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AN INVESTIGATION OF THE MECHANICAL CHARACTERS OF ALUMINUM 7075 /ZRO2 RE-INFORCED NANO COMPOSITE USING ULTRASONICATION PROCESS

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ABSTRACT

The present study confers to the fabrication and its characterization of AA 7075 alloy based nano composites with nano Zirconium oxide ($Zr'2$) particulate reinforcements. Ultrasonication technique was adoptedfor fabrication of the composite, this process will combine the advantages of ultrasonic probe as well as stir casting process. This will improve the uniform dispersion of nanoparticles due to ultrasonic cavitation effect and avoid the settlement agglomeration of nano particles in metal matrix and the grain size formation is controlled. An average particle size of less than 100nm was used as reinforcement to disperse in matrix. The prepared composites later subjected to various mechanical, optical image tests and results are studied. The test was carried out in accordance with the ASTM Standards on the alloy and nanocomposites. The effects of change in weight fraction of reinforcements on the distribution of particles, particle- matrix interfacial reactions, physical as well as mechanical properties were reported. Composites are widely used in many automotive, nuclear technologies, shipping industries and aerospace structures due to their greater weight savings. Overall, the investigational outcomes are very interesting and motivates to do further more projects.

KEYWORDS: Nano Composites, Fabrication, Image tests and Ultrasonication technique.

1. INTRODUCTION

Material scientists and researchers in this area have been fulfilling the demand of the engineering sector since decades in synthesizing materials to attain the demanded properties to enhance efficiency and cost savings in the manufacturing sector. In fulfilling this demand, a certain trend has been followed, the materials presently been used is tried for improvement through known methods of alloy additions, heat treatment, grain modification, and the like. Once the limit is reached through these methods, either due to economic constraint. Difficulty in mass production, or further improvement is ruled out, a different line of thought emerges in further improving the properties or decreasing cost and increasing efficiency. At times, a completely new system takes over, like was done around three decades hack when metal matrix composites (MMCs) were thought of Since a few years, the economically feasible routes, dispersoids, and alloy system that can give meaningful improvement have been narrowed down.

Among MMCK, Aluminium -alloy-based composites were always on the forefront of research. Parallel areas of research had then emerged butafter about two decades of research in various disciplines to further enhance the properties to satisfy the ever-increasing demand of the engineering sector, composites took a lead compared to the other processes when the cost and ease of fabrication were compared. The other methods changed track and chose for themselves differed areas of application and Aluminium - based metal matrix composites (AMMCs) remained as the most potential candidate to be researched on for making engineering components viable. Worldwide research in the wes of AMMCs established beyond doubt the advantages of Al-based metal matrix composites (AMMC) over the base alley in the laboratory scale. With time, the demands moved ahead and engineering components were demanded from AMMCs. The present paper details highlight the effect of dispersing ZrO2 in Al 7075 alloy matrices adopting the liquid metallurgy route associated with ultrasonication method.

2. LITERATURE SURVEY

AMIR HUSSAIN IDRISI ET AL. (2019), Work carried using conventional stir casting and ultrasonic assisted stir casting method, the findings are the drawbacks of conventional stir casting method is eliminated by ultrasonic assisted stir casting process by controlling the grain size by minimizing the agglomeration of nano particles and retaining the enhanced micro structure.

VEERESH KUMAR ET AL. (2019), Work carried out by ZrO2 nano particle reinforcement with Al6061 matrix material, the conclusions are the optical micrographs of all MMCs noted excellent bonding between matrix and nano reinforcement materials for the wt% variation of ZrO2 from 0% to 6%, the wear resistance and tensile strength increased, ductility reduced.

M. RAJASEKAR, ET AL. (2020), In this study Zro2 5%, 6%, and 7% volume fraction and fly ash 4% volume fraction are reinforced with Aluminium 6061 matrix material, the result obtained is at 7% Zro2 the Tribological characteristics of developed composite was good.

