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Evaluation of mechanical properties for AL6061 based hybrid nano composites reinforced with Al_2O_3 and ZrO_2 particles

Metal matrix composites (MMCs) are being progressively more known nowadays. The key point in this paper is to study the mechanical properties of aluminium 6061 alloy strengthened with Al_2O_3 and ZrO_2 and process is completed with the aid of stir casting system. The tensile and compressive test of the MMCs carried with the help of computerized UTM. The experimental results showing that the compressive and tensile strength increased with addition of Al_2O_3 as invariable of 2.5% along with a boost of 1, 2, 3 and 4% of ZrO_2.

Keywords: Aluminium 6061, ZrO_2, Al_2O_3, mechanical properties

1.0 Introduction

MMCs are gradually appropriate alternative material for aerospace application because of their best tailor-made properties through accumulation of selected reinforcements. In particular to particulate reinforced MMCs, it has found special concern on their precise gifts like potency, hardness etc., at a distinguished temperature. It is fine recognized elastic properties of MMCs are robustly influenced by micro structural limitations of the support such as size, orientation, shape, distribution of particles and volume fraction. Aluminum-based MMCs have received rising interest in recent decades as engineering material. The outline of a ceramic material into a MMCs is very beautiful blend of physical and mechanical assets which cannot be obtained with vast alloys. This escalation required knowledge on meeting out techniques and behaviour of particulate MMCs [1-6]. Importance in particulate reinforced metal composites is mostly due to effortless accessibility of particles and financial processing method adopts to produce in MMCs.

The profitable use of Al_2O_3 short fiber reinforced aluminum in automobile components like piston, cylinder liners etc. This maxim a chief boost up in their use. MMCs exhibit the same escalation mechanism as like as those of precipitate strengthen and distribution in alloys [7-12]. In the current days, large work has been carried out on ZrO_2 Particulate MMCs which show evidence of high strength and excellent seizing property [13-16]. The ZrO_2 in these composites it would seem imparts improved mechanical properties in the material through the structure of rich film on the face [17-19]. In earlier studies, Venkatesha B K et al. [30-32] investigated the influence of stacking sequence of multi layered woven bamboo and glass fibers reinforced with epoxy matrix composites.

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2.0 Methodology and materials

2.1 Material

In present work research work is carried out on casting process, preparation specimens and then studied their properties like tensile strength, young's modulus and so on. Aluminum alloy reinforced with aluminum oxide and zirconium oxides are in nano scale for the preparation of hybrid MMCs bulleted lists may be included and should look like this:

2.1.1 Aluminum (Al6061)

Al6061 is commonly used metal matrix in preparation of composite materials. With the various useful aluminum alloys, especially 6061 are usually characterized by properties fluidity, castability, resistance to corrosion and so on. This material has been frequently applied as a raw material for MMCs with a variety of particulate reinforcements. The compound composition and properties alloy are tabulated in the Tables 1 and 2. [21-23]

2.1.2 Aluminum oxide (Al_2O_3)

Al_2O_3 is most usually called as alumina, possesses muscular ionic inner atomic bond which gives the mount in their popular characteristics. It can execute numerous crystalline stages of all relapses to the hexagonal alpha phase at eminent temperature. Its elevated hardness and outstanding dielectric property give superior thermal property build the material of alternative for an ample variety of purposes [24-26]; its dimension is varying from 50 to 70 nanometres.

TABLE 1: AL606 COMPOSITION

Components	Manganese	Copper	Chromium	Magnetism	Zinc	Titanium	Iron	Silicon	Aluminium
% of Composition	1.0	0.36	0.20	0.10	0.10	0.10	0.5	0.2	97.44

TABLE 2: COMPOSITIONS OF AL6061, AL_2O_3 AND ZRO_2

Material	Density	Melting temperature	Young's modulus	Poisons ratio	BHN	UTS
Al 6061	2.69 gm/cc	580ºC	70-80 GPa	0.33	30-33	110-182 MPa
Al_2O_3	3.78 gm/cc	1700ºC	300 GPa	0.21	450-500	650-660 MPa
ZrO_2	5.89 gm/cc	2715ºC	92-95 GPa	0.34	130-145	300-330 MPa

