International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 6, June-2018

EFFECT OF EQUAL CHANNEL ANGULAR PRESSING ON THE MECHANICAL PROPERTIES OF AL 4032–SiO_2 NANO COMPOSITE MATERIAL

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Abstract*— The objective of the present study is to analyze the effect of Equal Channel Angular Pressing (ECAP) on the mechanical properties of Al4032–SiO_2 composite. These composites have been prepared by stir casting route in which the weight % SiO_2 nano particles are 0.25, 0.5, 0.75 and 1wt%.The ECAP process is done at a room temperature using a die with channel angle of 105^o and corner angle 30^0. The influence of ECAP on mechanical properties of Al4032 –SiO_2 composite is evaluated. In general in any composite the distribution of reinforcement particles can be observed with the micro-structural examination, but the effect of ECAP will be there on the mechanical properties of composite, so that here we have taken the evolution of Al4032-SiO_2 mechanical properties before and after ECAP process. As the agenda of ECAP is to improve the mechanical properties we have observed the great improvement in the mechanical properties.

Keywords*— AL 4032, SiO2, Composite Material, Stir-Casting, ECAP, & Mechanical Properties.

I. INTRODUCTION

From the past few years, many of the researchers are focused on finding the light weight and better performance materials to replace the existing heavy weight materials [14,15]. The aluminium alloys (Al4032) are widely used for manufacturing the internal combustion pistons in place of cast iron and other heavy weight materials [1,3], because of their lesser weight[14,15]. Some of the researchers prepared the Al base metal matrix composites reinforced with SiO_2 to enhance the mechanical properties [2,14,15]. To prepare the composite material people choose a best and easy process called stir casting process [4,5]. This process is widely used to prepare the composite materials.

But the major problem is dislocations or porosity or defects those occur in the composite material while casting. These defects reduce the strength of the materials. To overcome this issue we have advanced technique called sever plastic deformation. By using the SPD (sever plastic deformation) technique we can produce an ultrafine grained (UFG) and even Nano grained materials [7,8]. We have some of the SPD techniques to produce the UFG or Nano grained materials. These are 1. Equal Channel Angular Pressing (ECAP), 2. Multi Axial Compression (MAC), 3.High Pressure Torsion (HPT) and 4. Accumulative Roll Bonding (ARB) [7, 8],.5. Twist Extrusion (TE). In the above five methods the ECAP is most efficient and easiest technique [9, 10, 11].

. In the ECAP die we have two intersecting angles i.e. channel angle105^o (ɵ) corner angle 30^0 (Φ).The sample specimen is simply pressed through the die with application of load and lubricant.

Figure-1 : Equal Channel Angular Pressing Die

II. PREPARATION OF COMPOSITE MATERIAL

In this experiment we analysed the mechanical properties of Al4032 reinforced with SiO_2 0.25, 0.5, 0.75 and 1 Wt%. By using stir casting we produced 16mm diameter and 200mm length rods by pouring molten metal into the permanent mould. The melting is done by open hearth furnace with a prepared mechanical stirrer. Once the material comes to liquid state the stirrer starts rotating with 250rpm by 20 minutes and then the reinforcement is added to molten Al4032 alloy. And then reinforced SiO_2 is completely mixed with molten aluminium

Figure-2: Stir Casting Setup and Casting Mould

III. EXPERIMENTAL PROCEDURE:

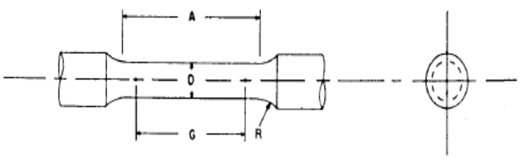
In this stage, the samples are machined into 14.6 mm diameter and 100 mm length rods from cast composite billets. For ECAP process, the surfaces of the samples are polished using emery paper to reduce the friction between die walls and surface of the samples [13]. The samples were subjected to ECAP using a die with two channels having an equal circular cross section with diameter of 15 mm. The two channels of the die intersect at angle of $\theta = 105^o$ and

$\phi = 30^o$. In order to reduce the drag friction between the die wall and sample surface lubricant is used [13].