3. OBJECTIVES

To fabricate high stiffness and less weight nanocomposite material for the application of automobile and aerospace industries to replace steel alloy. To select the nano particle that will improve mechanical properties and thermal stability and to reduces the weight of the AA 7075 Aluminium alloy. To produce new metal matrix nano composite of AA 7075 Aluminium alloy (matrix material) with ZrO_2 nano particles (reinforcement material). At final stage of project work the mechanical and tribological properties of AA 7075 alloy is compared with the new fabricated AA 7075 / ZrO_2 nano composite and result will be concluded.

4. METHODOLOGY

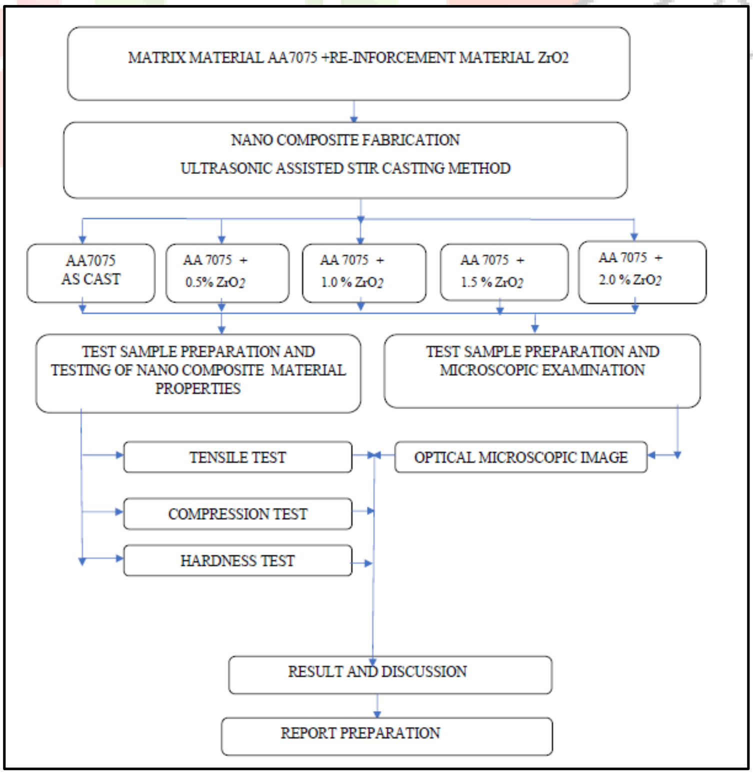

FIGURE: 1 METHODOLOGY

5. FABRICATION OF NANO COMPOSITES

5.1 COMPOSITION OF NANO COMPOSITES

S.No.	TYPE OF MATERIAL (Reinforcement In wt %)	AA 7075 in g	Zr�2 in g
Sample 1	AA 7075 (As cast)	1034	--
Sample 2	AA 7075 + 0.5% ZrO2	1031.6	5
Sample 3	AA 7075 + 1.0 % ZrO2	1031.2	10
Sample 4	AA 7075 + 1.5% ZrO2	1032.4	15
Sample 5	AA 7075 + 2.0% ZrO2	1025.9	20

FIGURE: 2 SAMPLE COMPOSITION

5.2 ULTRASONIC ASSISTED SIR CASTING

Dispersion of nano sized reinforcement in metal matrix composite is challenging due nano sized particles large surface to volume ratio which results in agglomeration and clustering. This affects the resulting properties of composite materials. Poor wettability of nano particles also produces the composite with inferior mechanical properties. The ultrasonic probe assisted sonication method helps in this case to uniformly distribute the particles in metal matrix. The ultrasonic cavitation effect is utilized to generate nuclei in casting. The ultrasonic cavitation-based processing of MMNCs have been successfully utilized by researchers to fabricate bulk metal matrix composite. The process is very effective in dispersing nano sized particles in the metal matrix. The process generally requires resistance heating furnace for melting metal, nano particle feeding mechanism, inert gas envelope for protection and an ultrasonic system. The ultrasonic processing system consist of an ultrasonic probe, a transducer and power source.

