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Mechanical Properties of 7075 Aluminum Alloy Matrix/Al_2O_3 Particles Reinforced Composites

Abstract-*7075 Aluminum alloy metal matrix composites (MMC_s) with different wt % of Al_2O_3. (0.2, 0.4, 0.6, 0.8, and 1), the size of reinforced particles is 10 Nano meter , were fabricated using stir casting technique. The influence of adding Al_2O_3 particles content on the mechanical properties of the MMC_s. It was observed that the nanomaterial reinforcement led to high improvement in BHN hardness ultimate strength (σ_u), yield stress (σ_y) and ductility. The improvements were due to regular distribution of Al_2O_3 and refinement of aluminum 7075 grains. The maximum improvement in BHN hardness, σ_u and σ_y was observed at 0.2 wt %. Al_2O_3. While the minimum value of ϵ % was obtained at 0.2 wt % Al_2O_3.*

Keywords- *7075 Al. matrix, Al_2O_3 nanomaterial, stir casting method MMC_s , mechanical properties (MMC_s).*

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1. Introduction

Aluminum alloys is one of the most important industrial alloys, and due to toughness, ductility and strength. Aluminum matrix composite is being advance-engineering materials. The aluminum alloys is very low density, which can be used in many applications by strengthened with nanoparticles like Al_2O_3, SiC etc. This alloys replaced Bronze and Cast iron to it high resistance of wear. In addition, these alloys are widely used in aircraft like (7075) [1].

By using Aluminum alloys, the mass can be lowered by 50%, which makes it, increased the speed or the load carrying capacity and enhances the stability, Aluminum alloys are acceptable for plastic working and wieldable, The Aluminum – Zn-Mg alloys like (7075) is higher strength property e comparative. With Aluminum–Mg alloys [2]. Depending on tensile test for applications of selection material, material specifications and quality ensures, developing new material can be compare to others different materials, the tensile test usually used to predicts the material beavers more than other permit analysis [3].

Akbari et al. [4] used A356 reinforced by nano Alumina particles added into Aluminum molted used stirring speed 450 r.p.m.and 850 c for casting and stirring time period. Cast iron mold for composite, the heat treatment is 8 hour at 495 c and at 520 c is 2 hours, water quenching and artificiality aged, the tensile and hardness increased.

Ezatpour et al. [5] used Al6061 and Al_2O_3 by stir casting, the Nano material is heated tell 550 c, using planter machine weight ratio (8:1) and steel balls of (8-10mm) Argon gas used to melt when injections composite powder and hydraulic press, heat treatment is 550 quenching in water and aged time 2 hours and 3 hours .the increased in Nano increased the porosity and decreased the porosity of extrusion.

Sajjde et al. [6] investigated the properties of Aluminum reinforced by micro or Nano Alumina used 20un and 50um heated to 1100 c injected with Argon gas in 200r, 300 and 450 rpm speed of stir, find that the porosity increased by increased Al_2O_3 ratio, and the stirring speed increased porosity in nano more than micro particles composite. Anasry et al [7] investigated Aluminum alloys composite with MgO by stir casting A356 with different ratio of nanoparticles at 800, 850 and 950 c, hardness is increased by increased the ratio of nanoparticles and temperature of stirring cast.

Bharath et al. [8] tested 6061 Al-alloy-Al_2O_3 composites with two different wt% of Al_2O_3 i.e. (6% and 9%) and they found that the mechanical properties of the composite increased with

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increasing the wt % Al_2O_3 nanomaterial while the ductility was less compared to the Al. matrix. Maazahery et al. [9] studied the A356 Al-Al_2O_3 composites using (0.75, 1.5, 2.5, 3.5 and 5 vol%) of Al_2O_3 particles at 800 °c, 850 °c and 950 °c. the concluded remarks were , the hardness (BHN), the ultimate tensile strength and ductility of composites improved with increasing the vol% of Al_2O_3 and the maximum (BHN) occurred in 2.5 vol% of Al_2O_3 composites at 800 °c. Therefore the main purpose of this work is to study the influence of adding fire wt% of Al_2O_3 of 10 Nanometer size to 707 Al. alloy for fabricating the MMC_S composites , on the mechanical properties of the composites i.e. hardness, ultimate tensile strength, yield strength and ductility. In addition, comparison between the present results with other workers is made.