(a) Al6061 (b) ZrO_2 (c) Al_2O_3

Fig.1: (a) Raw materials of Al6061; (b) Zirconium dioxide (40-50nm); (c) Al_2O_3 (50-70nm)

2.1.3 Zirconium dioxide (ZrO_2)

ZrO_2 is also called as zirconia; these are in white crystalline oxide of zirconium. The most logically stirring outline, with a monoclinic crystalline arrangement. A do pant stabilize cubic controlled zirconia, cubic zirconia, is synthesized in a variety of ensign to utilize as a precious stone like diamond stimulant [27-30]

2.2 PREPARATION OF MMC

2.2.1 Melting process

Cleaned 1.5kg aluminum ingots are placed inside the crucible and this crucible is positioned in inside the furnace. Temperature is set about 900ºC in the furnace. Once the metal reaches into the fluid condition, the slag fashioned in the furnace is detached and then reinforcement is added to the liquid base material. Then liquefy metal is stimulated continuously at a steady pace to blend accurately.

2.2.2 Pouring

The whole mixture in crucible of molten mixture is taken out from the furnace and pour into the die and for stir casting. Stir casting with the speed about varying 850rpm to 1500 rpm for different casting as is shown in Fig.3 [31]

2.2.3 Specimen preparation

The molten metal blend is poured into the die later than it gets solidified and next it is removed slowly by removing the clamp of the mould which. The machining processes of mould components were conceded as per the ASTM standard specification.

Fig.2: Electric furnace

3.0 Experimental details

The mechanical properties test are conducted on Al6061 reinforce with Al_2O_3 and ZrO_2 tests specimens as per the ASTM standards.

3.1.1 Hardness test

Brinell hardness test is carried as ASTM E10 standards, with indent diameter of 5mm and load applied on sample is 1kg. The hardness test sample is as shown in Fig.5.

3.1.2 Tensile test

This test is carried to find properties like UTS, young are modulus, positions ratio etc., of the composite by using UTM. All the test samples are prepared as per ASTM A370 standards with the following dimensions for the specimens whose gauge length is 50mm and its diameter is 10mm.

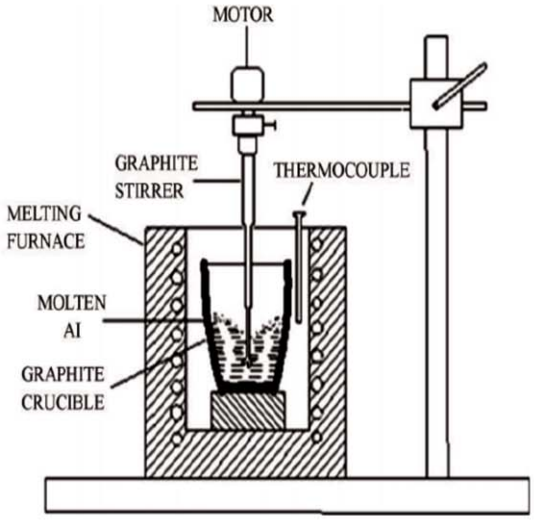

Fig.3: (a) Stir Casting

(b) Mixing the reinforcement with base metal

TABLE 3: COMPOSITION USED FOR SPECIMEN PREPARATION

Specimen	Composition (Al+ Al_2O_3 + ZrO_2)
A	Al 6061
B	Al 6061 + 5% + 0%
C	Al 6061 + 5% + 2%
D	Al 6061 + 5% + 4%
E	Al 6061 + 5% + 6%
F	Al 6061 + 5% + 8%

TABLE 4: BHN RESULTS

Specimen	Value of BHN
A	46
B	54
C	62
D	71
E	79
F	85

TABLE 5: TENSILE PROPERTIES

	Specimen	Ultimate tensile Strength in MPa	Yield strength in Mpa	Percentage of elongation
1	A	119.18	88.61	10.63
2	B	134.23	94.68	9.4
3	C	140.65	108.32	7.9
4	D	159.62	121.63	6.3
5	E	172.51	135.11	5.1
6	F	188.62	154.61	3.66

4.0 Results and discussions

4.1 HARDNESS TEST

Brinell hardness test is carried out by using the Brinell hardness test equipment at ambient temperature. The Table 4 and Fig.5 shows BHN of different composites variy. Increase in percentage of aluminium oxide with constant ZrO_2 increases the hardness.