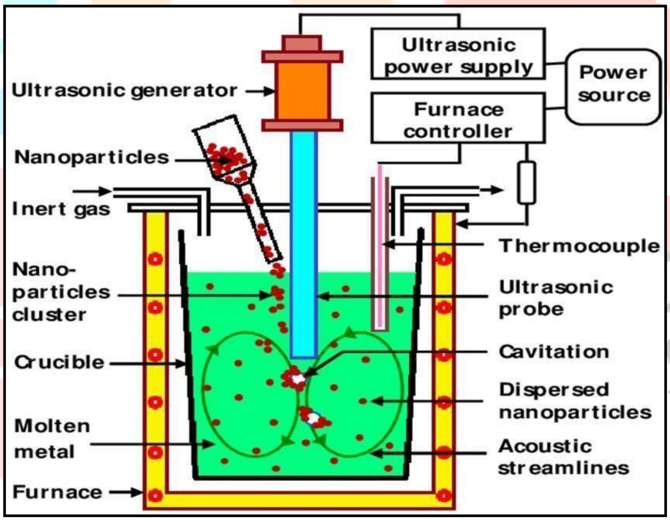

FIGURE: 3 ULTRASONIC ASSISTED SIR CASTING

5.3 FABRICATION OF NANOCOMPOSITES USING ULTRASONIC ASSISTED STIR CASTING PROCESS

In the proposed method ultrasonic assisted stir casting method is used for the fabricate nano composite this process will combine the advantages associated with ultrasonic probe as well as stir casting process. The combined process will improve the uniformity in dispersion of nano particles due to ultrasonic cavitation effect and avoid the settlement of nano particles in metal matrix due to continuous stirring with the stirrer This will help to produce MMNCs which enhanced mechanical properties. Matrix material is melted in the electric furnace when all the metal became liquid form reinforcement nano particle is added in the liquid melt mechanical stirrer is used to stir for a particular time , after the mechanical stirrer is removed from the melt the ultrasonic probe is dipped in the melt to create cavitation inside the melt this cavitation blast inside the melt this explosive energy of cavitation gives the momentum energy for the uniform distribution of the nano partial which will prevent the agglomeration, after preset time ultrasonic probe is stopped and the molten metal is transferred into the mould cavity, after solidification cat sample is removed out for the further process.

5.4 COMPOSITION OF NANO COMPOSITES

S.No.	TYPE OF MATERIAL (Reinforcement In wt %)	AA 7075 in g	ZrO2in g
Sample1	AA 7075 (As cast)	1034	-
Sample 2	AA 7075 + 0.5% ZrO2	1031.6	5
Sample3	AA 7075 + 1.0 % ZrO2	1031.2	10
Sample4	AA 7075 + 1.5% ZrO2	1032.4	15
Sample5	AA 7075 + 2.0% ZrO2	1025.9	20