IV. SPECIMEN PREPARATION:

The caste rods are machined into 14.6mm diameter and 100 mm length rods for ECAP process. After ECAP process the specimens are machined for mechanical tests like tensile test, compression test, Impact (IZOD-V) test, Impact (CHRPY-V) test and hardness tests. For specimen preparation we followed ASTM Standard dimensions.

i. **Tensile test** : The specimens are prepared as per ASTM E8/E8M-08 standards and in this the specimen dimensions are taken from the table of round tension test specimen and examples of small-size specimens Proportional to the standard specimen sub size 3 in for test specimens with gage length four times the diameter [e 8]



G—Gage length : 25 mm

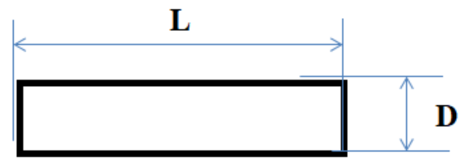
D—Diameter : 6 mm

R—Radius of fillet : 6 mm

A—Length of reduced section : 30 mm

Figure-3: Tensile Test Specimen

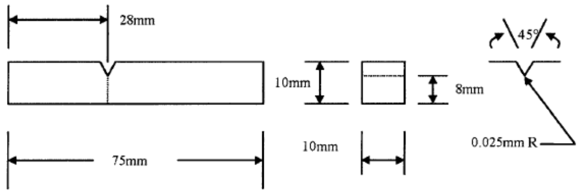
ii. **Compression Test**: As per ASTM E 9 – 89a Suggested Solid Cylindrical Specimens.



Diameter (D) : 13 ± 0.2 mm
Length (L) : 39 ± 1mm
L/D ratio : 3

Figure-4: Compression Test Specimen

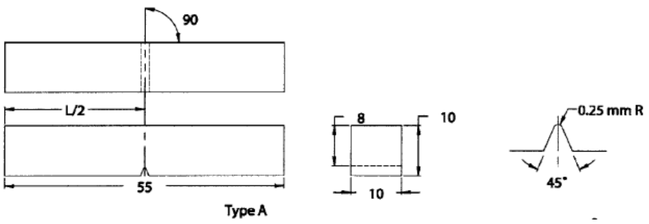
iii. **Impact (Izod-V) Test:** As per ASTM E23 – 07a Izod (Cantilever-Beam) Impact Test Specimen, Type D.



Length : 75 mm
Width : 10mm
Height : 10mm
Notch depth : 2mm
Notch angle : 45°

Figure-5: Izod Test Specimen

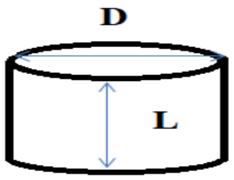
iv. **Impact(chapry-V) Test**: As per ASTM E23 – 07a Charpy (Simple-Beam) Impact Test Specimens, Type A



Length : 55 mm
Width : 10mm
Height : 10mm
Notch depth : 2mm
Notch angle : 45°

Figure-6: Charpy Test Specimen

v. **Hardness (Brinell) Test**:



Diameter (D): 15 mm
Length (L): 10 mm

Figure-7: Hardness Test Specimen

V. ANALYSIS AND RESULTS:

To evaluate the mechanical properties like ultimate tensile strength, ultimate compressive load, impact strength and hardness test we performed some mechanical tests. These are, Tensile Test, Compression Test, Impact (IZOD-V) Test, Impact (CHRPY-V) Test and Hardness (Brinell) Tests.

i. Tensile behavior of AL 4032-SiO_2 (02.5, 0.5, 0.75 and 1 Wt %).

The tensile behavior of AL 4032-SiO_2 (02.5, 0.5, 0.75 and 1 Wt %.) is evaluated as cast and after ECAP. The ultimate tensile strength of Al 4032- reinforced with 0.5 Wt% SiO_2 after ECAP is much higher than the before ECAP. Similarly the ultimate breaking load is greater for AL 4032- reinforced with 0.25 Wt% SiO_2 after ECAP sample among the all samples.