2. Experimental Method

The stir casting method was adopted to fabricate the 7075 Al/Al_2O_3 composites (MMC_S). Before introducing the Al_2O_3 material with 10 Nanometer dimension, into the melt they were preheated to 200°C. Five wt% of Al_2O_3 were used i.e. (0.2, 0.4, 0.6. 0.8 and 1). The stirring speed was 450 rpm and the casting temperature was 850 °C using the metal die casting [4]. The above procedure was done by nanocomposites manifesting device shown in Figure 1. The procedure of the manufacturing described by the following steps:

- Aluminum alloys are cutting into cubes [1-2] cm^3, it is washed parts resulting from the cutting process with alcohol and distilled water several times (3-5 times).
- Dry the parts washed steam of hot air to temperature of 100°C.
- Dried parts are heated 200°C by an electric heater.
- The oven lids lifted and loaded parts resulting from the heating process from the top and close the lid tightly. Air is withdrawn from the oven by vacuum.
- Alarcon gas is pumped into the oven and heat the oven to 800°C.
- The addition of nanomaterial's to the molten Aluminum Alloy with gas pump.
- After rotate for several minutes is poured molten metal in the mold to obtain the final product.

3. Material Used

The matrix metal for current work is 7075 Al alloy the chemical composition of the matrix is shown in Table 1 the specimens is analyses was down in company for Inspection and Engineering Rehab ration (CIER) .

The nanomaterial used in this study is Al_2O_3 which has good thermal stability, high hardness and wear resistance and this reinforcement was chosen because, up to now, Al_2O_3 particles is the most commonly used with Al matrix to generate the metal matrix composition MMC_S.

The specimen surface were grinded by 200 , 300, 500, 800, 1000, and 1200 grit paper and then polished by 2 μm diamond paste in order to measure the surface roughness. The chemical composition of Al_2O_3 in wt% are shown in Table 2**.** The roughness measurements were listed in Table 3. To study the mechanical properties characterizations of the matrix and composite the tensile tests were performed using three tests were done for each wt% of Al_2O_3. The average reading was adapted. Note that, the above results are for one group of tensile specimens while the other two groups are not mentioned.

4. Experimental Results and Discussion

I. Hardness test results

Figure 2 shows the experimental results of Brinell hardness against the weight percentage of Al_2O_3 particles. It is clear that a significant increase in hardness of the MMCs when adding the Al_2O_3 particles.

The above figure revealed that the hardness of the MMCs specimens increased with increasing the weight percentage of the reinforcement material except the value of 0.6 wt. % which shows reduced in BHN and the reason may be the MMCs has high porosity and the Al_2O_3 particles haven't uniform distribution leading to weak BHN compared to others value of Al_2O_3. .Bharath et al [8] concluded that increasing of Al_2O_3 wt. % resulting in increase of VHN hardness of 6061 Aluminum based composite.

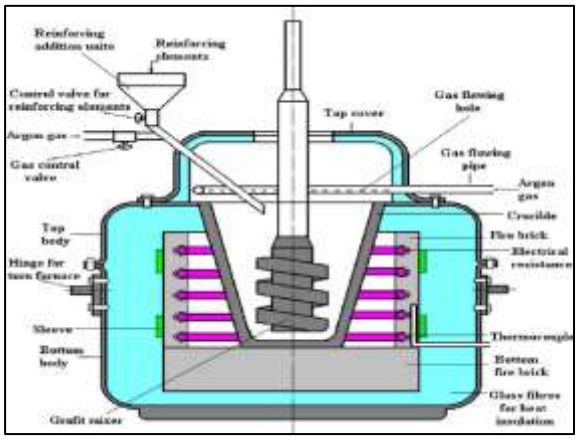

Figure 1: X Manifesting device for manfuracting the MMC_S composites

Mohson et al [10] tested MMCs composite of the Al-Si Aluminum alloy as a matrix .They found that the BHN hardness increased with increasing the vol. % Al_2O_3 but the hardness was absented at 3% volume Al_2O_3.