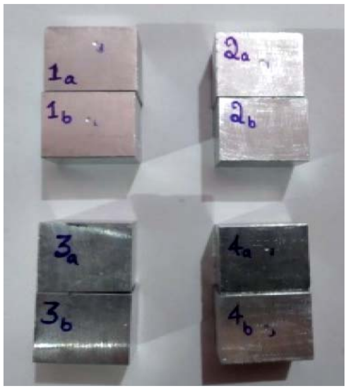

Fig.4: Hardness test specimens

3.2.2 Tensile test

Tensile tests are conceded to estimate the mechanical characteristics for the synthesised composites. Table 5 gives the clear results for various properties like ultimate tensile strength in MPa, yield strength in MPa and percentage of elongation for the tensile test conducted for the various samples as tabulated in the Table 5. Fig.6 shows the result of aluminium oxide (Al_2O_3) and Zro_2 reinforcement on the universal testing machine of the aluminium 6061 composites. Due to the existence categorization of the synthesised composite. Fig.6 shows the outcome of aluminium oxide (Al_2O_3) and Zro_2 particle reinforcement on the UTS of the Al6061 composites. Due to the subsistence of Zro_2 and increasing wt. % of Al_2O_3

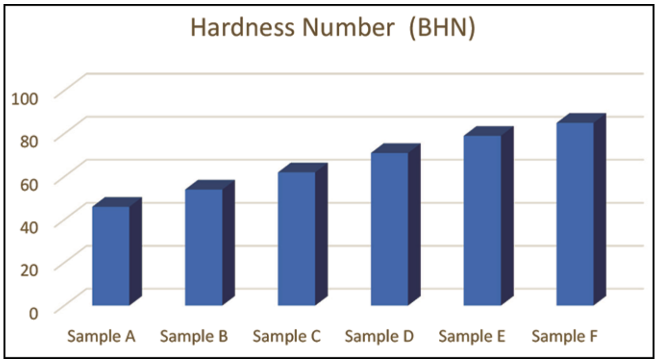

Fig.5: Graphical representation of hardness comparison

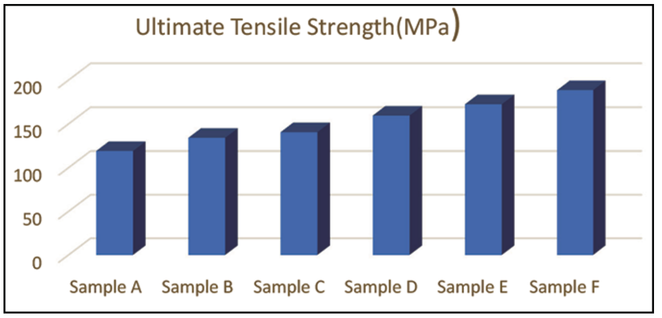

Fig.6: Graphical representation of ultimate tensile strength (MPa) for various samples

