Stir Speed and Reinforcement Effects on Tensile Strength in Al-Based Composites

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Abstract: This study focuses on the preparation of Al-based hybrid composites using AA7475 as the main alloy reinforced with two materials, ZrO2 and SiC. The combination of stir-squeeze processing techniques was employed to create various specimens by varying four parameters: Stir-speed, Stir-time, reinforcements, and squeeze pressure. Taguchi design was utilized to generate specimens for analyzing their mechanical properties, specifically tensile strength, hardness, and porosity.The results indicated that the highest porosity (4.44%) was observed in the L16 test, with a combination of 700rpm stir speed, 25 mins stir time, 2wt% reinforcements, and 80MPa squeeze pressure. On the other hand, the lowest porosity (2.61%) was found in the L7 test, with 800rpm stir speed, 30 mins stir time, 2wt% reinforcements, and 100 MPa squeeze pressure.Regarding tensile strength (UTS), the maximum value (285.23MPa) was achieved in the L13 experiment, while the minimum value (187.58 MPa) was observed in the L1 experiment. This variation in UTS can be attributed to the applied load, the strengthening effect of the reinforcements, and the grain size of SiC.

Keywords: AMCs, Squeeze casting and optimization Techniques

1. Introduction

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Ceramic reinforcement for AMCs has many benefits, including increased tensile and impact strength, increased abrasion resistance, and superior physical qualities. [1]. The 7475 aluminum alloy is a significant member of the 7XXX series of alloys, widely utilized in various businesses such as aviation, navigation etc. [2].SiC/ZrO2 reinforced AA7475 composites that were created using a stir-and-squeeze casting technique.In comparison to base metal, the findings for UTS and HN were much greater. The inclusion of silicon carbide and zirconium dioxide to the composites is responsible for this improvement [3].Transferring molten metal into common moulds with stir casting is a successful technique for creating high-quality pieces. Weight ratio, variables, and the bonding of the base metals and additives all affect the mechanical properties. [4].the widespread use of reinforcing MMCs across various industries has been impeded by the higher production costs associated with manufacturing components in complex shapes. [5]. K. Umanath et al. conducted a study on the improvement of Al6063 alloys with SiC-MoS2 reinforcements, mainly focusing on the particle sizes of additives. They found that corrosion resistance decreased as the temperature increased. [6].Out of the various methods available for producing Advanced Metal Matrix Composites (AMMCs), the Stir Casting (STC) process stands out as the most cost-effective approach compared to other methods such as powder metallurgy, plasma sintering (PS), etc. This cost advantage makes STC a popular choice for materials gathering and processing under a wide range of conditions. [7].Conventional casting processes often result in various defects, such as shrinkage cavity, porosity, and misrun. However, the SC (Squeeze Casting) process, which involves pressurized extrusion molding of materials, offers a high degree of manufacturing flexibility [8]. Adeolu et al. successfully fabricated Al7075-TiO2 composites using the STC (Stir Casting) method. They observed that the ultimate tensile strength significantly improved when employing specific STC parameters, such as a temperature of approximately 750ºC and a stirrer speed of 500 RPM. [9].This research aims to fabricate hybrid composites using AA7475/ZrO2/SiC and determine the optimal parameters to enhance their mechanical properties, thereby promoting the utilization of Al7475 in various applications. The study employs the Taguchi technique to evaluate four-level parameters, seeking to identify a specific set of input parameters that can enhance the desired outputs HN), UTS, and porosity of the prepared composites.

2. Materials and methodology

2.1 Stir casting

The chemical composition of AA 7475 and the properties of SiC/ZrO2 are provided in Table 1 and 2. AA 7475 were mixed with ZrO2 and SiC to produce a hybrid composite through stir casting, as shown in Fig. 1. An electric furnace was used to melt the aluminium alloy, which was put inside of a crucible and heated to about 800°C. In a different furnace, the reinforcement powders was warmed to 400°C before being weighed on a digital weighing scale [10-13]. The Al alloy metals and reinforcement were then combined, and the temperature was raised to approximately 780°C.The melted grains were continually stirred using a stirrer attached to a motor for 5-7 minutes before being poured into the necessary moulds to create Al-based composites. Several samples were created by adjusting parameters such as stirrer speeds, mixing duration, and weight percentage of reinforcement ingredients. Table 3 displays the parameter levels used in this study, where four parameters were chosen to analyze the mechanical properties, The results of the experiments are summarized in Table 4. Fig. 2 shows the setup for the squeeze casting procedure, where the melting metal was transferred into the appropriate die with measurements of 50*60*85mm3. During the squeeze procedure, a plunger was used to provide 60MPa of

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pressure from the top of the dies for a certain amount of time before the solidified component was removed.

