Comparative study of Al - 10 wt.% Zn alloy processed through As-cast and Centrifugal Casting.

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Abstract

Al-10 wt% Zn alloy was As-cast and centrifugal casted, the comparative study of mechanical, microstructure and tribilogical properties where found. The chemical composition in Spark Optical Emission Spectrometer founds that Al-10 wt% Zn as 90.83% ± 0.0745% of Aluminum and 8.68 % ± 0.0747% of Zinc. Density of the Al-10 wt% Zn alloy increase in centrifugal increased by 0.8 % then the as cast. The hardness of alloy in centrifugal is 45.7± 2.6 HV1 wile in the As cast is 43.5 ± 4.7 HV1. Due to centrifugal force in centrifugal casting the grain size and porosity percentage is lower to the as cast, is found in the optical microscope, the ultimate tensile strength of alloy in as cast is 165.24 ± 19.39 MPa and in the centrifugal cast is 177.01 ± 4.213 MPa. The SEM images gives the microstructural abnormalities that might contribute to the failure and EDX provided the fully characterize elemental composition of alloy. X-ray diffraction technique is used for qualitative analysis of phases in Al-10 wt% Zn alloy for intermetallics formed during As-cast and Centrifugal Casting. The wear rate of the alloy in as cast is 300 µg/Nm while in centrifugal casting is 250 µg/N in 20N lad, speed of 800rpm and disc diameter of 130mm. wear rate in centrifugal casting is lower than the as cast.

Keywords: *Dendroid, Interstitial porosity, Joint Committee on Powder Diffraction Standards, Fragmentation.*

1. Introduction

Al-Zn alloys are the alternative materials in engineering applications to reduce the cost of production without sacrificing the functional requirements of the components [1,2] . The basic motive of such an investigations is of course, of economic nature. Namely, the Zn-Al alloys are characterized by significantly lower price [3]. The generic metal casting processes fulfill most of these requirements, the inherent problems such as large segregate spacing and coarse grain structures severely limit the direct use of cast products in critical applications, consequently micro structural refinement is achieved by increasing the cooling rate and secondary processing operations[4]. These alloys feature clean, low-temperature, energy-saving melting, excellent castability, high strength and equivalent or often superior bearing and wear properties as compared to standard bronze bearing [5].

Metal casting is one of the most common casting processes. Metal patterns are more expensive but are more dimensionally stable and durable. Metallic patterns are used where repetitive production of castings is required in large quantities. With normal sand casting process the dimensional accuracies and surface finish is less. Defects are unavoidable. Low cooling rate and grain refinement is less compare to centrifugal and spray forming [6-7]. Centrifugal casting is a permanent mold is rotated continuously about its axis at high speeds as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with a very fine-grained outer diameter, Casting machines may be either horizontal or vertical-axis.Horizontal axis machines are preferred for long, thin cylinders, vertical machines for rings, castings can be made in almost any length, thickness and diameter[8-9]. Different wall thicknesses can be produced from the same size mold.

In this study, As-cast and Centrifugal Casting. Al-Zn alloy were investigated. Micro structural analysis of Al-Zn alloy is carried out using OM, and SEM TEM techniques[1-10]. Structure properties of Al- Zn alloy are determined using XRD. The mechanical properties such as Vickers hardness, 0-2% Yield strength and ultimate tensile strength of the alloy are determined by conducting the tensile test using Universal Testing Machine. Finally, the structure property correlations of the alloy processed through different processing technique are made.

2 Experimental Work

2.1 Casting process.

The casting process has been starts from placing empty crucible in the furnace. Then in order to maintain homogeneous mixture temperature of the heater is slowly increased to temperate of about 850°C. In the preprocessing dust particles present in Aluminum alloy removed and weighed, and stir for some time by using ladle made by cast-iron. Thealloys take 45minutes to heat at a temperature of 550°C. When mixture of alloy coverts to liquid state condition at 600 °C, 10 grams of D gas agent will be added to the alloyafter five minutes alloy forms completely dissolve and helps to remove the dust and prevents the oxidation in the molten metal.The casted material where brought in the desired shape and dimensions by EDM cutting machine. In witch the material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes. That will gives the precise dimensions like **ASTM E 92 for density test,** ASTM E8 for tensile and CNC lath machine is used for wear test sample having standard of ASTM G 98. And the samplescut in to 10mm x10mmx10mm size of ASTM E 92 samples, for conducting the density test using Archimedes' principle of water displacement technique. The tensile tests were conducted according to ASTM E8 standard in universal testing machine to analyses the strength of the alloys on basis of weight percentage.the wire Electrical Discharge Machining is used to cut the samples. In which 3 different samples are selected in different locations for testing.