Table-1: Ultimate Load

S.No	% OF SiO2	ULTIMATE LOAD	
		BEFORE ECAP	AFTER ECAP
1	0.25%	3.36	6.88
2	0.50%	5.08	6.64
3	0.75%	5.44	4.72
4	1.00%	6.2	4.92

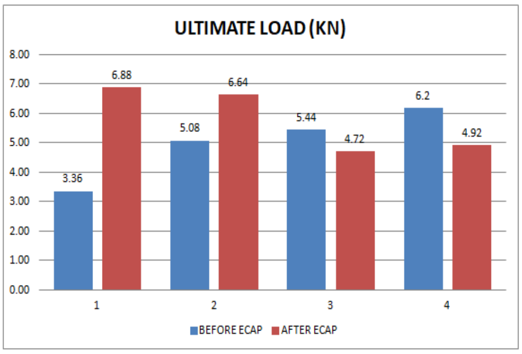


Chart-1: Ultimate Load (KN)

Table-2: Ultimate Tensile Strength (N/mm^2)

S.No	% OF SiO2	ULTIMATE TENSILE STRENGTH	
		BEFORE ECAP	AFTER ECAP
1	0.25%	97.902	215.877
2	0.50%	152.141	222.074
3	0.75%	170.16	134.665
4	1.00%	198.9	149.635

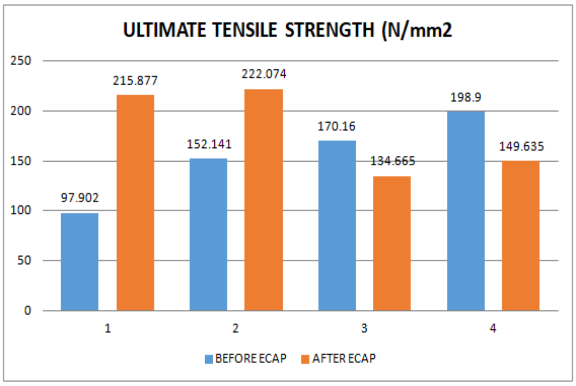


Chart-2: Ultimate Tensile Strength (N/mm^2)

Table-3: Elongation (%)

S.No	% OF SiO2	ELONGATION	
		BEFORE ECAP	AFTER ECAP
1	0.25%	0.76	1.28
2	0.50%	0.8	2.96
3	0.75%	2.16	0.32
4	1.00%	1.92	1.04

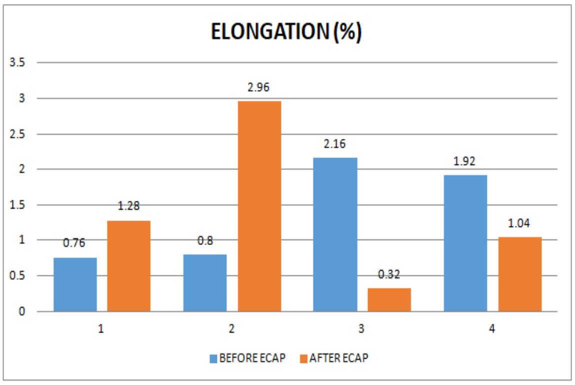


Chart-3: Elongation (%)

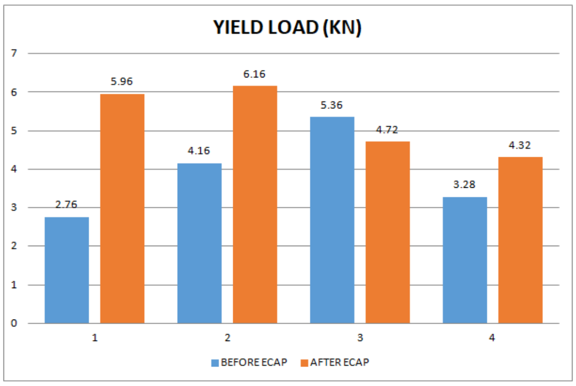


Chart-4: Yield Load (KN)

Table-4: Yield Lord (KN)

S.No	% OF SiO2	YIELD LOAD	
		BEFORE ECAP	AFTER ECAP
1	0.25%	2.76	5.96
2	0.50%	4.16	6.16
3	0.75%	5.36	4.72
4	1.00%	3.28	4.32