The high BHN is found at 0.2 wt. % Al_2O_3 and the high hardness may be coming from the high hardness of nanoparticles itself which attributed positively to hardness of composites [8].

Comparison has been made for four studies used Al_2O_3 nanomaterial as given in Table 4. It is clear that the Nano material structures have the ability to create new features and improved the mechanical properties. The improvement may due to their good properties of Al_2O_3, e.g. high hardness, good stability, high optical sensitivity and high mechanical properties [11].

Table 1: Chemical composition of Al 7075, wt%

Components	Element Wt%
Zinc	5.5
Magan	2.4
Silicon	0.2
Copper	1.4
Iron	0.3
Titanium	0.1
Manganese	0.2
Chromium	0.21
Zirconium	-
Tungsten	-
Aluminum	Balance

Table 2: The chemical composition of Al_2O_3 in wt% [10]

Element	Wt%
CaO	1.1
TiO_3	1.8
Fe_2O_3	0.8
α-aluminum	93
Other	0.02

Table 3: Average Roughness results of tensile specimens

Specimen No.	Ra (μm)	Rt (μm)
1	0.7	2.1
2	0.9	2.4
3	0.55	1.8
4	0.8	1.9
5	0.61	1.55
6	0.45	1.21

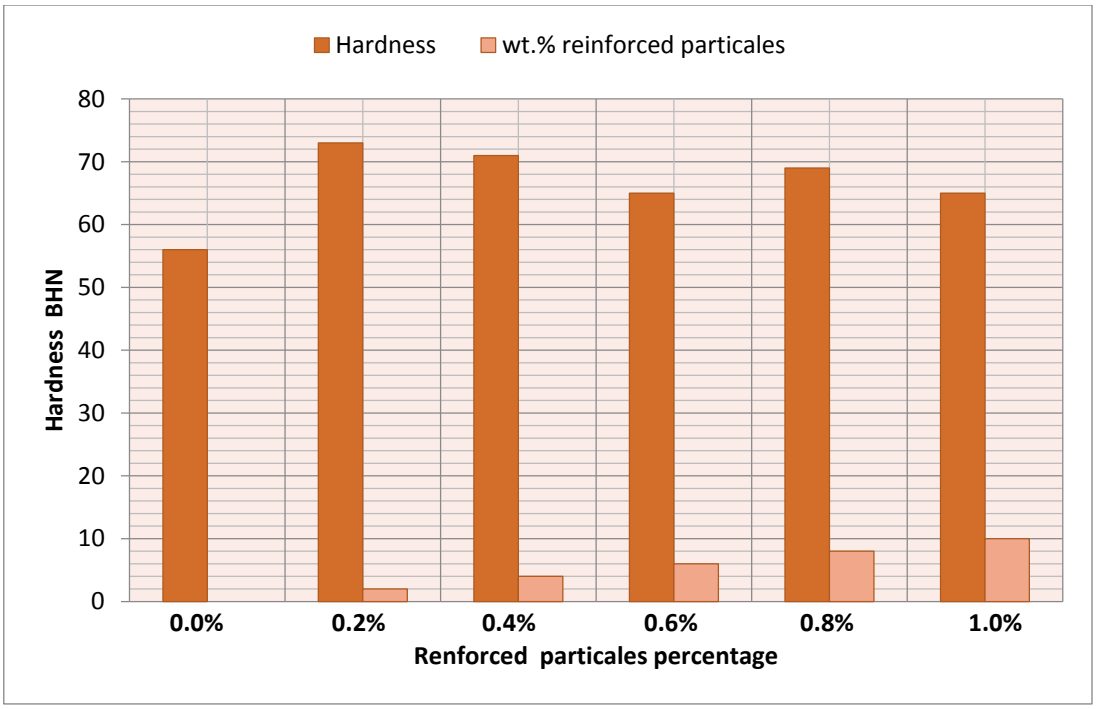

Figure 2: Hardness (BHN) against Al_2O_3 wt% , average of three attempt testing

Table 4: Comparison between the hardness of the present work with three previous workers