2.2 Metallurgical Characterization

The Microstructure specimens were examined by optical microscopy (OM) using a Nikon microscope LV150. Scanning electron microscopy (SEM) using TESCAN VEGA 3 machine fitted with Tungsten heated cathode having acceleration voltage of 200V to 30kV and resolution up to 3nm (Czech Republic), X-ray diffraction in X'Pert^3 Powder machine having capacity of 4kV, step size of 0.001^0 and scanning range from -40^0 to $+220^0$ of 2θ (UK).

2.3 Physical and Mechanical Characterization

The density of alloy where measured by water displacement method (Archimedes principle) using CAH-1003 Sartorius electronic digital-weighing balance. The chemical composition where measured in Spark Optical Emission Spectrometer of POLY SPEK, ASTM E1251, and spectral range is 174-455 nm (UK). The hardness samples were tested in micro Vickers Hardness testing machine. TUKON1102 having test force range of HV0.01 to HV1kgf, automatic loading and unloading and magnification of 100X to 500X with ASTM E384 standard. For tensile testing flat samples of 25-mm gauge length and 3-mm thickness was prepared according to specifications stated in ASTM E8/E8M-04 in BISS Nano Test System BI-7000 having 25kN force rating and +/-25mm stroke servo-actuator (USA). The tensile test specimens of dog bone shapes were prepared using EDM technique (Model: CONCORD, DK 7732, wire EDM). Wear test is conducted on pine on disk wear testing machine DUCOM TR-20-M26 having rotating hardened steel disc of 40 mm diameter, 0.11µm surface roughness(USA).

3 Results and Discussions

3.1 Chemical composition test.

Table 1.shows the Results of percentage of composition of Al- Zn alloys in the samples.

Composition	As – cast		Centrifugal casting	
	Al	Zn	Al	Zn
Al -10 wt% Zn	90.83 ± 0.0745	8.68 ± 0.0747	90.95±0.1741	8.56 ± 0.1746

In above Table 1.Shows the average percentage of Al – Zn mixture. With the chemical composition test in Spark Optical Emission Spectrometer.In which the inert gasses are used to create the spark that will emits the vapors of different elements in different wavelength based on the percentage of elements present in alloy, the weight percentage of Aluminum in Zn-10%.is processed through As Cast is found the average percentage of to be 90.83% and

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zinc is around 8.68 % and in Centrifugal casting is 90.95% Aluminum and zinc is 8.56% which is close to the 10%of zinc and 90% of Aluminum.

3.2Microstructure

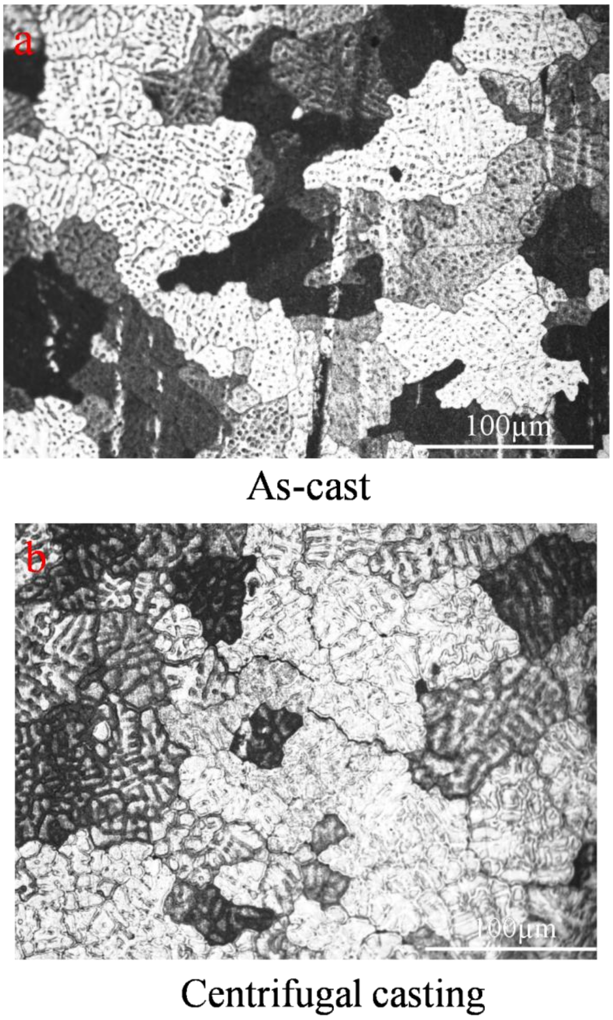

Fig 1. Microstructures of Al -10 wt% Zn alloy in 100X magnification (a) for as-cast,(b) forcentrifugal casting.

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This shows that Microstructure of the Al-Zn alloy, in Fig1.it clearly shows the grain distribution of aluminum and zinc. In which the brighter grains are aluminum and the dark one is zinc. The above micro structural comparison shows the grain size of 25µm to 50µm in as-cast where as in centrifugal cast is 10µm to 15µm which is lower than the as-cast,due to the centrifugal force effect in the centrifugal casting and the faster cooling rate gives the small grains rather than the as-cast. And also the percentage of porosity in the as-cast in more compare to the centrifugal casting.