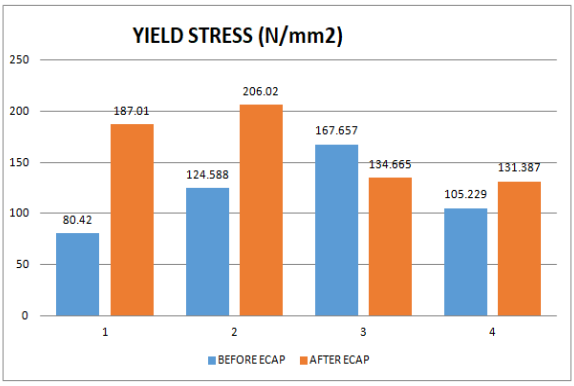


Chart-5: Yield Stress (N/mm^2)

Table-5: Yield Stress (N/mm^2)

S.No	% OF SiO2	YIELD STRESS	
		BEFORE ECAP	AFTER ECAP
1	0.25%	80.42	187.01
2	0.50%	124.588	206.02
3	0.75%	167.657	134.665
4	1.00%	105.229	131.387

ii. Compressive behavior of AL 4032-SiO_2 (0.25, 0.5, 0.75 and 1 Wt %).

The compressive behavior of AL 4032-SiO_2 (0.25, 0.5, 0.75 and 1 Wt %.) were evaluated as cast and after ECAP process samples. The ultimate compressive load is maximum for AL 4032- reinforced with 0.5 Wt% SiO_2 before ECAP sample.

Table-6: Ultimate Compression Load (KN)

S.No	% OF SiO2	ULTIMATE COMPRESSION LOAD	
		BEFORE ECAP	AFTER ECAP
1	0.25%	41.68	32.88
2	0.50%	50.88	35.92
3	0.75%	47.64	34.56
4	1.00%	44.68	37.4

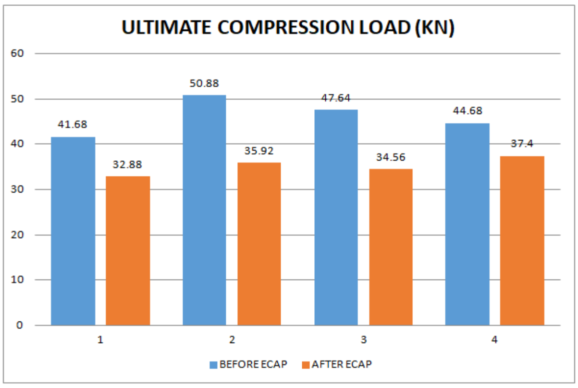


Chart-6: Ultimate Compression Load (KN)

iii. Impact strength of AL 4032-SiO_2 (0.25, 0.5, 0.75 and 1 Wt %).

The impact strength of AL 4032-SiO_2 (0.25, 0.5, 0.75 and 1 Wt %.) were evaluated as cast and after ECAP process samples for both IZOD and CARPY tests .In both the cases the breaking load of Al4032-reinforced with 0.25, 0.5, 0.75 and 1 Wt % of SiO_2 after ECAP samples are having maximum values.

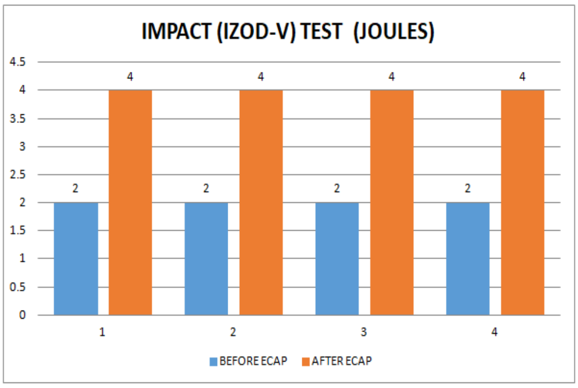


Chart-7: Impact (Izod-V) Test (Joules)

Table-7: Impact (Izod-V) Test (Joules)

