting modern consideration because of their predominant wear and mechanical properties [3]. From the previous years, the MMC is manufactured by two techniques, for example, solid-state casting strategy and fluid state casting technique [4-6]. Be that as it may, solid-state casting process (powder metallurgy) isn't conservative [4] contrasted with different techniques so the manufacturing industries concentrated on making parts utilizing fluid state casting strategy, where the alloys are straightforwardly mixed in the liquid metal by mixing and then cast [5]. In Al-Si alloys when Silicon particles mixed in the liquid metal own some difficulties like poor dispersion and wettability [6] because of more surface area. [7] Therefore the casting problems (poor dispersion and wettability) can be overthrown by choosing new casting procedures.

Various reports have been described on the physical properties of Al-Si alloys. T V S Reddy et.al. examined the microstructural and tribological behavior of Al–Si-Cu alloys and found that the hyper-eutectic alloys have good wear resistance with improved microstructure by rheo manufacturing route [12]. Whereas Zhao et.al. conducted experiments on aluminum-silicon MMC and described that the microstructure and mechanical of the alloys are greatly enhanced by liquid state casting route [8].

Alireza et.al. described that the MMC microstructure changes from thinner to contrasted with the rate of cooling and also the primary silicon particles with magnesium particulates improve the wear resistance properties [9, 10]. [11] Ramesha et.al. conducted numerous studies by changing ZrSiO4 (wt%) percentages and announced that the liquid-state casting with stirring notably enhances the tensile and hardness properties. From the above literature, it is clear that the manufacturing of AlSiCuMg alloy through the stir casting course enhances the micro-structural and tensile properties [13 -16]. M. da Silva et.al. [17] reported the properties of Al alloys (6061) with the addition of Al2O3/SiC particles under UV and concluded that the notable changes have been observed in microstructure and mechanical properties. Moreover, Poovazhagan et.al. described by their studies that the properties of Al-alloys like wear greatly enhances by UV-assisted casing route at lower loads [18-20]. Further from the above literature, the stir casting with the UV casting route possesses the poor dispersion of Si particles in the alloy matrix which causes the low wear rate at higher loads.

Many researchers reported that the dispersion stability of Al-Si alloys is improved by squeeze the casting route [21-25]. Yuan-Ji Shi et.al. performed experiments on AlSi17.5Cu4Mg0.5 alloy by squeeze casting route and reported that the microstructure properties are greatly improved at different loads [21, 22]. Besides Yang et.al. made MMC (AZ-91-Ca) with the Squeeze casting process with T6, detailed that Squeeze-casting method surprisingly improves the tribological properties [23]. In spite of the fact that Wei Dai et.al. and Chong Lin et.al. described by their tests that the noteworthy changes in the harness and tensile properties were seen with the enhanced form temperature by high squeeze pressure (UV) system [24-25]. Moreover Yang et.al. manufactured alloy (AZ-91-Ca) with the Squeeze-casting route with T6, reported that the squeeze casting route remarkably enhances the tribo properties [23]. Though Wei Dai et.al. and Chong Lin et.al. described by their studies that the notable improvements in the physical properties were seen with the increased melt temperature by high squeeze pressure casting (UV) technique [24-25].

Furthermore, the manufacturing of the alloy was continued by squeeze casting with strring technique for important merits. Pooja Verma et.al. [26-27] conducted experiments on squeeze cast alloy and reported that the good distribution of Si-C particles and fine grain structure was obtained by stir-squeeze casting technique. Whereas Vineet Tirth et.al. from their experiments concluded that the increasing squeeze pressure improves the mechanical properties greatly [28]. Additionally S. Ghosh et.al. seen the squeezed MMCs with Al-Si have great mechanical and low wear charecteristics contrasted with the natural processes [29]. Hence the MMC (Al-Si) which are made utilizing both squeeze and stir processes with heat treatment method have great mechanical and wear properties contrasted with the conventional procedures [30-33].

It is clear that nobody investigated the impact of CRSS technique on tensile and hardness properties of Al-Si17 MMC, hence the present examination performed to discover the impact of CRSS process on physical properties of Al-17Si-T6 composite. EDS, AMM, and SEM were utilized for characterization of MMC. Additionally, Brinell hardness analyzer and Tensometer were utilized for mechanical properties of AlSi17Cu3.5Mg0.8alloy.

1. Experimental procedure

The MMC (AlSi17Cu3.5Mg0.8) was manufactured utilizing CRSS process, (Fig. 1) though in step one the MMC matrix is made by stir casting (UV) (Table. 1) later it was kept utilizing high pressure squeeze casting.

