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Tailoring The Microstructure And Mechanical Properties Of Aluminium 7075 / Yttrium 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 Yttrium nano (Y) particulate reinforcements. Ultrasonication technique was adopted for 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: Yttrium Nanoparticles, Metal Matrix Nanocomposites, Ultrasonication Process, Nano Reinforcement and Composite Materials.

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 but after 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 west 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 Yttrium in Al 7075 alloy matrices adopting the liquid metallurgy route associated with ultrasonication method.

2. LITERATURE SURVEY

Mehrabadi, H.B et al. (2024) Work carried by refining different amounts of yttrium in of Al-20%Sn alloy. the findings are, he compressive strength of the alloy increased with the addition of yttrium, The hardness of the alloy with 1% yttrium has increased by more than 80%. The wear resistance has been improved by adding 0.5 wt% yttrium

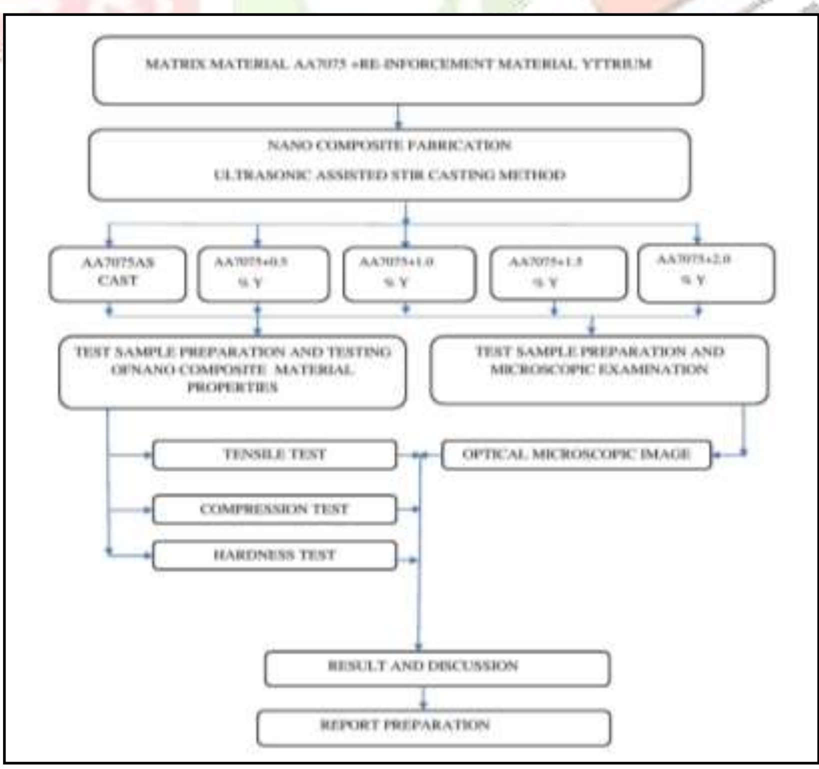
Jinbing Hu, et al. (2024) In this work, the effect of RE yttrium on the microstructure and properties of AISI 321 stainless steel at different solid solution temperatures was studied. The findings are with the increase of solid solution temperature; austenite grain coarsening has a deteriorating effect on the mechanical properties. The addition of RE yttrium can inhibit the grain coarsening.

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.

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 Yttrium nano particles (reinforcement material). At final stage of project work the mechanical and optical image properties of AA 7075 alloy is compared with the new fabricated AA 7075 / Yttrium nano composite and result will be concluded.

4. METHODOLOGY



5. PROCESSING OF COMPOSITES

Metal matrix composite materials can be produced by many different processes, the selection of suitable process engineering is the desired End, quantity and distribution of the reinforcement components (particles and fend the matrix alloy and the application. By altering the manufacturing method. the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved. Metal matrix compotes can be made by liquid or solid-state processes.

Liquid State Fabrication of Metal Matrix Composites: Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed phase into a molten matrix metal, followed by its Solidification. In Ander to provide high level of mechanical properties of the composite, good official bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix.