3.3Physical Property

Table 2.Shows the results of density test according Archimedes' principle.

Composition	As - cast gm/cc	Centrifugal cast gm/cc
Al -10 wt% Zn	2.31 ± 0.0613	2.29 ± 0.0582

The above table 3. shows the results of density test of Aluminium Zinc alloys processed through Centrifugal casting and As-cast technique according Archimedes' principle. The density of pure Aluminium is 2.77g/cc and that of Zinc is 7.13g/cc. Theaverage density of as-cast is 2.31 g/cc where as in centrifugal casting is 2.29 g/cc it is evident that with the change of casting process from as-cast to centrifugal cast the alloy weight have been increased by 0.8%, that is due to centrifugal effect and shrinkage effect in centrifugal in higher cooling rates.

3.4 SEM Analysis

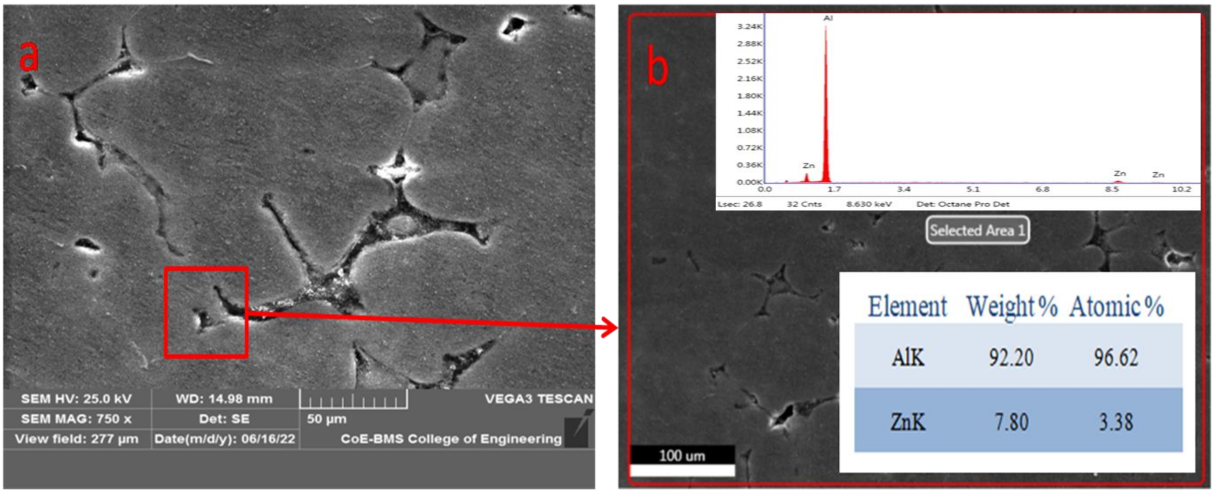

Fig 2. Shows the SEM image of surface topography of Al -10 wt% Zn (a) of as cast,(b) shows the Square EDX image with peaks and composition.

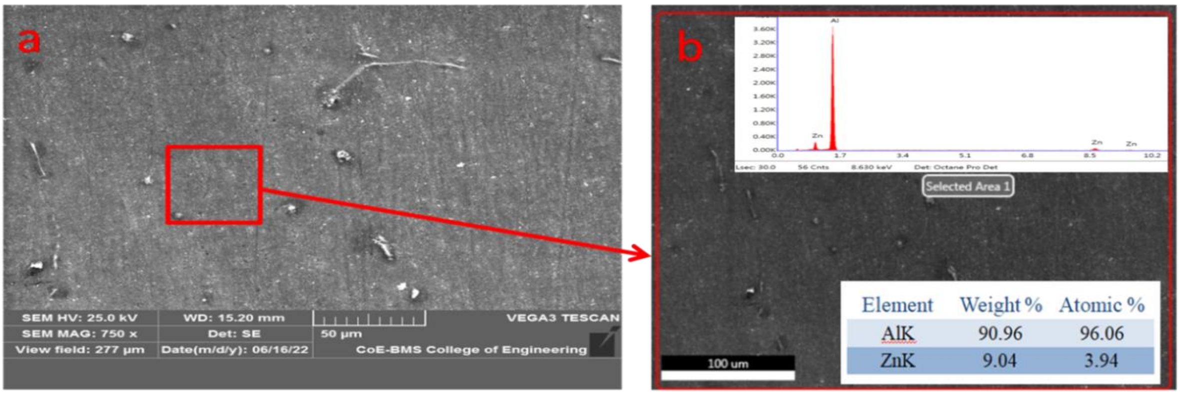

Fig 3. Shows the SEM image of surface topography of Al -10 wt% Zn (a) of Centrifugal casting, (b) shows the Square EDX image with peaks and composition.