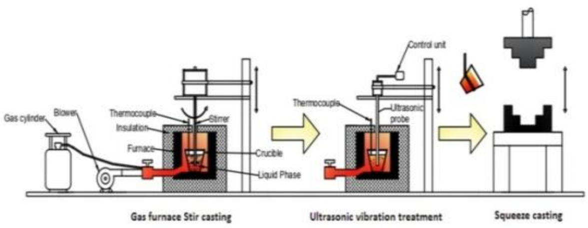


Fig. 1. Combined rheo stir squeeze casting process.

Table 1 Al-Si17 alloy chemical composition

Alloy	Fabrication Process	Composition (wt %)			
		Si	Cu	Mg	Al
AlSi17	RSC & CRSS	17	3.5-4	0.6-0.8	Balance

The procedure begins by melting the Al-Cu in a ceramic container of the gas furnace. At the same time Si powder warmed at 270^0C in the pre-warmed heater before adding to the composite. The MMC was completely liquified at 1100^0C, and cooled to 720^0C with strring. Si powder (pre-heated) and Mg particles were incorporated into the stirring liquid by keeping up the RPM of 300 around 15 min. at the point when the stirring mixing activity was finished, the MMC was heated again upto 1100^0C and maintained for 20 min. Further Ultrasonic testing was brought into the ceramic container melt about 5min for scattering of Silicon particles. After step one (UV with stirrer), the MMC liquid was transfered into a pre-warmed (200^0C) shape of steel mold and afterward step two (squeezing) activity was performed. In step two, the liquefied MMC was squeezed with a pressure of 200MPa and formed a 40X40mm square of 100mm length casted square block. Though, the manufactured Al-17Si MMC (Rapid solidified) is experienced the T-6 heat treatment state. The T-6 state have a 500^0C solution heat-treatment with soaking time of 4 hours then the specimen was (<50^0C) quenching in water rapidly and then continued by 4 hours of artificial-aging treatment at 165^0C afterward cooled in air.

Moreover the prepared square blocks are cut into 10 mm thick plates and afterward EDS testing was performed. In addition, SEM and AMM (VFM-9100 Metzer Metavision) were utilized to examine the distribution of primary Si reinforcements. The specimens were surface finished with Si-C papers (800, 1000 sized) later the final finishing (mirror) accomplished with diamond paste (1 µm). Specimens were cleaned acetone and benzene to remove any foreign particles that may remained during cleaning and finishing operations.

Hardness of samples was performed using BHN equipment (Brinell hardness) with a load of 250 kgf and 5mm ball diameter, later the BHN number is acquired from equation-1. Furthermore to investigate the tensile properties, Tensometer (20N capacity) is used with a test speed of 0.5 mm/min (Fig. 2&3).

$$\mathrm{BHN} = \frac{2P}{\pi D\left(D-\sqrt{D^2-d^2}\right)}$$

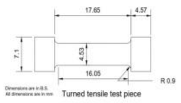


Fig. 2. Dimensions of tensile test specimen

Fig. 3. Al-Si17 tensile test specimens

2. Results and discussion

2.1. Microstructural Observations

The MMC micrographs of both processes (RSC & CRSS) are shown in Fig. 4(a-b). Fig. 4(a) shows the presence of primary Si-particles (polygon-shaped) which in turn describes the alloy was not properly distributed. Whereas, there is an improvement observed in morphology in Fig. 4(b) which describes the CRSS technique improves the distribution of the Si-particles (primary). Though Fig. 4(c) confirms that the MMC chemical elements are observed in a meld of the AlSiCuMg phase (Table. 2).

Fig. 4. (a) Metallurgical micrograph of RSC AlSi17 alloy, (b) Metallurgical micrograph of CRSS casted AlSi17 alloy and
(c) EDS analysis of AlSi17 alloy

Table 2 EDS analysis of Al-Si17 alloy

S.no	Alloy	Elements (wt %)					
		Si	Cu	O	Mg	C	Al
1	AlSi17	15.98	3.61	1.12	0.47	4.99	73.83

The alloys SEM images are shown in Fig. 5(a-b), though Fig. 5(b) confirms that the new casting process (CRSS) greatly improves the Si-particles distribution evenly compared to the regular casting technique (RSC (Fig. 5(a)) and also gives low agglomeration. The results of micrographs clearly describes that the CRSS casting process has good effect on porosity, densification of microstructure and the grain refining of Al-SI alloys.