FIGURE: 4 COMPOSITION OF NANO COMPOSITES

5.5 FABRICATED SAMPLES

Dimensions120 mm × 120 mm, 25 mm Thick

FIGURE: 5 CASTING IMAGE WITH DIMENSION

5.6 SAMPLE PREPERATION

FIGURE: 6 SAMOLE PREPARATION IMAGE

5.7 PREPARED TEST SAMPLE WITH DIMENSIONS

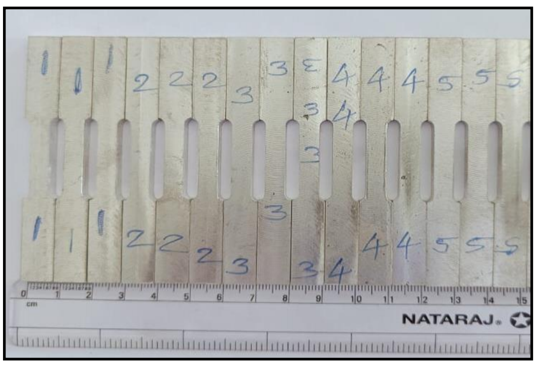

FIGURE: 7 TENSILE SAMPLE

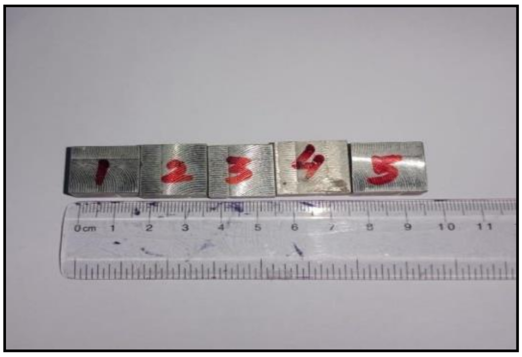

FIGURE: 8 HARDNESS TEST SAMPLE

FIGURE: 9 IMPACT TEST SAMPLE

FIGURE: 10 OPTICAL MICROSCOPIC IMAGE SAMPLE

6. TEST CONDUCTED

6.1 TENSILE TEST

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area, from these measurements the following properties can also be determined: Young's modulus, Poisson's ratio yield strength and strain hardening characteristics Uniaxial tensile testing in the most commonly used for obtaining the mechanical characteristics of isotropic materials. For anisotropic materials, such as composite materials and textiles, biaxial tensile testing is required. The most common testing machine used in tensile testing is the universal testing machine. This type of machine has two crossheads one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. There are two types: hydraulic powered and electromagnetically powered machine.

6.2 HARDNESS TEST

The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test piece. It is one of several definitions of hardness in material science Proposed by Swedish engineer Johan August Brinell in 1900, it was the first widely used and standardized hardness test in engineering and metallurgy. The large size of indentation and possible damage to test- piece limits its usefulness. The typical test uses a 10 millimetres (0.39 in) diameter steel ball as an indenter with a 3,000 kg (29 kN; 6,600 lbf) force. For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is substituted for the steel ball.

6.3 IMPACT TEST

The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry. since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative. The apparatus consists of a pendulum of known mass and length that is dropped from a known height to impact a notched specimen of material. The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after the fracture (energy absorbed by the fracture event). The notch in the sample affects the results of the impact test, thus it is necessary for the notch to be of regular dimensions and geometry. The size of the sample can also affect results, since the dimensions determine whether or not the material is in plane strain. This difference can greatly affect conclusions made.

6.4 OPTICAL MICROSCOPIC TEST

A general optical microscope mainly consists of an objective lens, ocular lens, lens tube, stage, and reflector. An object placed on the specimen stage will be magnified through the objective lens. When the target is focused, a magnified image can be observed through the eyepiece. Microscope will emit light onto or through objects (Sample placed on the specimen stage) and magnify the transmitted or reflected light with the objective and ocular lenses. Firstly, Magnification is the ability of a microscope to product an image of an object at a scale larger (or even smaller) than its actual via the use of objective lens. Difference lens have different magnification such as x 10, x 50 or x 100 to enlarge samples with precision.

7. READING AND CALCULATION

7.1 READING OF TENSILE TEST

Sl.No	TYPE OF MATERIAL (Reinforcement In wt %)	Tensile Strength In Mpa		
		Zone-1	Zone-2	AVERAGE
Sample 1	AA 7075 (As cast)	116	123	119.5
Sample 2	AA 7075 + 0.5% ZrO2	142	129	135.5
Sample 3	AA 7075 + 1.0 % ZrO2	216	210	213
Sample 4	AA 7075 + 1.5% ZrO2	248	262	255
Sample 5	AA 7075 + 2.0% ZrO2	221	217	219

