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Characterization of AA 6061–Alloy Composites Reinforced by Al_2O_3 Nano Particles Obtained by Stir Casting

Abstract *The aim of this work is generated a Nano materials having good mechanical properties for 6061AA-alloy.Fivewt% of Nano particles (Al_2O_3) (20-30nm grain size) were adoptees (1, 1.5, 2, 2.5 and 3wt% AL_2O_3).The Nano composites were manufactured by stir casting technique. The mechanical properties of Nano composites were obtained at room temperature and was found that the matrix hardness is improved by 35.36%, matrix ultimate by107%, yield by36.84% and ductility by 12% at 1.5wt% AL_2O_3.Also it was obtained that all the mechanical properties of the Nano composites are higher than that of metal matrix. The above improvements are due to less porosity, high uniform distribution and good bounding between metal matrix and Al_2O_3.*

Keywords *AA6061-alloy / Al_2O_3 / nano composites, mechanical properties, stir casting.*

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1. Introduction

The nano composites represent a new The Nano composites represent a new field of materials which used in industrial engineering in which the Nano reinforced material is incorporated in to the composites to enhance its mechanical properties such as strength ,elastic modulus ,corrosion resistance and wear resistance . The Nano material used (Al_2O_3) is found to be potential reinforcement due to very good mechanical, physical and electrical properties [1].

2. Reinforced Nano material on Aluminum metal matrix

Hamid et al. [2] tested AA6061–Al_2O_3 Nano composites, which were fabricated by stir casting. There nano composites were extruded at 550˚C as a secondary process to reduce the agglomeration and porosity leading to improve the bounding process.

The micro structures of the Nano composites after extrusion were examine d and it was found that a decrease in porosity and uniform distribution of nano alumina was observed which in turn led to improve the ductility ,strength and hardness.

Emal and Eman [3] fabricated nano composite (AA7075-SiCp) using stir casting method and found that there was increase in hardness and strength by 10% when compared to 6061 AA-alloy. Tabandeh et al. [4] used ultrasonic casting technique for nano composite 2wt% Al_2O_3 (10nm) with aluminum alloy. The mechanical properties were compared with the metal matrix and it found that an increase in hardness by 92% and yield strength by 56%.

Another study done by Sajjadi et al [5] used 2wt% Al_2O_3 as a nano material which improved the hardness by 50%, yield strength by 66% and ultimate strength by 80%.

EL-Mahallawi et al. [6] studied the Nano composites mechanical properties using AL_2O_3, TiO_2 and ZrO_2 as nano particles of 40nm to A356AL .cast. The weight percentages were from (0-5%) with different stirring speed ranging (270, 800, 1500, 2150 rpm) with stirring time of 1 minute. It was found that, the best mechanical properties were found at stirring speed 1500 rpm and if the speed increased this value causes reduction in the tensile strength The composites A356-2wt% Al_2O_3 gave the best mechanical properties when compared with A356 -3% ZrO_3 and A356-3% TiO_2 composites. Bharath et al. [7] manufactured AA6061-Al_2O_3 composites with 0,6 and 9wt% Al_2O_3 using stir casting method. These composites were tested under tensile tests the experimental results revealed that the VHN (hardness) improved from 93.67(0wt %) to 104.7(3wt %) and 145.67(6wt %).While the tensile strength improved by 12.13% and the yield stress enhanced by 12.95% at 9wt% Al_2O_3. The ductility reduced from 15.16 to 8.34 at 9wt %

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Al_2O_3. Mahazahery and Mohsen [8] examined the mechanical properties of the A356Aluminum alloy-SiC particles composites and they observed that the addition of 3.5% SiC showed highest strength and yield stress while reduction in ductility was obtained. Al-alkawi et al [9] studied the Nano composites of 2017 metal base fabricated by stir casting. It was found that the HV (Vicker hardness) was improved by 5.88% the ultimate by 4.88% and the yield by 0.79% at 0.3wt% of Al_20_3 while the ductility almost remain constant.