The above fig 2(a)shows the grain distribution of aluminum and zinc is SEM at 750. The as cast has the high interstitial porosity and dendroid where as in fig 3(a) the centrifugal cast has less interstitial porosity and dendroid. The highly irregular shape that are essentially the unfilled gaps among the pre-solidified liquid in mould or splat boundaries are noticed in as cast process due to the centrifugal force effect in the centrifugal casting and the faster cooling rate gives the small grains rather than the as-cast. And also the percentage of porosity in the as-cast in more compare to the centrifugal casting. The spot EDX gives the evidence of fragmentation of the slow solidified atoms leads to the porosity in as cast process.

The above fig 2(b) shows the EDXimage and peak aptterns, the characteristic Xrays will reveals the presence of elements present in the specimens in withc the weight % and Atomic % of elements present in the samples are measured.The weight % of Al is 92.20% and zinc is 7.80% and Atomic % is 96.62% and 3.38%. It is nearer to the composition of Al -10 wt% Zn.The above fig 3(b) shows the EDX image and peak aptterns, the weight % and Atomic % of elements present in the samples are measured. The weight % of Al is 90.96% and zinc is 9.04% and Atomic % is 96.06% and 3.94%. It is nearer to the composition of Al -10 wt% Zn

.5 XRD Analysis

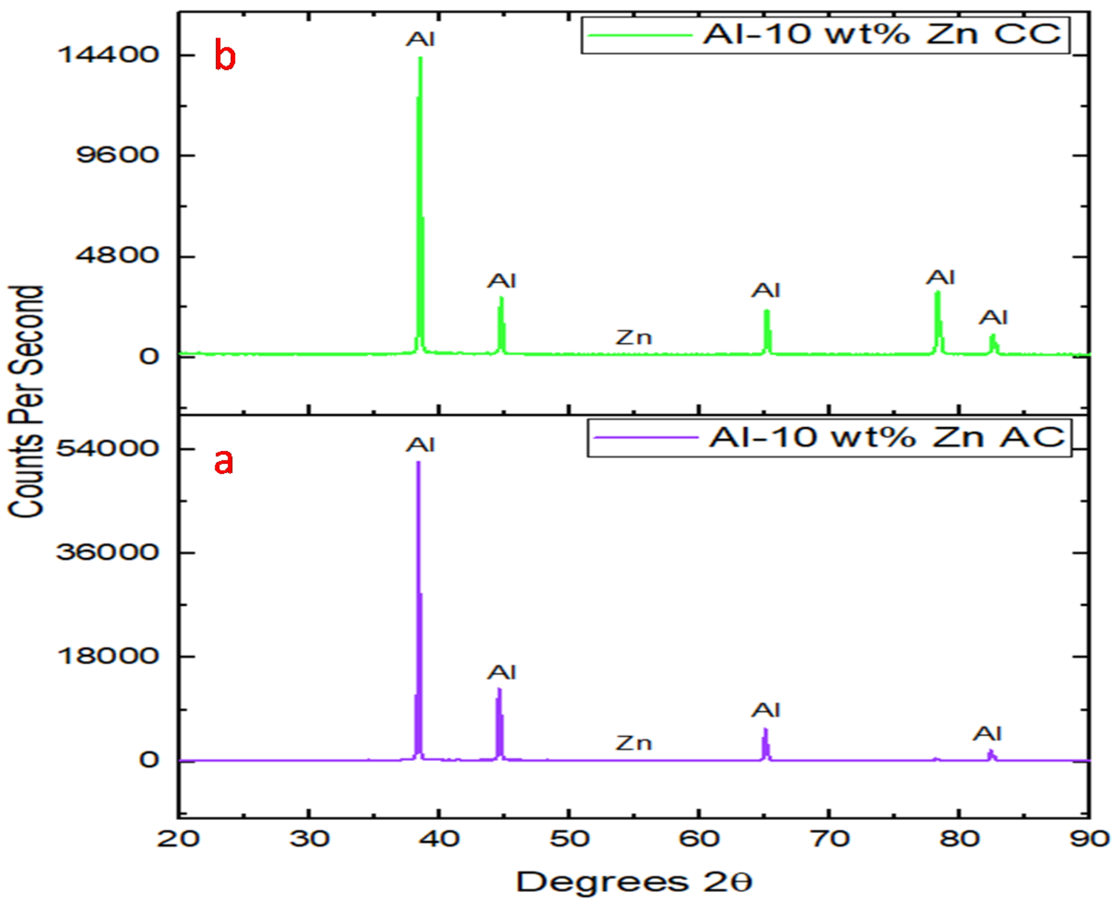

Fig 4. Shows the ray Diffraction Peaks patrons (a) as cast and (b)centrifugal casting.