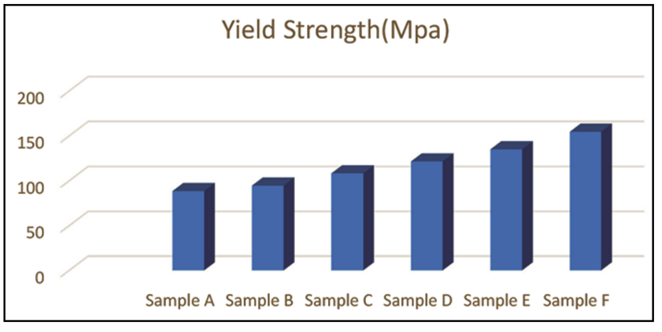

Fig.7: Graphical representation of yield strength (MPa) for various samples

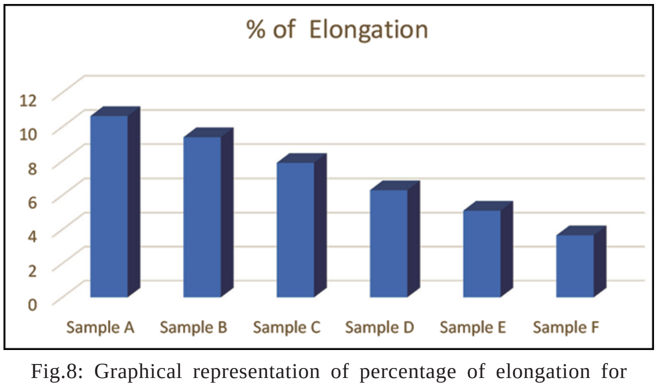

Fig.8: Graphical representation of percentage of elongation for various samples

particulates, the ultimate tensile strength of the composites increased. UTS of cast of aluminium combination Al6061 is 119.18MPa and this augment to a maximum of 188.62MPa for the matrix of sample F exhibits.

Fig.7 shows the various samples exhibiting the yield strength in MPa on conduction of tensile test. The applied load transfers to the insistently strengthened Al_2O_3 and Zro_2 nano particles in Al6065 alloy. It is furthermore evident that the extended departure stupidity is identified with the matrix-reinforcement line. The extra conceivable justification remains qualified to the grain-refining stimulating component. Strength increments gradually with the boost in weight percentage levels of Al_2O_3 and Zro_2 particle reinforcement in casted samples. This upgrade of commonality can be grasped by different means that take in load transmit and disruption in strength, with on existence of both reinforcements like $Al_2O_3$and Zro_2 particles have solid hold, great allotment, and close filler, clear and regular commandeering of reinforcement inside these-cast material. Fig.8 depicts the graphs of % of elongation for various samples.

5.0 Conclusions

Al_2O_3 and Zro_2 reinforced with Al6061 MMC arranged effectively with the assistance of stir cast process. From the testing the hardness improved progressively with enhance in proportion of reinforcement. Tensile properties of the composite specimens will be improved more than the percentage of reinforcement. Metallurgical micrographs publicized that reinforced atom are well disseminated in aluminium matrix. Hence minimizes defects of casting like blow holes and porosity and will give better upshot than simple of composite material. % of elongation declines with improvement in weight % of reinforcement, though owing to the presence in hard particulates, brittleness take place that shrinks the ductility of the composite. This may equally be qualified to the harder ceramic Al_2O_3 and ZrO_2 particles.

References

[1] Sharanabasappa R Patil., B.S Motgi, *ACS Applied Nano Materials* 7(6), 41-46.

[2] Sandeep Kumar Ravesh, T. K. Garg (2012): *International Journal of Engineering Research and Applications*, 2(6), 727-731

[3] Mahendra Boopathi, M., K.P. Arulshri and N. Iyandurai., (2013): *American Journal of Applied Sciences*, 10 (3): 219-229.

[4] Prasad B.K., Dan T.K. and Rohatgi P.K. (1993): *Mater. Trans.*, 34(5), 474-480.

[5] G Venkateshwarlu, A.M.K. Prasad and K Ramesh Kumar (2011): Research Article, *International Journal of Current Engineering and Technology* 5(6), 201-206

[6] Maulikkumar Patel, (2011): *International Journal of Current Engineering and Technology*, 32(4), 1066-1071

[7] B.G. Park, A.G. Crosky and A.K. Hellier, (2008): *Material today* 39(6), 127-132.

[8] Devaraju, Kumar, Kotiveerachari, (2013): *Material today* 45, 576–85.