S.No	% OF SiO2	IMPACT (IZOD-V) TEST IN JOULES	
		BEFORE ECAP	AFTER ECAP
1	0.25%	2	4
2	0.50%	2	4
3	0.75%	2	4
4	1.00%	2	4

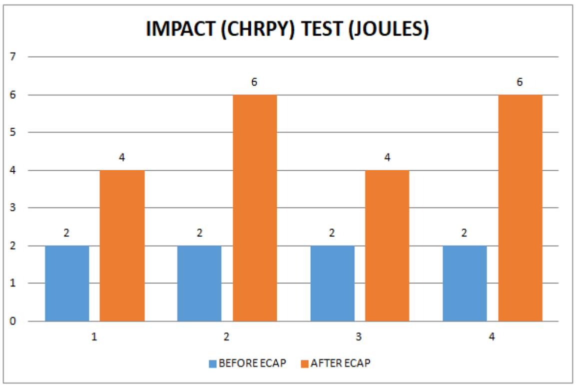


Chart-8: Impact (Charpy-V) Test (Joules)

Table-8: Impact (Charpy-V) Test (Joules)

S.No	% OF SiO2	IMPACT (CHARPY) TEST IN JOULES	
		BEFORE ECAP	AFTER ECAP
1	0.25%	2	4
2	0.50%	2	6
3	0.75%	2	4
4	1.00%	2	6

iv. Hardness (Brinell) test of AL 4032-SiO_2 (0.25, 0.5, 0.75 and 1 Wt %).

The hardness of the AL 4032-SiO_2 (0.25, 0.5, 0.75 and 1 Wt %.) were evaluated as cast and after ECAP. The Brinell hardness number (HB) is maximum for AL 4032- reinforced with 0.25 Wt% SiO_2 after ECAP.

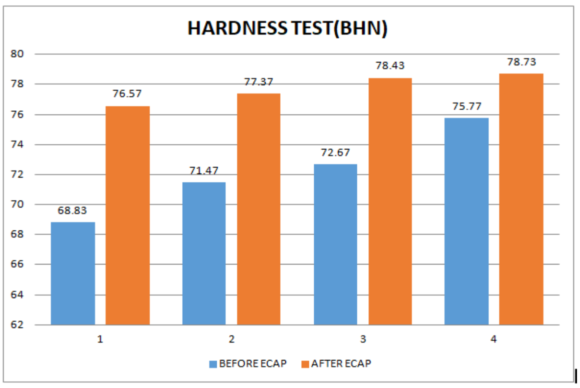


Chart-7: Hardness Results (BHN)

Table-8: Hardness Results (BHN)

S.No	% OF SiO2	HARD NESS TEST(BHN)	
		BEFORE ECAP	AFTER ECAP
1	0.25%	68.83	76.57
2	0.50%	71.47	77.37
3	0.75%	72.67	78.43
4	1.00%	75.77	78.73

VI. CONCLUSIONS:

In the present investigation the following conclusions are drawn.

1. The stir casting method was successfully employed for casting of Al4032 composite reinforced with sio2. The experimental study reveals that the distributions of particulates in the matrix are uniform.

2. The effect of the SiO_2 reinforcement on AL 4032 metal matrix is appreciable in Ultimate tensile strength, Impact and hardness after ECAP.

3. After ECAP process, the size and distribution of the SiO_2 partials are not changed but significant reduction in the grain size of matrix alloy was observed based on the mechanical tests.

4. By increasing the %SiO_2 the impact strength is increased.

5. The maximum value of ultimate tensile strength through the ECAP process is exhibited by AL 4032- reinforced with 1Wt% SiO_2.

6. Also the maximum hardness exhibited by AL 4032- reinforced with 1Wt% SiO_2. After ECAP.

7. Hence I conclude that the mechanical properties of AL 4032- reinforced with 1Wt% SiO_2 are dramatically increased after ECAP except in compression strength.