Lakhnir Singh et al. [10] studied the influence of adding Al_2O_3 particles content on the mechanical properties of the metal matrix composites by used aluminum with various weight of the Al_2O_3 i.e.(3,6,9wt%). Anasry et al. [11] they studied the alloying technique of alloying of AA-alloy compounds with MgO for various ratios of Nano particles in (800,850 and 950)ºC to increase the hardness by increasing the ratios of adhesive material. Reddy [12] investigated the Nano composites aluminum based metal with (10%,20% and 30%) vol fraction using stir casting technique. It was concluded that the mechanical properties of composites increase with the volume fraction while the ductility decrease. Also the fatigue properties were observed to be improved. The aim of this study is to investigate the effect of different wt% of Al_2O_3 nano particles (20-30nm) an mechanical properties such as Brinell hardness, Ultimate strength, Yield stress and ductility.

The section below describes the material used, its chemical and mechanical properties and the preparation of composite with the mechanical testing.

3. Materials Used

I. Metal matrix

The matrix metal used for the current work is 6061 AA-alloy, which is widely used in different applications such as transport. Auto motive, aerospace, military and electricity industries. The chemical composition compared to the standard is given in Table 1. The standard chemical analysis was taken from Ref [7] while the experimental analysis was done at SIER(state company for inspection and engineering rehabilitation in Iraq) The physical and mechanical properties of 6061 AA-alloy can be shown in Table 2.

II. Nano material

The reinforcement material used in this work is Al_2O_3. The physical and mechanical properties of the Alumina Al_2O_3 is given in Table 3.

The experimental testing 0f the present work was done in the university of Ibn al-Haytham

III. Rule of mixture

Table 4 shows the rule of mixture using 6061 AA. alloy as a metal matrix.

IV. Preparation of composites

The stir casting method has been adopter for fabricating the composites as follows:

1-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).

2-Dry the parts washed steam of hot air to temperature of 100ºC.

3-Dried parts are heated to 200ºC by an electric heater.

4-The oven lids lifted and loaded parts resulting from the heating process from the top and close the lid tightly. Air is with drawn from the oven by vacuum.

5-Alarcon gas is pumped into the oven and heat the oven to 800ºC.

6-The addition of nanomaterial´s to the molten Aluminum alloy with gas pump.

7- preheated the AL_2O_3 particles to 250ºC.

8-The furnace temperature was first raised above the liquid temperature of Aluminum near about 850ºC to melt the Aluminums alloy completely and was then cooled down just below 650ºC.

9- The stirring time designed for 10 minutes at 450rpm.

10- Adding the AL_2O_3 particles to the furnace.

11-Raising the temperature of the mixing to 850±10ºC.

Table 1: Chemical composition of 6061 AA-alloy in wt%

Element	wt% standard	wt% experimental	element	wt% standard	wt% experimental
Chromium	0.01-0.35	0.22	Silicon	0.4-0.8	0.66
Titanium	Max 0.15	0.09	Zinc	Max 0.25	0.17
Iron	Max 0.7	0.52	Manganese	Max 0.15	0.11
Magnesium	0.8-1.2	0.98	Others	0.05	_
Copper	0.15-0.4	0.31	Aluminum	Balance	Balance

Table 2: Physical and mechanical properties of 6061 AA-alloy

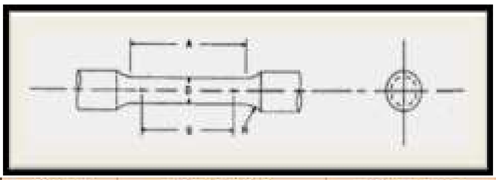
Metal matrix	Density gm/cm^3	Hardness HB500	Tensile Strength(MPa)	Elastic modulus	Yield stress(MPa)	-
AA 6061 alloy	2.7	30	115	75	96	Ref [7]
	2.7	31	112	73	98	Current work

Table 3: Physical and mechanical properties of Al_2O_3 nanomaterial

References	Density gm/cm^3	Grains size (nm)	Hardness HB500	Tensile strength (Mpa)	Elastic modulus (Gpa)
[7]	3.7	-	1175	2100 compression	300
Present Work (experimental)	3.62	(20-30)	1205	2018 compression	297

Table 4: Rule of the mixture used in this work [1]