The methods of liquid state fabrication of Metal Matrix Composites are:

- Stir Casting
- Ultrasonic assisted sir casting
- Infiltration

6. FABRICATION OF NANO COMPOSITES

6.1 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 consists of an ultrasonic probe, a transducer and power source.

6.2 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.

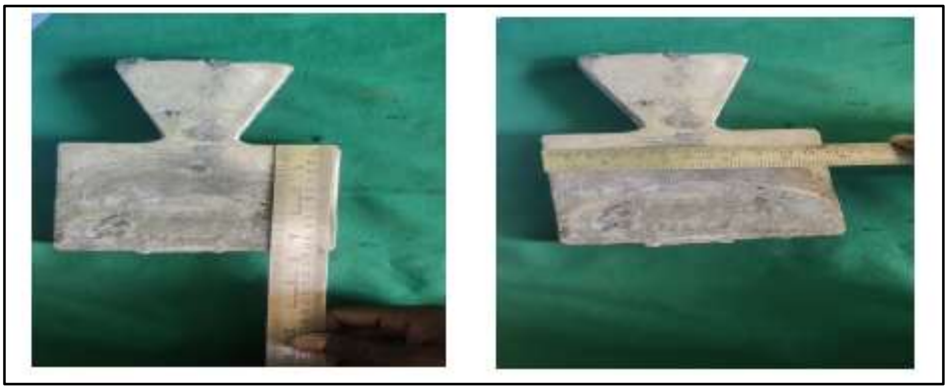
6.3 COMPOSITION OF NANO COMPOSITES

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

Table :1 Composition of Nano composites6.3 Nano Composite Fabrication Process

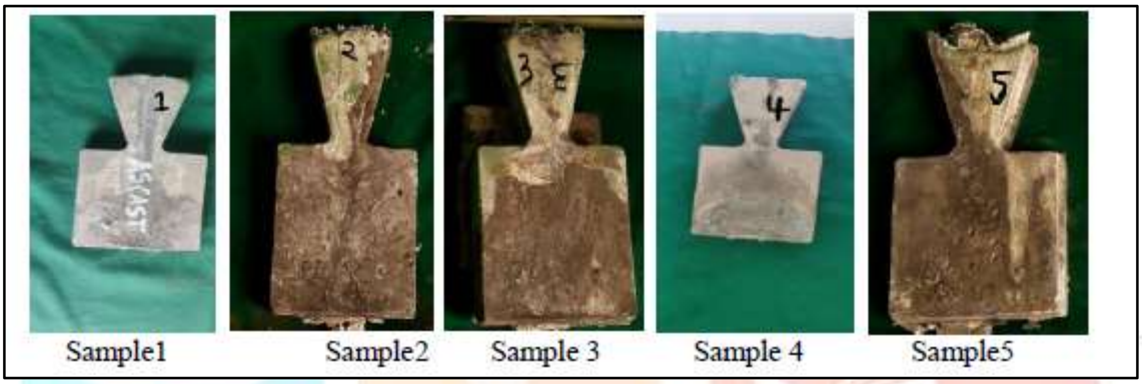
Figure: 1 Fabrication Process Image

6.4 FABRICATED SAMPLES



Dimensions120 mm × 120 mm, 25 mm Thick

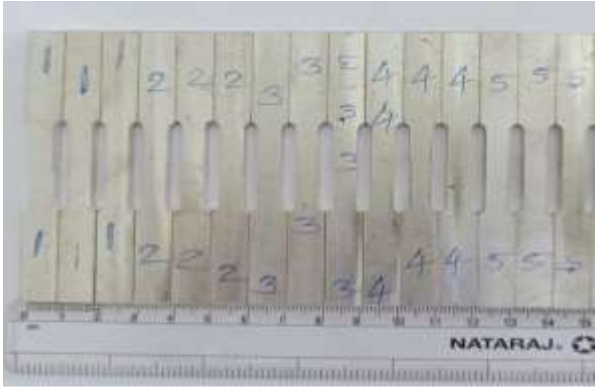
Figure. 2 Casting image with dimension