Workers	matrix	Zero% wt	0.2% wt	0.4% wt	0.6% wt	0.8% wt	1.0% wt	Reinforcement
Present work	7075Al alloy	56 BHN	73 BHN	71 BHN	65 BHN	69 BHN	65 BHN	Al_2O_3
Bharath [8]	6061Al alloy	Zero % wt		6 % wt		9 % wt		Al_2O_3
		93.67 VHN		104.7VHN		145.67 VHN		
Mohsen [10]	Al–SiAl alloy	Zero %	1% vol.	2% vol.	3% vol.	4% vol.	5% vol.	Al_2O_3
		52 BHN	62 BHN	70 BHN	75 BHN	73 BHN	72.2 BHN	
Alalkawi [12]	2017Al alloy	Zero%	0.3% wt	0.5% wt	0.7% wt	-	-	Al_2O_3
		136 VHN	144 VHN	132 VHN	140 VHN	-	-	

II. Tensile strength

Table (5) gives the tensile strength results with different wt% of the reinforced material. it is clear that the tensile strength values of MMCs for all the amount of wt% Al_2O_3 is larger than the matrix compared to the as cast 7075 Al. alloy excepted the value of 0.6% . The results of Бu in comparison with other workers are also made as given in Table 5.

The tensile strength results obtained from the experimental work observed that the tensile strength .of the MMCs increase with increasing the amount of Al_2O_3. The higher tensile strength of the MMCs could be attributed to the fact that Al_2O_3 particle act as obstacles to the movement of dislocation [2]. Kok reported that the introducing Al_2O_3 into the aluminum matrix resulted in raising the mechanical properties. The compression of the results tableted above shows some MMCs in the recent work and Reference [11] exhibit slightly reduced in ultimate stress and yield stress and the reason may be coming from the following;

1. The distribution of Al_2O_3 in metal matrix is not completely uniform.
2. The porosity of MMCs is relatively high compared to others MMCs.

Table 5: Ultimate strength results in comparison with three previous researches

Recent work		**Reference [8]**		**Reference [10]**		**Reference [11]**	
Wt% of AI_2O_3	Бu (MPa)	Wt% of AI_2O_3	Бu (MPa)	Vol.% of Al_2o_3	Бu (MPa)	Wt% of Al_2o_3	Бu (MPa)
0.0	228	3.0	149.76	0.0	125	0.0	450
0.2	245			0.75	165	0.3	472
0.4	236	6.0	167.93	1.5	184	0.5	400
0.6	165			2.5	175	0.7	462
0.8	238	9.0	173.61	3.5	162	-	-
1.0	216			5.0	160	-	-