FIGURE: 11 READING OF TENSILE TEST

7.2 TENSILE TEST GRAPH

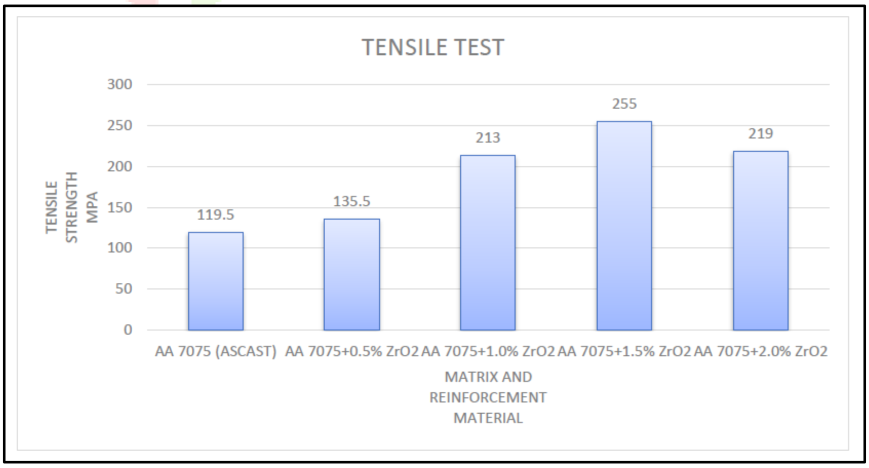

FIGURE: 12 TENSILE STRENGTH AND MATERIAL COMPOSITION

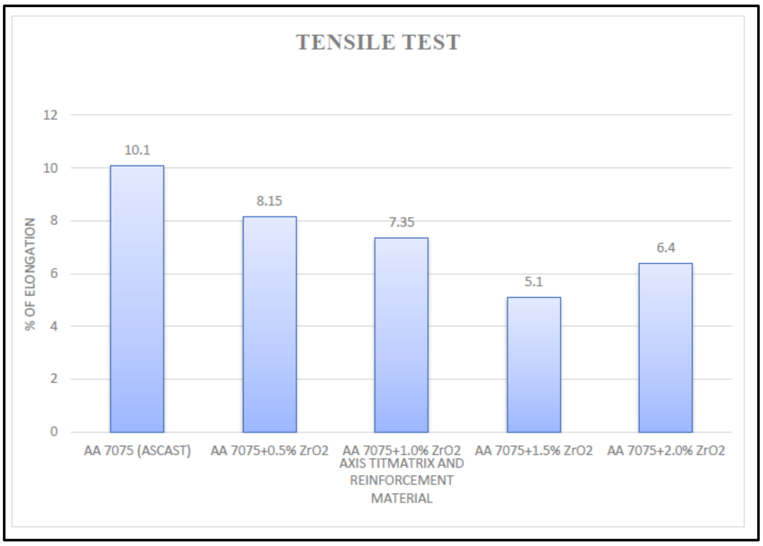

FIGURE: 13 % OF ELONGATION AND MATERIAL COMPOSITION

Tensile test is performed and the reading are tabulated, from tabulation is identified that the tensile strength of the fabricated nanocomposite is higher than the base metal, the maximum ultimate tensile stress is observed in sample 4 is 255.47 Mpa for the composition AA7075+1.5%ZrO2. On further increase the quantity of the reinforcement in the matrix material reduces the tensile strength of the nanocomposite. % of elongation is reduced from ascast to sample 4 again at sample 5 % of elongation increases due to decrease in strength.

7.2 READING OF MICRO HARDNESS TEST

Load : 0.5 Kgf
Dwell : 10 Sec
Scale : H.V @ 0.5 Kgf
Unit : Hardness Vickers
Scale : H.V @ 0.5 Kgf

Sl.No	(Reinforcement in wt %)	Zone-1 (HV)	Zone-2 (HV)	Zone-3 (HV)	Average (HV)
Sample 1	AA 7075 (As cast)	80	85	89	84.6
Sample 2	AA 7075 + 0.5% ZrO2	122	134	127	127.6
Sample 3	AA 7075 + 1.0 % ZrO2	140	136	141	139
Sample 4	AA 7075 + 1.5% ZrO2	149	152	146	149
Sample 5	AA 7075 + 2.0% ZrO2	123	128	130	128.6