AA 6061 Alloy (gm)	wt% AL_2O_3	AL_2O_3 (gm)	AA 6061 alloy (gm)	wt%AL_2O_3	AL_2O_3(gm)
1000	0	0	980	2	20
990	1	10	975	2.5	25
985	1.5	15	970	3	30



Symbol	Descriptions	Dimensions (mm)
D	Diameter	9
G	Gage length	36
R	Radius of fillet	8
A	Length of reduced section	45

Figure 1: Tensile specimen

V. Tensile tests and specimens

Tensile tests were performed using computerized tensile testing rig. The tensile specimen is given in Figure 1. All the tensile tests were done at University of Technology, Materials Engineering Department using (test machine WDW-100) with maximum capacity of (100KN).The material of the specimens was received as 16mm in diameter and (10mm) in length from the cast molds. Five tensile specimens were examined for each run and the average readings are presented in the experimental results.

VI. Roughness test

Surface roughness, average and peak roughness were measured using roughness tester type (pocket surf by Mahr with limitation 2.9±0.005) which is worked according to ISO1320. The values of roughness were listed in Table 5. which are recorded accordance to ISO1320 [2].

Table 5. Roughness results for 15 tensile specimens

Specimens No.	Ra (µm)	Rt (µm)
1	0.8	1.82
2	0.91	1.78
3	1.1	2.06
4	1.12	1.77
5	0.65	8.05
6	0.82	2.25
7	1.06	2.6
8	1.15	1.91
9	0.77	1.78
10	0.82	1.9
11	0.96	1.88
12	1.07	1.68
13	1.18	2.5
14	1.4	3.1
15	1.27	2.8

VII. Hardness test

Brinell hardness test was carried out using the CMS-51 hardness tester Before testing polished the specimen by (200, 400, 600, 800, 1000 and 1200) emery papers .The applied load is (1500kgf) for (10 to 15 seconds) with ball diameter 2.5mm.The Brinell hardness results for five readings using the as –cast specimens zero nanomaterial is shown in Table 6.

Table 6: Brinell hardness results for as –cast specimens

	1	2	3	4	5	Average
Brinell Hardness(BH)	83	86	85	89	87	86

3. Results and discussion

I. Hardness results

Fig.3 illustrates the Brinell hardness results of 6061 AA- alloy (as-cast) and the6061 AA-alloy composites (1,1.5,2,2.5,3wt%) ofAl_2O_3.

Fig 2 shows significant increase in hardness which can be seen with the addition of Al_2O_3 reinforcement material. It is revealed that ,the maximum increase in HB was occurred at 1.5wt% of Al_2O_3 but all the values of composites are greater than that of metal matrix .

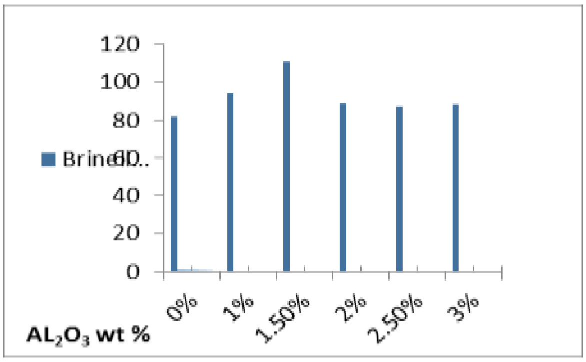


Figure 2: The HB. Hardness as -cast AL_2O_3 wt%

1. The high mechanical properties of Al_2O_3espically the high hardness itself could be the main factor I for increasing the hardness of composite. Baharath et al [7] measured the hardness of Al_2O_3 and they found it about 1175(HB500).

2. The less amount of porosity and uniform distribution of Al_2O_3 leading to raise the hardness. This finding is in well agreed with what it found by Tsakiris [12].

3. The thermal mismatch between the base metal and the Al_2O_3particles is the main factor for increasing the density of dislocation leading to increase the hardness and strength [13].