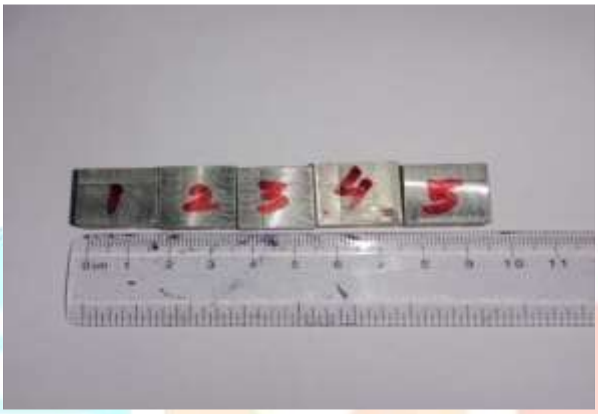
6.5 SAMPLE PREPERATION

6.6 PREPARED TEST SAMPLE

6.6.1 TENSILE SAMPLE



6.6.2 HARDNESS TEST SAMPLE



6.6.3 IMPACT TEST SAMPLE

6.6.4 OPTICAL MICROSCOPIC IMAGE SAMPLE

7. READING AND CALCULATION

7.1 READING OF TENSILE TEST

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

Table: 2 Reading of Tensile Test

7.2 TENSILE TEST GRAPH

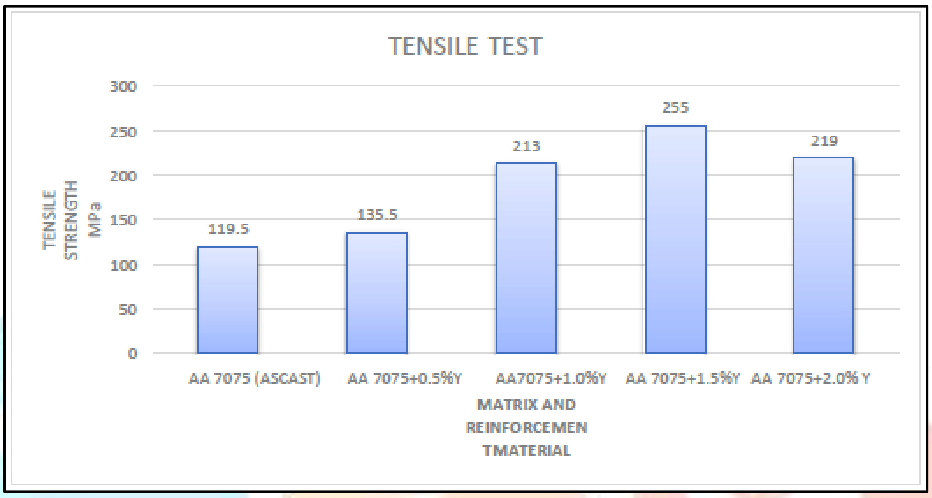


Figure: 3 Tensile Strength and Material Composition

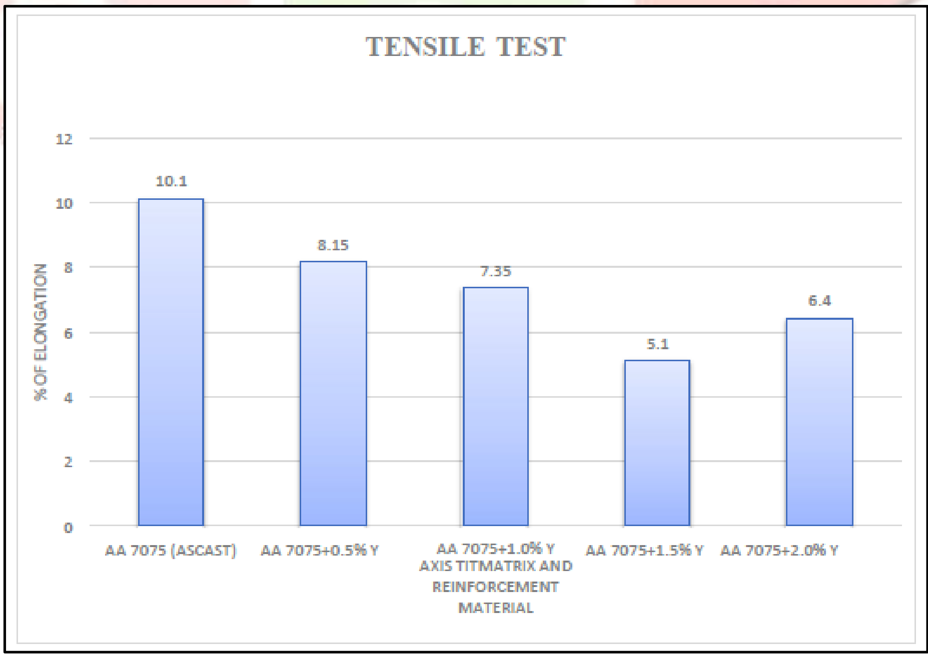


Figure: 4 % Of Elongation and Material Composition

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 Map for the composition AA7075+1.5%Y. On further increase the quantity of the reinforcement in the matrix material reduces the tensile strength of the nanocomposite. % of elongation is reduced from as cast to sample 4 again at sample5 % of elongation increases due to decrease in strength.