The above fig 4(a) shows the ray Diffraction Peaks positions of Al and zinc, in which the as cast sample has the higher intensity for the peak where the centrifugal casting sample have the lower intensity, but the peak positions for first two peaks are almost same and the lower intensity peaks are in different positions, it shows change in grain size and shape for same composition but different casting process. The results of XRD where analyzed in X-Pert high score in which the JCPDS card number is **96-901-2003** for as cast and for centrifugal cast is **96-431-3218.**According this card number **96-901-2003**the chemical formula is $ZnAl_{4,}$ density is 2.7 g/cm^3 and Volume of cell is 66.43 10^6 pm^3, and fig 4(b) of centrifugal casting having card number **96-431-3218** the chemical formula is $ZnAl_{4,}$ density is 2.69 g/cm^3 and Volume of cell is 66.53 10^6 pm^{3}and having face centered cubical structure for aluminum and HCP structure for zinc for both the composition.

3.6 Micro Vickers Hardness

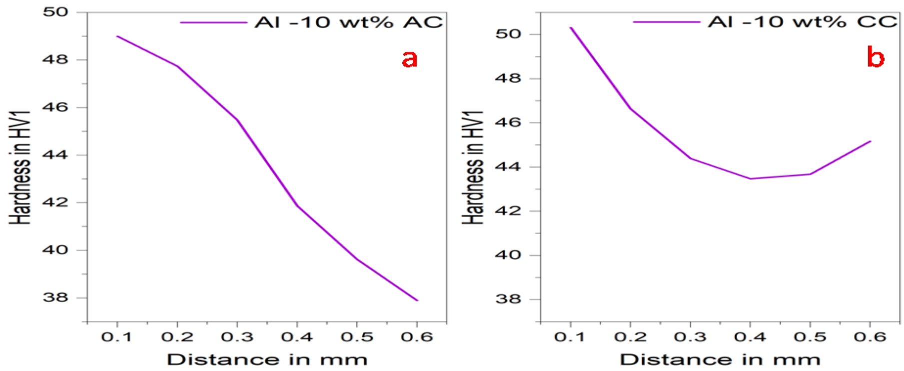

Fig 5. Shows the graph of average hardness of Al -10 wt% Zn alloy over a distance of 0 to 0.6 mm, a) As cast and b) centrifugal cast

Table 2. Shows the average values of hardness of Al -10 wt% Zn alloy

Composition	As cast HV 1	Centrifugal cast HV 1
Al -10 wt% Zn	43.5 ± 4.7	45.7± 2.6

The Vickers hardness numbers for Al -10 wt% Zn processed through fig 5 (a) and (b) As-cast and Centrifugal casting technique is conducted on micro Vickers hardness testing machine following ASTM E-384 [7] for the load of 10 kg with diamond indenter for the period of 100 seconds and within the distance of 10mm the hardness value in as cast in linearly decreasing where as in centrifugal casting the value initially decreases and slightly increased over the distance. The shown in Table 2, shows that hardness values of as-cast is 43.5 HV1 where as in centrifugal casting is 45.7 HV1 the hardness of the Al-Zn alloy increases centrifugal casting by 6%. This is due to increase change in density and tensile strength in centrifugal casting.

3.7Tensile Test

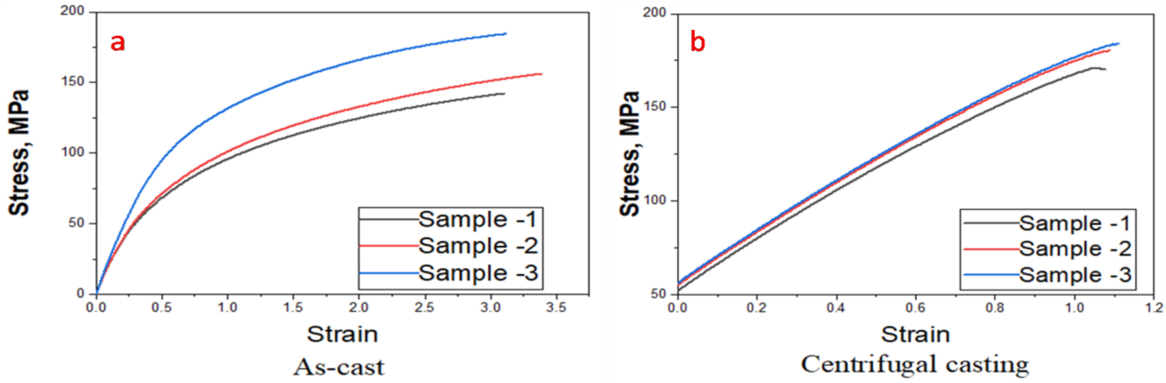

Fig 6. Shows the stress Vs strain curve of Al - 10 wt% Zn a) As cast and b) centrifugal cast

The fig 6 (a) and (b) shows the ultimate tensile strength for Al - 10 wt% Zn processed through As-cast and Centrifugal cast technique, in as-cast process the average peak strength is 165.24 MPa for3 samples in different locations, but in centrifugal casting the average peak strength 177.01 MPa.The table 3shows that ultimate tensile strength of the Al-Zn alloy increases with the increase in the weight percentage of Zinc. This is due to the increment of Zinc amount, which is harder then Aluminum.