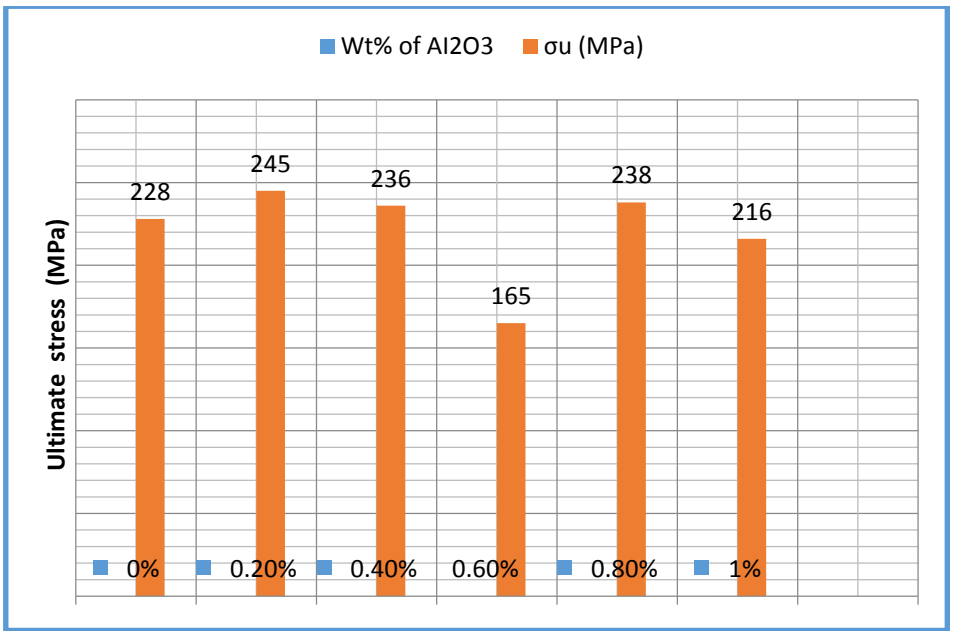

Figure 3: Variation of Ultimate tensile strength against Al_2O_3 wt %

For the present work and Ref [8], Ref [10], it is reported that the ultimate tensile strength of nano composites is enhanced with an increasing in the Al_2O_3 wt.% or vol.% .The experimental analysis of the current research showed that the highest ultimate tensile strength occurred with 0.2 wt.% of Nano particles Al_2O_3 .while Mohsen et al [10] found that the highest ultimate tensile strength with 1.5 volume % Al_2O_3. Bharath et al [8]. obtained the best ultimate strength of Al_2O_3 with 9 wt.% of Al_2O_3. Al-alkawi et al [12] concluded that the higher ultimate strength was obtained with 0.3 wt.% Al_2O_3.

III. Yield strength

Yield strength (Бy) shows an increasing trend compared to as cast 7075 Al Yield strength is extracted from the stress-strain curves and are plotted in Figure 4.

