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Preparation and Evaluation of Mechanical Properties of Aluminum Nanocomposite

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Abstract: *Nanocomposite materials with metal matrix are commonly practiced by researchers for improving mechanical properties. In this study a novel nanocomposite was formulated by reinforcement of alumina-zirconia nanoparticles in pure aluminum. Sol-gel synthesis was used to obtain the nanoparticles and stir casting method was applied to formulate nanocomposite aluminum. The specimen was prepared for microstructural and mechanical characterization. It was found that the said nanocomposite performs excellently in hardness and wear resistance but poor in tension.*
Keywords: *Nanocomposite, Aluminum, Microstructure, Wear resistance.*

I. Introduction

Industrial, household and consumer products are rapidly demanding developments of advanced engineering materials for specific applications. Materials development has shifted from monolithic to composite materials for adjusting to the global need for reduced weight, low cost, quality, and high performance in structural materials. Composites, specifically metal matrix composites are frontline candidate and reliable source to meet such demands.

Aluminumcompositeshave fascinated the recent researchers due to their combination of high strength, low density, durability, machinability, availability and cost effectiveness. The reinforcement in aluminum matrix is usually non-metallic or ceramic such as Al_2O_3/TiO_2, Al_2O_3/SiO_2, SiO_2/Ni, Al_2O_3/SiC and Al_2O_3/CNT etc. [1].Nanocomposites are a class of materials that contain at least one phase with constituents in the nanometer size range (1 nm = 10^{-9} m) [2-4]. Nanocomposite is a multi-phase material which has nano particles in its composition within its structure, the size will be less than 100 nm. The properties including mechanical, electrical and thermal may differ depending upon the composition of the materials used for the synthesis of the composites.

II. Experimentation

2.1 Preparation of Alumina-Zirconia (Al_2O_3-ZrO_2) Nanocomposite by sol-gel method

Nanoparticles were formulated by sol-gel synthesis route found in literature [5]. In the preparation of nanocomposite particles we take $Al(NO_3)_3$ $ZrOCl_2$ in proportion of 20:1 by weight. The $Al(NO_3)_3$ $ZrOCl_2$ are dissolved in distilled water and continuous stirring is done by magnetic stirrer till solution become stable. Due to stirring gel network was formed in the solution; after gel formation it was kept aside for sedimentation of the gel as shown in Fig. 1. After 24hours the gel is filtered for post processing.

When the water was filtered completely from gel then it was kept in hot air oven for removing moisture contents. The temperature of hot air oven is maintained at 50^0C for 24 hours, and then it was further heat treated by using muffle furnace at 900^0C to remove impurities.

2.2 Preparation of die

After formation of nanocomposite material next step is preparation of split die for casting of pure aluminum along with nanocomposite which is formed in preceding stage. For making of split dies take two halves of mild steel of dimension 225*125*16mm these plates were in irregular shape when it is purchased from the market then it is shaped in sharp corner regular shape by using shaper machine. Final dimensions obtained after shaping is 213*116*14mm. The drilling operation was done on the die in three steps to make pattern for casting. Twist drill tool of diameter 8mm, 12mm and 15mm were used for the drilling operations. Holes produced in halves of the die are further finished by using hand grinder manually. Split and assembled die is shown in Fig. 2.

2.3 Casting of aluminum reinforced with nanocomposite

Die casting is metal casting process that is characterized by forcing molten metal into mold cavity under high pressure. The pure aluminum meltsat 659^{0}C in furnace. After melting of aluminum, nanocomposite is added to molten metal and mixed manually. Then mixture is poured in cavity very carefully and kept for solidification. To avoid the sudden solidification die is preheated at 800^{0}C.After solidification process the samples were withdrawn from the die cavity by unscrewing the bolts. It is important that crucible is not cooled by using water.

2.4 Specimen preparation

For observing microstructure of casted samples with varying proportion of nanocomposite (Table.3) etching operation was done. Etching solution consists of distilled water, nitric acid, hydrochloric acid and picric acid in proportion 90 ml, 5 ml and 5 ml respectively per 100 ml solution.

Table.1 Proportion of nanocomposite in aluminum

Sample No.	I	II	III	IV
Nanocomposite % by Weight (gm)	0	5	8	10

III. Characterization

3.1 Microscopy:

Optical microscope was used for testing microstructure of samples with magnification400x. Microstructure with 0, 5, 8 and 10 % nanoparticles are shown in Fig. 3. It was observed that as nanoparticle composition increases the microstructure depicts more globules and cluster.

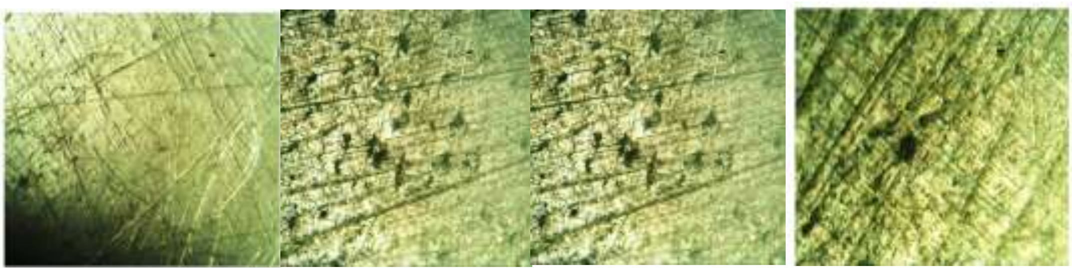

Fig.3 Microstructure of Nanocomposites containing 0, 5, 8 and 10% nanoparticles

3.2 Tensile test

Tensile test carried on sample having different proportion of nanocomposite as shown in Fig. 4. The test is performed on universal testing machine to observe various properties of sample of different proportion. Specimen is prepared for tensile test as shown in figure. The load and elongation at which breakage occurs is noted, data obtained in this test is further utilized to calculate stresses, deflection etc.