Table 3. Shows the Results ultimate tensile strength of the alloy

Composition	As-Cast in MPa	Centrifugal cast in MPa
Al -10 wt% Zn	165.24 ± 19.39	177.01± 4.213

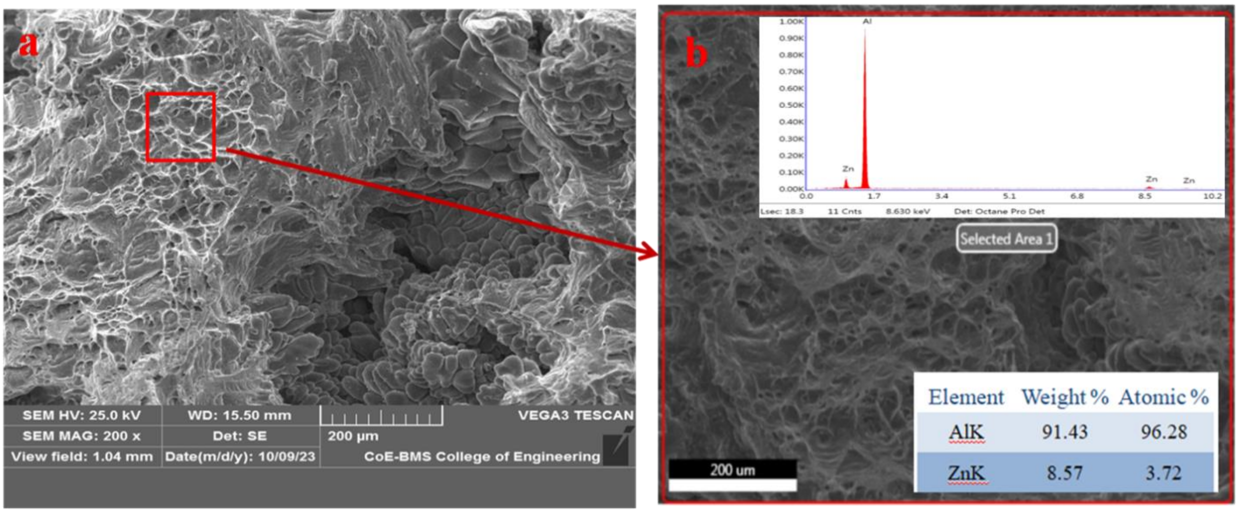

Fig 7. Shows the SEM image of surface topography of Al -10 wt% Zn broken sample (a) As cast,(b) shows the Square EDX image with peaks and composition

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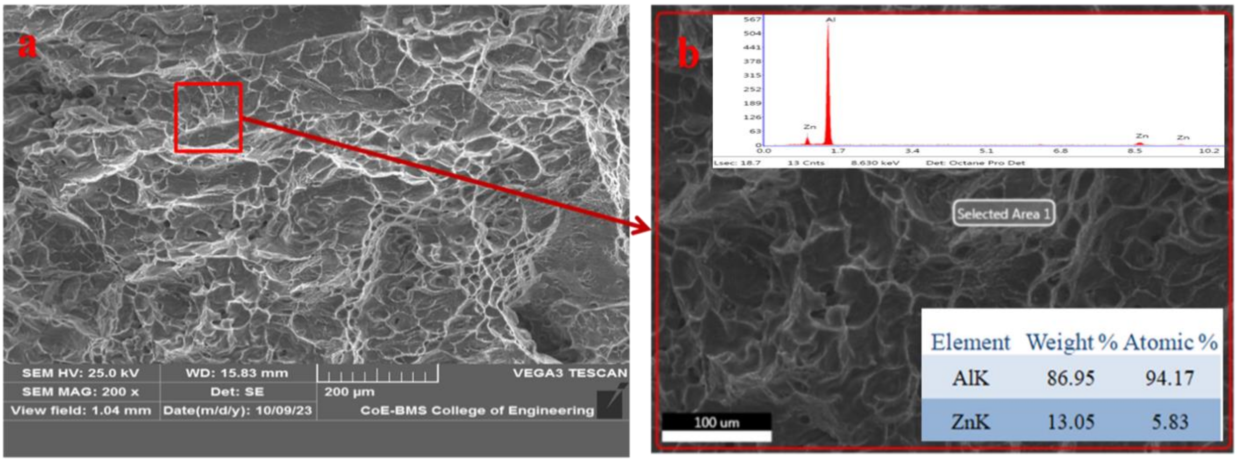