Fig. 1 stir casting steup

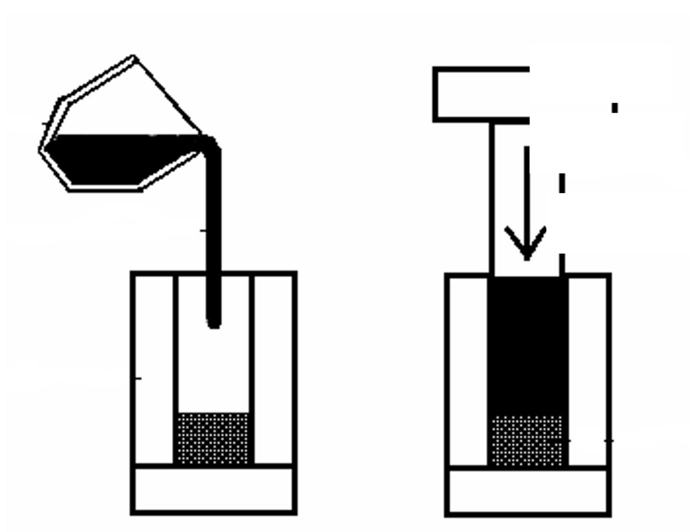

Fig. 2 Squeeze casting setup

Table .1 AA 7475 elements

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
0.6	0.45	0.23	0.9	1.4	0.1	0.23	0.35	Bal

Table 2 Reinforcements properties

Properties	**SiC**	**ZrO2**

Molar mass (g/mol)	54.26	183
Density (g/cm^3)	4.56	4.23
Melting point (°C)	3256	1900

Table 3 Casting Parameters and levels

parameters	Levels			
	1	2	3	4
Stir speed (S)	500	600	700	800
Stir time (T)	15	20	25	30
Reinforcement (R)	2	4	6	8
Squeeze pressure (P)	60	80	100	120

Table 4 Experimental results

Exp. No	Process parameters				Experimental results		
	Stir speed	Stir time	Reinfor cement	Squeeze Pressure	Tensile Strength	Hardne ss	Porosity
L1	500	15	2	60	187.58	85.5	2.9
L2	500	20	4	80	195.27	76.5	3.4
L3	500	25	6	100	200.33	79.5	3.54
L4	500	30	8	120	198.55	72.5	3.43
L5	600	15	4	100	213.32	83.5	3.8
L6	600	20	2	120	255.27	79.7	3.93
L7	600	25	8	60	201.1356	75	4.23
L8	600	30	6	80	255.0856	77.86	3.58
L9	700	15	6	120	278.0556	84.66	4.88
L10	700	20	8	100	207.2556	84.76	3.48
L11	700	25	2	80	208.0656	77.56	4.44
L12	700	30	4	60	227.6056	81.56	3.71
L13	800	15	8	80	285.231	85.9	3.82
L14	800	20	6	60	198.901	82	3.34
L15	800	25	4	120	265.091	80.6	3.12
L16	800	30	2	100	280.661	79.4	2.61

3. Result and Discussion

3.1 Porosity

Both reinforcements densities were calculated to be 4.91 g/cm3 and 4.55 g/cm3, correspondingly. Because there was insufficient interfacial bonding between the Al alloy and the SiC/ZrO2 particles, the amount of porosity in the AMCs varied depending on the density sample. The chosen parameters have an impact on the bonding quality. Figure 3 illustrates the porosity results of all specimens.It was observed that the highest porosity (4.44%) was found in the L16 test, which had parameters of 700rpm stir speed, 25 minutes stir time, 2wt% reinforcements, and 80MPa squeeze pressure. On the other hand, the lowest porosity (2.61%) was noted in the L7 test, with parameters of 800rpm stir speed, 30 minutes stir time, 2wt% reinforcements, and 100 MPa squeeze pressure.

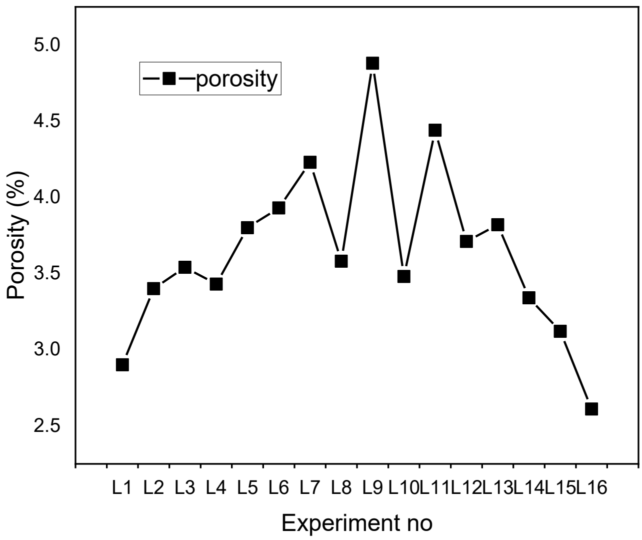

Fig. 3 Porosity result

3.2 Tensile Strength

The fabricated specimens shown in Fig. 4 underwent tensile tests. All specimens were polished and cleaned with abrasive paper to eliminate any debris from the surface before the load was applied [14-17]. The tensile strength (TS) was calculated based on elongation, stress, and strain, and the results are presented in Fig. 5.The findings indicate that the maximum TS (285.23 MPa) was achieved in the L13 experiment, while the minimum TS (187.58 MPa) was observed in the L1 experiment. This variation in tensile strength can be attributed to the applied load, the strengthening effect of reinforcements, and the grain size of SiC. Squeeze pressure and grain refining both contribute to the decrease in the porosity gap. However, the produced composites might have low ductility and brittleness. The discrepancy between the Al matrix and nano-particles at room temperature, along with the hard reinforcements in the matrix.