FIGURE: 14 READING OF MICRO HARDNESS TEST

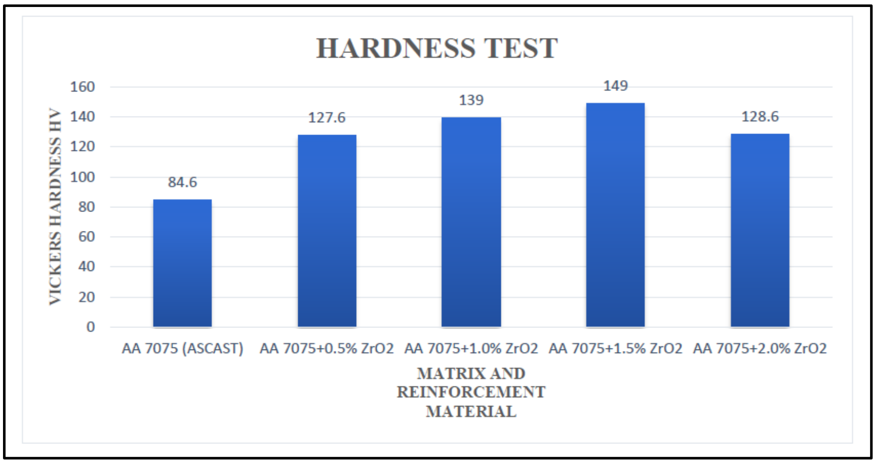

FIGURE: 15 HARDNESS STRENGTH AND MATERIAL COMPOSITION

Hardness of the Magnesium alloys can be increased by converting it into nanocomposite, due to the addition of the nano particle the formation of dentrated grain structure is prevented during solidification process and the fine grain structure are formed this phenomenon increases the hardness of the nanocomposite. Three impressions are made from each specimen for Vickers hardness test and the results obtained are tabulated. From the result is clear that the hardness of AA 7075 matrix material is improved due to the addion of nano particle. The maximum hardness value obtained in the fabricated nano composite is 149 HV in sample 4 for the composition of AA 7075 +1.5 %ZrO2.

7.3 READING OF IMPACT TEST

S.No	TYPE OF MATERIAL (Reinforcement In wt %)	Impact Energy Joules		Average J
		Zone-1 J	Zone-2 J	
Sample 1	AA 7075 (As cast)	92	95	93.5
Sample 2	AA 7075 + 0.5% ZrO2	138	1.3	140.5
Sample 3	AA 7075 + 1.0 % ZrO2	151	158	154.5
Sample 4	AA 7075 + 1.5% ZrO2	168	174	171
Sample 5	AA 7075 + 2.0% ZrO2	127	123	125

FIGURE: 16 READING OF IMPACT TEST

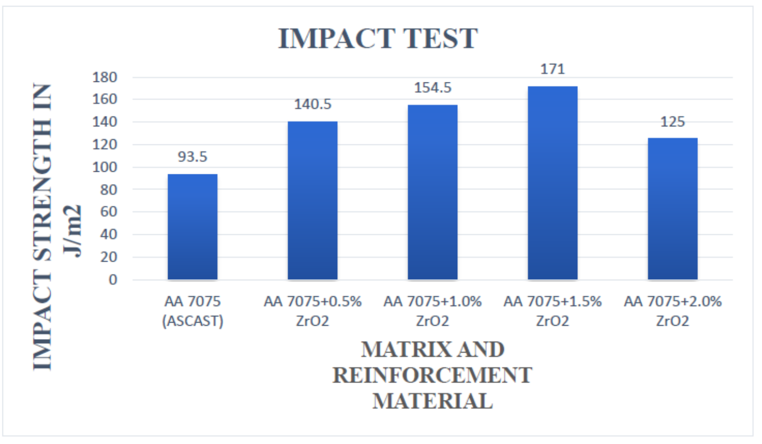

FIGURE :17 IMPACT STRENGTH AND MATERIAL COMPOSITION

Two impact test samples are made from each casting, sample are destructed in the impact test machine and the readings are tabulated, from tabulation it is observed that the impact strength of the nano composite is higher than the as cast sample this is due to the fine grain structure formed during solidification of nano composite and improved cohesive strength between the grain boundaries. The maximum impact strength of 171 J/m2 attained in the composition AA 7075 +1.5 %ZrO2., further the increase in the percentage of reinforcement impact strength is decreased.