[9] Ravindran P, Manisekar K, Vinoth Kumar S, Rathika P, (2013): *Material today*, 51, 448–456

[10] Madeva Nagaral, Auradi, V., Kori, S. A, (2014): *Applied Mechanics and Materials*, 592(5), 170-174.

[11] P. Maheswaran and C. J. Thomas Renald, (2017): *International Journal of Current Engineering and Technology* 5(2), 2347-235

[12] Supreeth. Pet.al. [15], V.S.K. Venkatagalapathy, 2012 2

11-15

[13] P. Pugalenthi and M. Jayaraman, A. Natarajan, (2015): *Applied Mechanics and Materials* 766-767, 246-251.

[14] C. Manikandan, (2017): *International Research Journal of Engineering and Technology* 4(4), 231-239

[15] Saheb DA. ARPN *Journal of Engineering and Applied science*, 6, 2011, 41-46.

[16] Bansal S, Saini JS. (2015): *Defence Science Journal*, 65, 330-338.

[17] Basaravaraju S, Arasukumar K, Bendigeri C, Umesh CK, (2012): *International Journal of Innovative Science Engineering and Technology*, 1, 107-112.

[18] Kumar HCA, Hebbar HS, KSR Shankar, (2011): *International Journal of Mechanical and Minerals Engineering*, 6, 41-45.

[19] H.C. Anilkumar, H.S. Hebbar and K.S. Ravishankar, (2011): *International Journal of mechanical and materials engineering* 6, 41-45

[20] Kok, M. J. Mater, (2005): Process. Technology, 161(3), 381-387.

[21] G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj, M. S. Bhagyashekar, (2010): *Journal of Minerals & Materials Characterization & Engineering*, 9(1), 43-55

[22] D. Ramesh, R.P. Swamy, T.K. Chandrashekar, (2012): *Journal of Minerals and Materials Characterization and Engineering*, 11(4), 353 - 363.

[23] S. Vignesh, C. Sanjeev, (2012): International Conference on Thermal, Material and Mechanical Engineering, 1, 15-16.

[24] A. R. K. Swamy, A. Ramesha, G.B. Veeresh Kumar, J. N. Prakash, (2011): *Journal of Minerals & Materials Characterization & Engineering*, 10 (12), 1141-1152

[25] B. Ravi, (2012): *International Journal of Engineering Science Invention*, 6 (10), PP 216-222

[26] Thirtha Prasad H.P Pradeep Sharma, Gulshan Chauhan, Neeraj Sharma. 2 (1), 2015, 315-319.

[27] G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj, (2011): *Journal of Minerals & Materials Characterization*, 10 (1), 59 – 91.

[28] Pradhan S N, Madev, Nagaral and V Auradi, (2012): *International Journal of Current Engineering and Technology*, 1(3), PP 201- 220.

[29] P.S. Shreyas, B.P. Mahesh, S. Rajanna, N. Rajesh, (2021): Materials Today Proceedings, 45 (1), 429-433, https://doi.org/10.1016/j.matpr. 2020.12.1012

[30] Venkatesha, B. K., Saravanan R. & Anand Babu, K. (2021): Effect of Moisture Absorption on Woven Bamboo/Glass Fiber Reinforced Epoxy Hybrid Composites, Materials Today Proceedings, 45(part1), 216-221. https://doi.org/10.1016/j.matpr.2020.10.421

[31] Venkatesha, B. K. and Saravanan, R. (2020): Effect of Cenosphere Addition on Mechanical Properties of Bamboo and E-Glass Fiber Reinforced Epoxy Hybrid Composites. *International Journal of Vehicle Structures and Systems*, 12(4), 447–451. https://doi.org/10.4273/ijvss.12.4.18

[32] Venkatesha, B. K., Pramod Kumar, S. K., Saravanan, R., & Ishak, A. (2020): Tension Fatigue Behaviour of Woven Bamboo and Glass Fiber Reinforced Epoxy Hybrid Composites. IOP Conference Series: Materials Science and Engineering, 1003 0120187 https://doi.org/10.1088/1757-899x/1003/1/012087