REFERENCES:

1. Friction and Wear of Aluminum-Silicon Alloys by Barrie S. Shabel, Douglas A. Granger, and William G. Truckner, Alcoa Technical Center ASM Handbook, Volume 18: Friction, Lubrication, and Wear Technology.
2. Fabrication and Performance of Aluminium Based Metal Matrix Composites with SiO2 and TiO2 as Reinforced Particles by Maninder Singh1, Khushdeep Goyal1,*, Deepak Kumar Goyal2 in Universal Journal of Mechanical Engineering 3(4): 142-146, 2015 http://www.hrpub.org DOI: 10.13189/ujme.2015.030404.
3. Development and Assessment of Piston by using Al-Si Hybrid Metal Matrix Composites Reinforced with Sic and Chemosphere Particulates by Vinoth M. A. Aru n L.R . Vinay Kumar Uppinal Arun L.R in International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 www.ijert.org Vol. 3 Issue 7, July – 2014.
4. Stir Casting Process in Particulate Aluminium Metal Matrix Composite: A Review by Suman Kant # and Ajay Singh Verma in International Journal of Mechanics and Solids. ISSN 0973-1881 Volume 9, Number 1 (2017), pp. 61-69 © Research India Publications http://www.ripublication.com/ijms.htm.
5. The Effect of Process Parameter on Metal Matrix Composite (Al+4%Cu+5%Sic) By Stir Casting By Mohd. Suhail1, Mahmood Alam2, Reyaz Ur Rahim3 in *International Journal of Engineering Trends and Applications (IJETA) – Volume 2 Issue 1, Jan-Feb 2015.*
6. A Review: Plastic Deformation through Equal Channel Angular Pressing by Mutiu F Erinosho, *Member*, *IAENG*, and Esther T Akinlabi, *Member*, *IAENG* in Proceedings of the World Congress on Engineering 2016 Vol II WCE 2016, June 29 - July 1, 2016, London, U.K..
7. Effect of Equal Channel Angular Pressing Process on Impact Property of Pure Copper by F. Al-Mufadi, F. Djavanroodi World Academy of Science, Engineering and Technology in International Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering Vol:8, No:1, 2014.
8. Effect of Equal Channel Angular Pressing (ECAP) on Hardness and Microstructure of Pure Aluminum by Nashith A.1, Sanjid P.1, Shamsudheen M.1, Rasheeque R.1, Ramis M. K.1,*, Shebeer A. R.1,2 in International Journal of Materials Engineering 2014, 4(3): 119-122 DOI: 10.5923/j.ijme.20140403.08.
9. Equal channel angular pressing technique for the formation of ultra-fine grained structures by Kazeem O. Sanusi1,2 Oluwole D. Makinde3 Graeme J. Oliver2 in https://www.sajs.co.za/ S Afr J Sci 2012; 108(9/10)

10. Effect of Equal Channel Angular Pressing on the Microstructure and Mechanical Properties of Al6061-SiCp Composites by T Lokesh 1*and U S Mallik2in IConAMMA-2016 IOP Publishing IOP Conf. Series: Materials Science and Engineering 149 (2016) 012119 doi:10.1088/1757-899X/149/1/012119.
11. Numerical simulation of plastic deformation of aluminium work piece induced by ECAP technology by R. Melichera in Applied and Computational Mechanics 3 (2009) 319–330 Received 3 September 2009; received in revised form 4 December 2009.
12. Enhancement of microstructure And mechanical properties Through equal channel angular Pressing of aluminium processed By powder metallurgy route By venkatraman r1, raghuraman s2, kabilan s3, ajay kumar ks4, balaji r4, viswanath m4 in international journal of innovative research in science, Engineering and technology *(an iso 3297: 2007 certified organization)* Vol. 2, issue 9, september 2013.
13. Effect of Equal Channel Angular Pressing on the Microstructure and Mechanical Properties of Hybrid Metal Matrix Composites T. Lokesh1* and U. S. Mallik2 by Indian Journal of Science and Technology, Vol 9(35), September 2016 ISSN (Print): 0974-6846 ISSN (Online): 0974-5645.
14. A review on various methods of fabricating aluminum metal matrix composites and the effect of manufacturing methods on some of their properties by Avinash Gudimetla in National Conference,JNTUK TAME16.
15. Tribological studies of aluminum metal matrix composites with micro reinforcements of silicon and silicon balloons by Avinash Gudimetla in international conference, ICAMME-2018, ANU, Guntur.