7.3 READING OF MICRO HARDNESS TEST

Sl.No	Matrix And Reinforcement	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%Y	122	134	127	127.6
Sample 3	AA 7075 + 1.0 % Y	140	136	141	139
Sample 4	AA 7075 +1.5%Y	149	152	146	149
Sample 5	AA 7075 +2.0%Y	123	128	130	128.6

Table: 3 Reading of Micro Hardness Test

7.4 HARDNESS TEST GRAPH

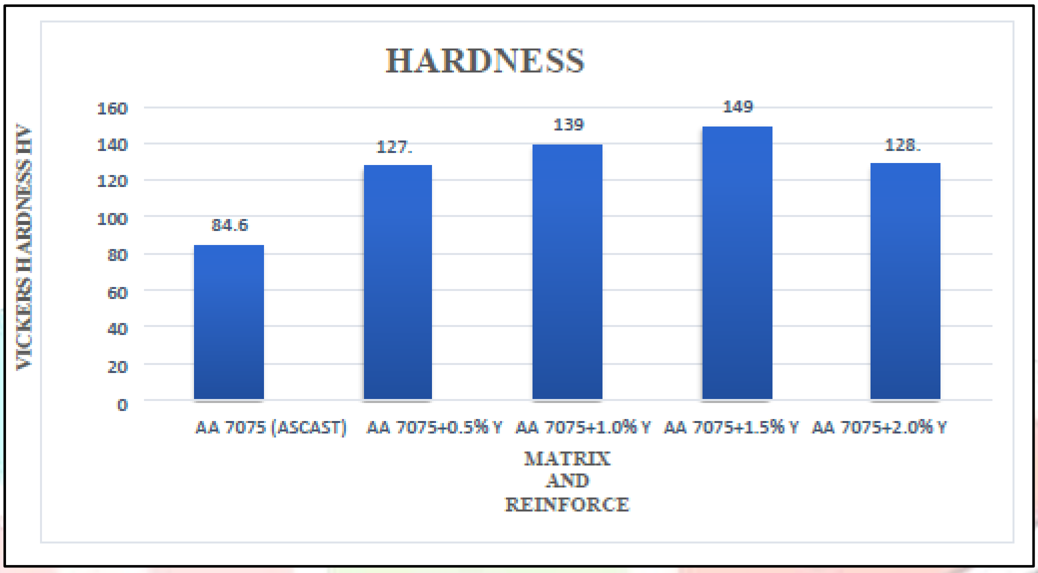


Figure :5 Hardness Strength and Material Composition

Hardness of the Magnesium alloys can be increased by converting it into nanocomposite, due to the addition of the nano particle the formation of dent rated 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 add ion 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 % Y.