Table.2 Tensile test readings

Sample No.	Maximum load KN	Elongation Mm	Stress N/mm^2
NP-0	13.82	12.72	187.10
NP-5	9.44	12.54	162.59
NP-8	6.56	8.52	130.57

Fig.4 Specimen for tensile testing; before and after fracture

3.3 Hardness test

Fig5 shows the results of micro hardness tests conducted on Aluminum and the Aluminumcomposite containing different weight percentage of Al_2O_3/ZrO_2particles. The BHN hardness were measured on the polished samples using 1/16 inch (1.587mm) indenter with a load of 100kgf and the value reported. A significant increase in hardness of the alloy matrix can be seen with addition of Al2O_3/ZrO_2 particles. Higher value of hardness is clear indication of the fact that the presences of particulates in the matrix have improved the overall hardness of the composites. This is true due to the fact that aluminum is a soft material and the reinforced particle especially ceramics material being hard, contributes positively to the hardness of the composites. The presence of stiffer and harder Al_2O_3/ZrO_2 reinforcement leads to the increase in constraint to plastic deformation of the matrix during the hardness test. Thus increase of hardness of composites could be attributed to the relatively high hardness of Al_2O_3/ZrO_2itself.

Table.3 hardness test readings

SampleNo.	Hardness(BHN)
NP-0	126
NP-5	172
NP-8	182
NP-10	190

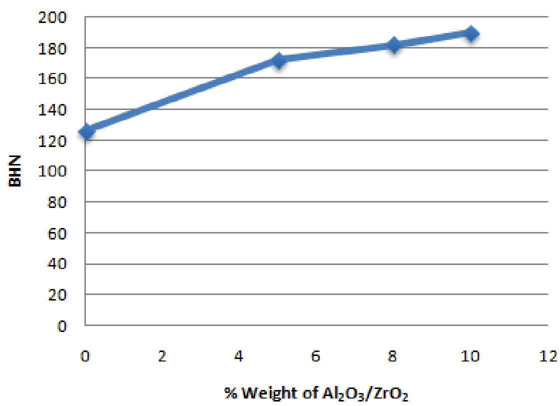

Fig. 5 Variation of BHN value

3.4 Wear test

The Wear test is carried on specimen of pure aluminum and aluminum containing different proportion of nanocomposite. The sample at constant pressure is allowed to pass through belt grinder and the weight before and after test is measured.

From that test it is clear that the specimen without reinforcement shows more reduction in weight and as proportion of nanocomposite increase wear rate decreases.

Table.4 Wear test readings

Sample No.	Weight before test (gm)	Weight after test (gm)	% reduction
NP-0	5.17	5.02	2.90%
NP-5	11.42	11.29	1.13%
NP-8	5.40	5.32	1.48%
NP-10	7.42	7.35	0.94%

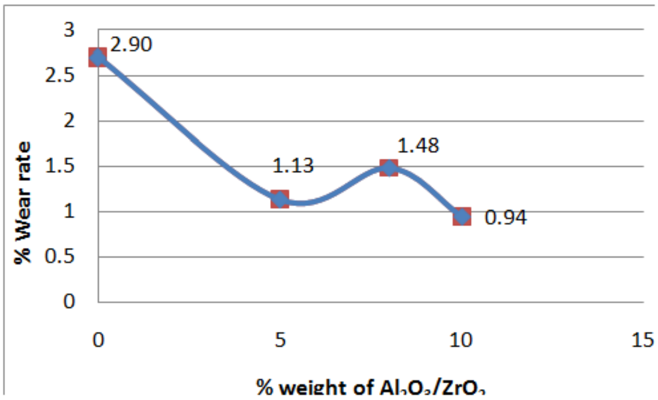

Fig. 6 variation of wear rate with nanocomposite

IV. Results And Discussion

From microscopic study of sample-I having no reinforcement exhibits only scratches and impurities which results due to polishing and etching process. The sample-II which contains 5% nano particles shows nano clusters along with impurities and scratches. Sample-III and sample-IV which contains 8% and 10% nanocomposite respectively are spread much more nanocluster in aluminum matrix than sample-II.

It was observed that nanocomposite samples exhibit decrease in tensile properties with increasing reinforcement; but hardness and wear resistance excellently increases. The above behavior may be a consequence of microstructure discontinuity due to ceramic nanoparticles.

V. Conclusion

1. From study of microstructure of the samples it concluded that nanoparticles are not distributed uniformly and they are agglomerated at different location in aluminum matrix which is mainly due to improper stirring of the mixture.
2. Tensile test shows that as the percentage of the nanocomposite are increases the tensile stress of the sample decreases with decrease in % elongation.
3. From hardness test it is clear that whenever proportion of reinforcement increases the BHN value also increases considerably.
4. Wear test exhibit that percentage wear rate decreases for nanocomposite.

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