II. Tensile strength

Fig 3 shows the stress- strain curves for six types of specimens starting from zero Al_2O_3, 1%, 1.5%, 2%, 2.5% and 3%wt of Al_2O_3. It is clear that in case of composites the tensile was greater than the as –cast and it was observed that the ultimate strength of all the composites are higher that the zero Al_2O_3. The maximum improvement percentage was occurred at 1.5% Al_2O_3 that is equal to 107%.

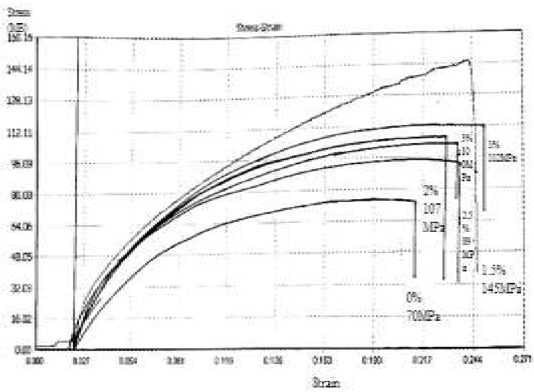


Figure 3: The tensile strength results for six specimens with different wt% of Al_2O_3

Table 7: Tensile strength results obtained from the experimental results.

Zero AL_2O_3	**1%**	**1.5%**	**2%**	**2.5%**	**3%**
70Mpa	112Mpa	145Mpa	107Mpa	89Mpa	100Mpa
-	60%	107%	52.85%	27.14%	42.85%

Table 8: Yield stresses for six specimens of different nanomaterial

Zero AL_2O_3	**1%wt AL_2O_3**	**1.5%wt AL_2O_3**	**2%wt AL_2O_3**	**2.5%wt AL_2O_3**	**3%wt AL_2O_3**
38Mpa	44Mpa	52Mpa	47Mpa	40Mpa	45Mpa

Table 9: Ductility various the wt% amount of Al_2O_3

Zero Al2O3	**1% AL2O3**	**1.5% AL2O3**	**2% AL2O3**	**2.5% AL2O3**	**3% AL2O3**
14	13	12.5	13	13.8	13.5

The main reasons of the above enhancement may be due to the following

1. Increasing the dislocation density due to good bounding between the metal matrix and Al_2O_3 [7].

2. Homogenous dispersion of Alumina oxide in the nano composites leading to improve the tensile strength [14].
3. Little porosity and uniform distribution of Al_2O_3 resulting in enhancement of tensile strength [15]

III. Yield stress
Table 8 presents the experimental yield stresses (Proof stress) for six specimens using the offset method 0.2% strain.
It is clear that the yield stresses of composites are higher than that of as –cast and the highest yield stress was found at 1.5% wt of Al_2O_3 The best of the composite is 36.84% occurred at 1.5wt% of Alumina oxide .
The above improvement may be coming from the same reasons mentioned for tensile strength improvement [16].

IV. Ductility
Ductility of the six specimens after fracture was calculated from the broken specimens shown in the Table 9.
The above table shows the ductility lower than the unreinforced material and this finding coin side with the finding of Baharath et al. [7]. The best improvement was happened at 1.5% Al_2O_3 which indicates the ductility reduce from 14 to 12.5 which gives 12% enhancement in ductility due to addition the nano Al_2O_3.

4. Conclusions

The following conclusions can be derived from this work.
1. Mechanical properties were improved when adding the nanomaterial Al_2O_3. The best improvement percentage (IP) for (HB) hardness was 35.36%, ultimate 107%, yield 36.84% and ductility 12% at 1.5%wt AL_2O_3.
2. ALL the mechanical properties mentioned above for nano composites were higher than that of unreinforced metal matrix.
3. The less porosity and uniform distribution of Al_2O_3in 6061AAgenerated good mechanical properties of nano composites.

References

[1] A. Mazahery, H.R. Baharvandi, H. Abdizadeh, “Development of high performance A356-nano AL_2O_3 composites, Mater. Sci. Eng. 518, 23-27A, 2009.

[2] R.E. Hamid, A.S. Seyed, H.S. Mohson, H. Yizhong, “Investigation of microstructure and mechanical properties of AL6061-nanocomposite fabricated by stir casting " Material and Design, 55, 921-928, 2014.