Fig 8. Shows the SEM image of surface topography of Al -10 wt% Zn broken sample (a) centrifugal casting, (b) shows the Square EDX image with peaks and composition

In above fig 7 and 8 shows the Al 100 wt % Zn alloy's tensile sample where examined in SEM for the facture analysis, the sample after breakage of dog bone shape of sample where cut in 10 mm distance in gauge length, the images we can analyze that the proper grain shapesare not seen in some portion it means the crack propagates inside the grain (Inter granular fracture) both in as cart and centrifugal cast it evidences that the fracture is ductile

3.8Wear Test

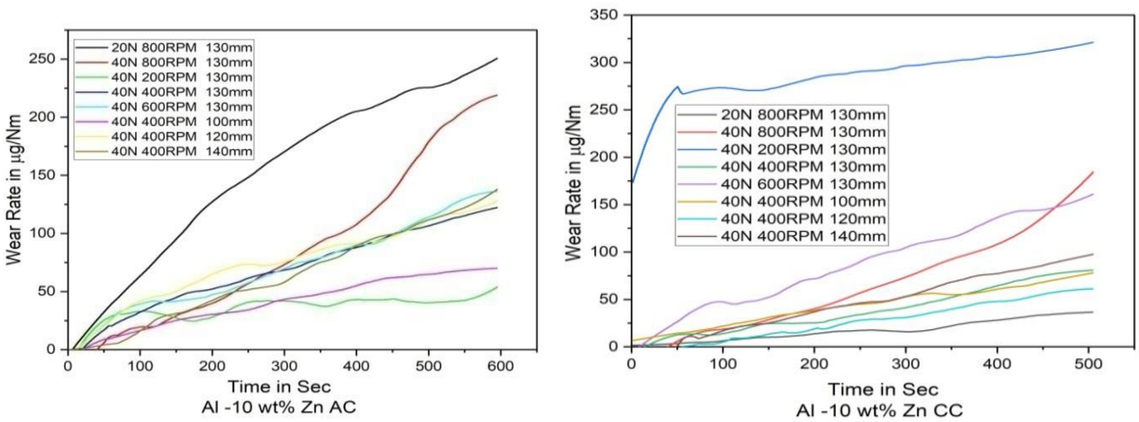

Fig 9. Shows the graph of time Vs wear rate for different lodes, Speed and Sliding distance.

Three samples are essential to perform pin-on-disk wear test. The pin was against the counter face rotating disk 'EN32 steel disk' [6] with the disc diameter is 200 mm,with the dead loading system the pin was against to disc load. The wear test samples prepared are 50mm length and 10mm diameter in CNC lath machine. The parameters of wear test are loads of 20N and 40N were applied with speed of 200, 400, 600, and 800 rpm, and sliding distance of 100, 120, 130 and 140mm for the time of 600 seconds. fig 4.1 shows the graph of wear rate vs time, in which the maximum wear rate is 300 µg/Nm in as-cast while in centrifugal casting is 250 µg/N in 20N load, speed of 800rpm and disc diameter of 130mm, it clearly shows the wear rate is 16% high in As-cast than compare to centrifugal casting.