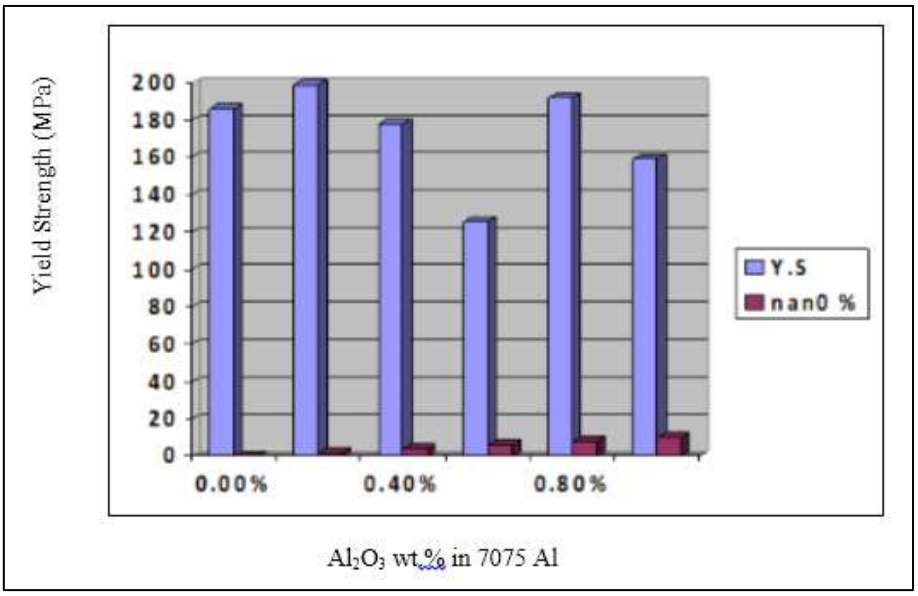

Figure 4: Yield strength of MMCs composite against wt% of Al_2O_3 in 7075 Al

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Bharath et al [8] found that the yield strength of nanocomposite increased when the wf% of Al_2O_3 increased. The best improved was occurred at 9wt % of Al_2O_3 showed highest value of yield strength .Al-alkawi et al [12] found that the 0.3 wt% realved best valve of yield strength. The increasing in the mechanical properties may be due to increasing of dislocations density of the matrix leading to increasing the strength of composite [13]. In addition, the mechanical properties increment can also be attributed to reduce the microstructure grain diameter. While at 0.6% the mechanical, the lower mechanical properties may be due to the high porosity levels of composite and should be kept to minimum. Porosity arises due to gas entrapment during mixing [13[. Al-Alkawi et al [12] noted that the ductility of MMCs almost remain constant with increasing the wt % of Al_2O_3.
Properties are reduced and the reason may be due to weak bonding between Al_2O_3 and matrix with high porosity.

5. Ductility

The ductility was calculated from the failed specimens after fracture and Table 6 illustrates the comparison between the present results with Reference [8]. The ductility at 0.6 wt. % Al_2O_3 may be due to irregulation distribution of Al_2O_3 in the metal matrix and the high porosity compare to the others metal matrix composite [13].

Table 6: A comparison of present work with Ref [8]

Present work ,7075 Al matrix			**Reference [8], 6061Al matrix**		
Wt % of Al_2O_3	Ductility %	Method	Wt % of Al_2O_3	Ductility	Method
0.0	18	Stir Casting	0	15.16	Stir Casting
0.2	12				
0.4	14		6	10.69	
0.6	17.5				
0.8	13		9	8.34	
1.0	15				

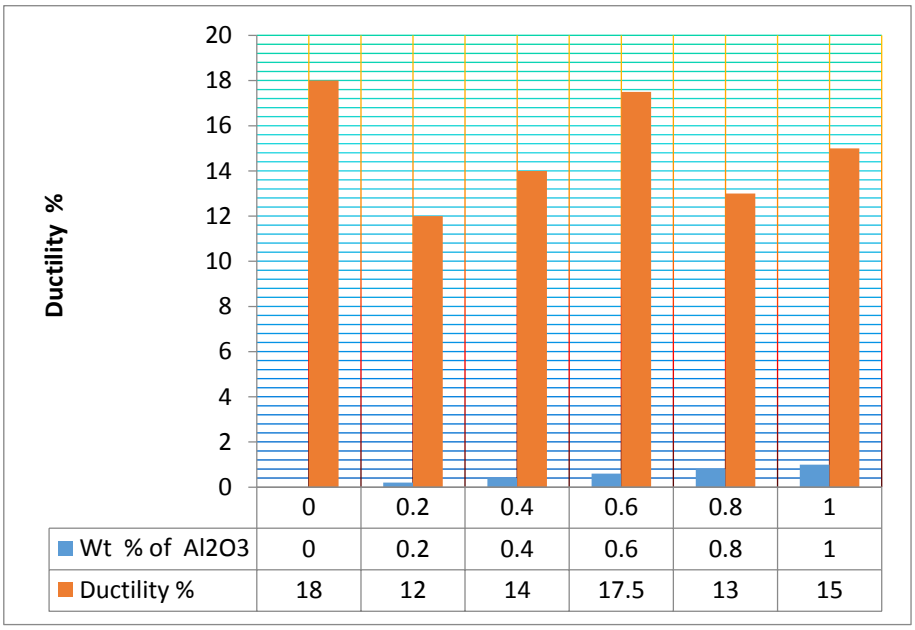

Figure 5: Variation of Ductility against Al_2O_3 wt. %

6. Conclusions

From the experimental analysis, it can be concluded that;

1. Tensile strength of 7075Al nanoparticles composite was higher than to as cast 7075Al, the highest value of Tensile strength was observed at 0.2 wt% of Al_2O_3.
2. It was obtained that the BHN hardness of composite specimens was higher compared to the 7075Al without nanoparticles. The best BHN was reviled at 0.2 wt% of Al_2O_3.
3. Yield strength of 0.2 wt% Al_2O_3 showed great value of yield strength compared to 7075 Al.
4. Ductility was observed to be improved when adding the nanoparticles Al_2O_3.the lowest ductility was obtained at 0.2 wt% of nanoparticles.

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