7.4 OPTICAL MICROSCOPIC IMAGE

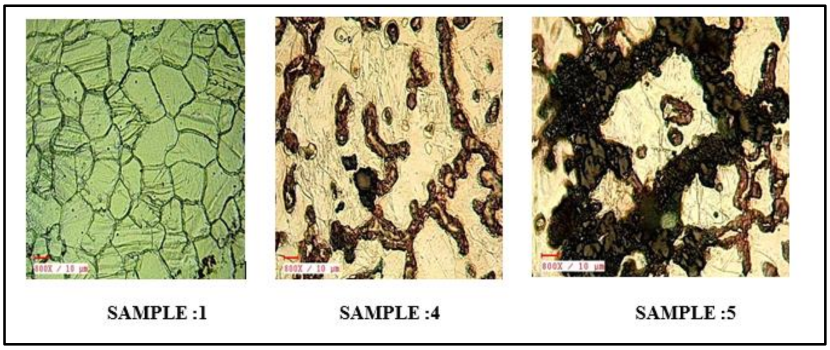

FIGURE :18 OPTICAL MICROSCOPIC IMAGE

Optical microscopic image is obtained from the prepared sample the result shows the grain size is reduced and the clear grain boundary is visible and the reinforcement particle are evenly distributed in the matrix material, From Optical microscopic image result it is also clear that there is no agglomeration seen and the nano particle are uniformly distributed for the samples AA 7075 + 0.5% ZrO2, AA 7075 + 01.0% ZrO2 and AA 7075 + 1.5% ZrO2 when further addition of nano particle agglomerations are seen in the AA 7075 + 2.0% ZrO2 sample this phenomenon will reduces grain boundary bonding strength and decreases the strength of the of the nanocomposite.

8. CONCULUSION

The cast nanocomposites' characterisation obtained by reinforcing various weight proportions of ZrO2 in the matrix of AA 7075 prepared by ultrasonic cavitation method are as follows.

Tensile strength tends to increase due to nano ceramic particles' proper bonding until 1.5% wt ZrO2, Orowan strengthening mechanism was the reason behind the improved strength. With higher addition of ZrO2, tensile strength tends to reduce due to nanoparticle agglomeration. The as-cast specimen shows a higher % elongation, i.e., the ductility is higher. But with the subsequent addi tion of ZrO2, % elongation tends to reduce as the ceramic particles lower the ductility of the composite due to higher interfacial bonding.

With ZrO2 addition, the micro-Vickers hardness value tends to increase due to the higher surface area of nano particles up to 1.5% wt, the fraction of ZrO2. The dislocations of the matrix were blocked by the nanoparticles such that, the hardness values get increased as the nano particles were seen in the grain boundaries.

The impact energy-absorbing capacity of the nanocomposites increases substantially with the inclusion of ZrO2. Higher energy-absorbing behaviour was observed with nanocomposite containing 1.5% wt. of ZrO2, with further addition, it tends to reduce due to reduced Strength.

From Optical microscopic image result it is clear that there is no agglomeration seen and the nano particle are uniformly distributed for 0.5,1.0 and 1.5% wt ZrO2 this shows the grain refinement and strengthening of AA 7075 is happened, agglomerations are seen in the 2.0 % wt ZrO2 sample this phenomenon will reduces grain boundary bonding strength and overall mechanical properties in the nanocomposite.

9. REFERENCES

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