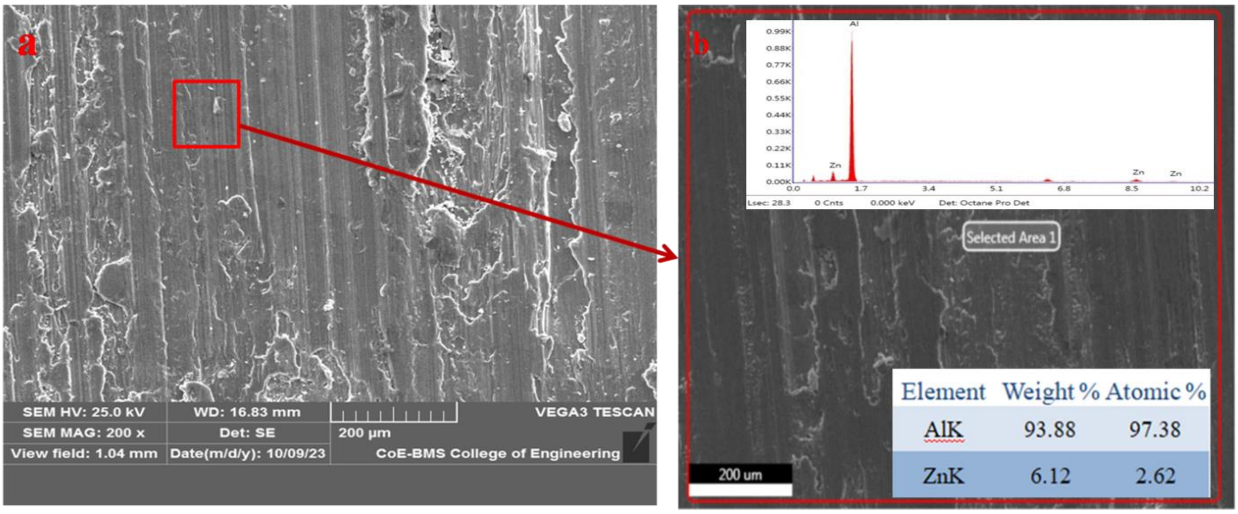

Fig 10.shows the SEM image of surface topography of Al -10 wt% Zn of Wear out sample of as cast ,(b) shows the Square EDX image with peaks and composition

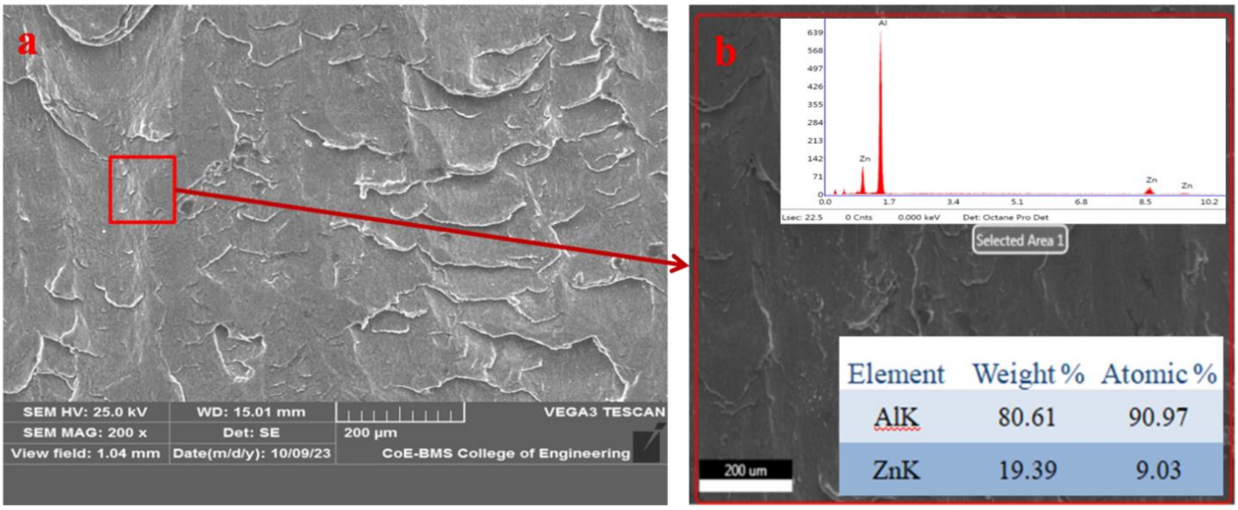

Fig 11. shows the SEM image of surface topography of Al -10 wt% Zn of Wear out sample of Centrifugal casting ,(b) shows the Square EDX image with peaks and composition

In above fig 10 and 11, Al 10 wt % Zn alloy's wear out samples were examined in SEM for the wear surface analysis, the sample after wear out where cut in 10 distance in length, theimages we can see clearly that in fig 10 the portions with full flow of grains and in fig 11 the portion noticed that the surface is in flakes formation it evidences that the wear of As cast sample is softer then the centrifugal casting.

4 Conclusion

Al -10 wt% Zn alloy of as cast and centrifugal where compared in microstructure, physical and mechanical properties. The grain size of 25µm to 50µm in as-cast where as in centrifugal cast is 10µm to 15µm which is lower than the as-cast. With the change of casting process from as-cast to centrifugal cast the alloy weight have been enhanced by 0.8% in density test. The average peak strength is 165.24 MPa for3 samples in different locations, but in centrifugal casting the average peak strength 177.01 MPa which is 7.2% higher strength. Hardness values of as-cast is 43.5 HV1 where as in centrifugal casting is 45.7 HV1 the hardness of the Al-Zn alloy improved centrifugal casting by 6%. The maximum wear rate is 300 µg/Nm in as-cast while in centrifugal casting is 250 µg/N in 20N load, speed of 800rpm and disc diameter of 130mm, it clearly shows the wear rate is 16% high. The as cast has the high interstitial porosity and dendroid where as in the centrifugal cast has less interstitial porosity and dendroid.The fracture analysis provides the inter granular fracture shows the ductility of the material and surface is in flakes formationin wear test evidences that the wear of As cast sample is softer then the centrifugal casting. The highly irregular shape that are essentially the unfilled gaps among the pre-solidified liquid in mould or splat boundaries are noticed in as cast process due to the centrifugal force effect in the centrifugal casting and the faster cooling rate gives the small grains rather than the as-cast.

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