[3] E.N. Amal, E.N. Eman, “Properties of aluminum matrix nanocomposites prepared by powder metallurgy processing,” Materials Today, Proceeding 2, 3403-340, 2015.

[4] K.M. Tabandeh, J.S. A.Jenabal, M.M. Moshkar, “Mechanical properties of tri-Modad AL-matrix composites reinforced by nano-and submicron-sized AL_2O_3 particulates developed by wet attrition milling and hot extrusion,” Materials and Design, Vol. 5, No.10, 1-16, 2010.

[5] S.A. Sajjadi, H.R. Ezatpour, M.P. Torobi, “comparison of microstructure and mechanical properties of A356 Aluminum alloy /AL_2O_3 composites fabricated by stir and compo- casting process,” Materials and Design Vol. 54, 106-111, 2012.

[6] I.S. EI-Mahallawi, A.Y. Shash, E.A. Amer, “Nano reinforced cast AL-Si alloys with AL_2O_3, TiO_2 and ZrO_2nano particles,” Metals, 5, 802-821, 2015.

[7] V. Bharath, N. Mahadev, V. Auradi “Preperation characterization and mechanical properties of AL_2O_3 reinforced 6061AL particulate MMCs,” International J. of Eng. Research and Technology, Vol. 1, No. 6, 2012.

[8] A. Mazahery, O.S. Mohsen, “Characterization of cast A356 alloy reinforced with nano SiC composites,” Irons. Nonferrous Met. Soc. China 22,275-280, 2012.

[9] H.J. ALalkawi, S.F. Abdulkaim, H.F. Abdul-ridha, “An experimental investigation for some mechanical properties of aluminum matrix composites reinforced by AL_2O_3 nano particles,” J. of Eng. and Technology – Accepted for publication, 2017.

[10] L. Singh, B. Ram, A.D. Singh, “Optimization process parameter for stir casted aluminum matrix composite using Taqchi, 02, 08, 2013.

[11] K.A. Anasry .M, Morhzan, H. Balaruil, Microstructure and mechanical properties of aluminum alloy matrix reinforced with nano particles MgO,” Joumal of Alloys and Composition, 484, 400-404,2009.

[12] A. Chennakeasava Reddy, “Mechanical properties and fatigue behavior of 6061, SiC_P metal matrix cast by low pressure die casting process,” Journal of Manufacturing Technology Research, 1, 273-286, 2009.

[13] Designation, F10/E10M, “Standard test methods for hardness Testing of metallic materials,” ASTM International, 2017.

[14] M.A.A. ALjaafari, “Cryogenic treatment effect on fatigue behavior of fatigue behavior of nano composite, Ph.D Thesis, University of Technology, 2017.

[15] H.J.M. ALalkawi, F.A. Shereen, F.A. Haneen, “An experimental investigation for some mechanical properties of aluminum–matrix composites reinforced by AL_2O_3 Nano –particles,” J. of Eng. and Technology, accepted for publication, 2017.

[16] V. Tasakiris, W. Kapped, E.G. Alecu, F. Albu, F. Grigore, V. Merinescu, M. Lungu, “Characterization

of AL.matrix composites reinforced with aluminum nano particles obtained by PM method," J. of Optical Electronics and Advanced Materials, Vol. 13, No. 9, 1172-1175, 2011.

[17] K.B. Rasesh, K. Sudhir, S. Das, "Fabricated and characterization of 7075 AL-alloy reinforced with SiC particles," Inter. J. of Advanced Manufacturing Technology, Vol. 65, 611-604, 2013.

[18] S. Ajay, K. Loxe, C. Mohite, N. Om, S. Pallaw, S.B. Piyush K. Chandra, A. Som, "Manufacturing of AMMCs wing stir casting process and testing its mechanical properties, Inter. J. Advance Eng. Tech., 26-29, 2013.

[19] H.J.M. ALakawi, F.A. Shereen, F.A. Haneen, "An experimental investigation for some mechanical properties of aluminum matrix composites reinforced by AL_2O_3nano particles," J. of Eng. and Tech. Accepted for publication, 2017.