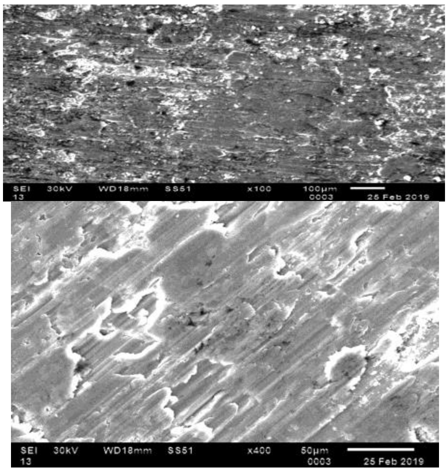


Fig. 5. (a) RSC casted AlSi17 alloy SEM micrograph and (b) CRSS casted AlSi17 alloy SEM micrograph

2.2. Mechanical characterization

The hardness values of both processes (RSC & CRSS) are shown in Table. 3. Fig. 6 describes the variation of harness values in the both cases, whereas the new process (CRSS) has great effect on harness which is 30% more than the regular method (RSC) because of the morphology variation and well dispersed Si-power. Table. 4 indicate the tensile values of prepared samples (Al-Si17) at room temperature. The alloys prepared using the new process (CRSS) lead to good strengthening effects mainly due to presence of well-dispersed Si in the matrix. Moreover because of the age hardening heat treatment (T6) the MMC experiences higher UTS and YS values i.e. 261MPa and 235MPa.

Table 3 Hardness results of Al-Si17 alloy

Composition	Load (kgf)	Ball diameter (mm)	RSC		CRSS-T6	
			Indentation diameter (mm)	Hardness (BHN)	Indentation diametsser (mm)	Hardness (BHN)
AlSi17	250	5	1.7	106.82	1.32	179.37

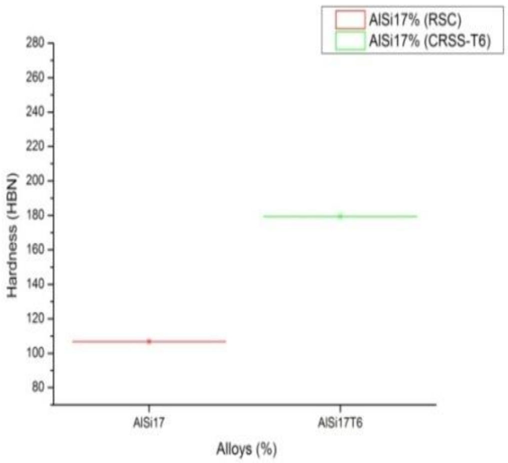
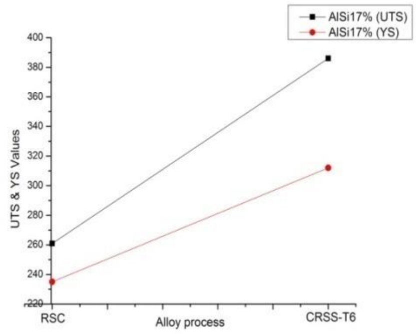


Fig. 6. Hardness values of Al-Si17 alloy

Table 4. Test results of Al-Si17 alloy tensile properties

Composition	UTS		YS		Elongation (%)	
	RSC	CRSS-T6	RSC	CRSS-T6	RSC	CRSS-T6
AlSi17	261	386	235	312	2.1	0.8



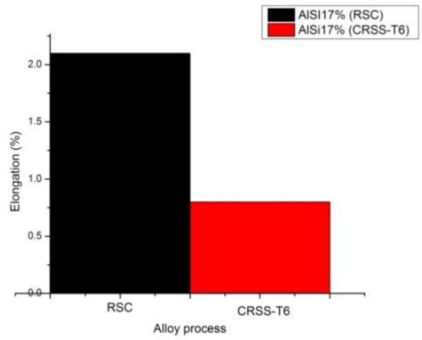


Fig. 7. Ultimate tensile strength and Yield Strength values of hyper-eutectic Al-Si17 alloy Fig. 8. Elongation values of hyper-eutectic Al-Si17 alloy

3. Conclusion

The investigation performed on AlSi17Cu3.5Mg0.8 alloy to find the mechanical and microstructure properties under age hardening heat treated (T6) condition. The alloy was prepared using two casting methods i.e. RSC and CRSS, though the results described that the CRSS-T6 process gave superior effect on mechanical properties. Moreover AMM and SEM micrographs confirm the well dispersed Si-particles are seen at the top faces of the CRSS casted alloy which in turn enhances the hardness and tensile properties greatly.

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