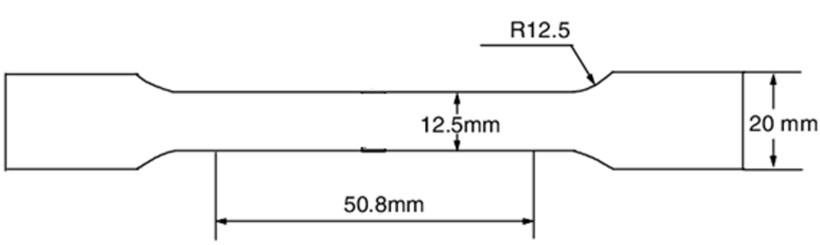

Fig. 4 ASTM B557M Standard-Tensile test

3.3 Hardness

Three trials were performed at different locations on each specimen, and the average value was determined [18-20]. The HN varied depending on the weight percentage of the reinforcement mixed with Al7475.The highest hardness value (85.9 Hv) was obtained in sample L13, with parameters of 800rpm stir speed,[21,22] 15 minutes stir time, 8wt% reinforcements, and 80MPa squeeze pressure. On the other hand, the lowest hardness value (72.5 Hv) was recorded in sample L4, with parameters of 500rpm stir speed, 30 minutes stir time, 8wt% reinforcements, and 120MPa squeeze pressure. The results indicate that increasing the reinforcement and applying higher squeeze pressure contribute to an increase in hardness. Fig. 6 displays the overall hardness readings for all experiments.[23,24]

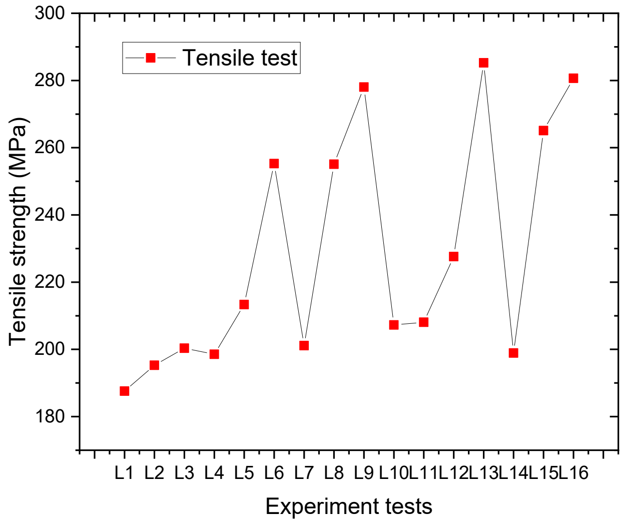

Fig. 5 Tensile test result

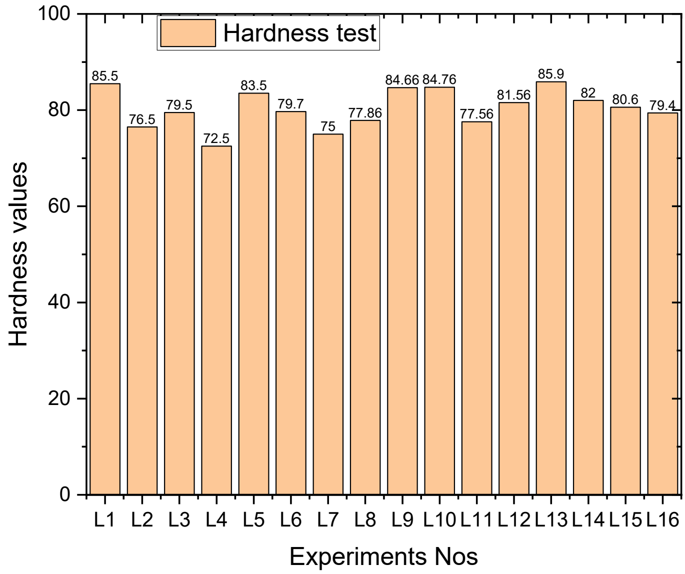

Fig. 6 Hardness observation results

4. Conclusion

- AA7475/SiC/ZrO2 compoites prepared by the Stir and Squeeze method. 4 parameters with 4 levels were selected to produce the Al composites.
- The Taguchi approach (L16) was employed to reduce the number of experiments and determine the parameter combinations for conducting the experiments.
- The highest porosity (4.44%) was observed in the L16 test, with parameters of 700rpm stir speed, 25 minutes stir time, 2wt% reinforcements, and 80MPa squeeze pressure.
- On the other hand, the maximum tensile strength (285.23 MPa) was achieved in the L13 experiment, while the minimum tensile strength (187.58 MPa) was observed in the L1 experiment.
- This difference in tensile strength can be attributed to the applied load, the strengthening effect of reinforcements, and the grain size of SiC.Moreover, the results indicate that increasing the reinforcement and applying higher squeeze pressure contribute to an increase in hardness.

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