7.5 READING OF IMPACT TEST

S.No	Matrix And Reinforcement	Impact Energy J/m2		Average J/m2
		Zone-1 J/m2	Zone-2 J/m2	
Sample 1	AA 7075 (As cast)	92	95	93.5
Sample 2	AA 7075+ 0.5 % Y	138	1.3	140.5
Sample 3	AA 7075+1.0 % Y	151	158	154.5
Sample 4	AA 7075+ 1.5 % Y	168	174	171
Sample 5	AA 7075+ 2.0 % Y	127	123	125

Table: 4 Reading of Impact Test

7.6 Impact test graph:

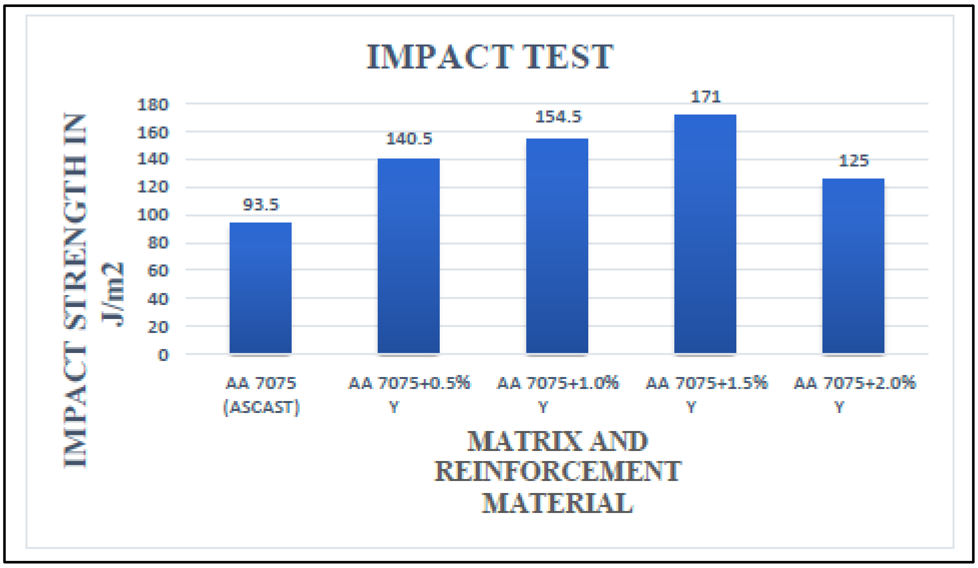


Figure:6 Impact Strength and Material Composition

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 higherthan 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 % Y., further the increase in the percentage of reinforcement impact strength is decreased.

7.7 OPTICAL MICROSCOPIC IMAGE

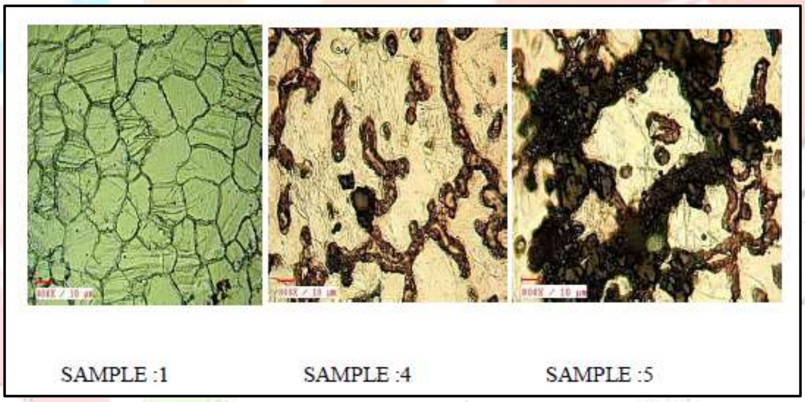


Figure :7 Optical microscopic image.

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% Y , AA 7075 + 01.0% Y and AA 7075 + 1.5% Y when further addition of nano particle agglomerations are seen in the AA 7075 + 2.0% Y sample this phenomenon will reduces grain boundary bonding strength and decreases the strength of the of the nanocomposite.

8. CONCULUSION

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

Tensile strength tends to increase due to nano particles proper bonding until 1.5% wt. yttrium, with higher addition of yttrium,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 yttrium, % elongation tends to reduce as the ceramic particles lower the ductility of the composite due to higher interfacial bonding.

With yttrium 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 yttrium. 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 yttrium. Higher energy-absorbing behavior was observed with nanocomposite containing 1.5% wt. of yttrium, 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. yttrium this shows the grain refinement and strengthening of AA 7075 is happened, agglomerations are seen in the 2.0 % wt. yttrium sample this phenomenon will reduces grain boundary bonding strength and overall mechanical properties in the nanocomposite.

9. REFERENCES

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