ISSN No:-2456-2165

A Synonymous Description of Al-Zn Alloy in Different Casting Process

Chethan V
M. Tech Scholar
Department of Mechanical Engineering
Nagarjuna College of Engineering and Technology
Bengaluru, Karnataka, India

Shashikanth G S
Asst. Professor
Department of Mechanical Engineering
Nagarjuna College of Engineering and Technology
Bengaluru, Karnataka, India

Abstract:- Last few decades rapid increase of utilization of Aluminum-zinc alloys, particularly in the area of automobile and aeronautical sector due to characteristics of high strength to weight ratio, low density, high wear resistance and low coefficient of thermal expansion. These advancements in the field of application is the motivation to study of their mechanical and microstructure important properties such as density, tensile, hardness and wear behavior.

In this paper, Aluminum based alloys containing 10%, 20% and 30% weight of Zinc were synthesized using casting method by using As cast and centrifugal casting. To study the Compositional analysis of Microstructure and Mechanical properties different samples of same composition shows near uniform distribution of zinc in the prepared alloys. The performance of the microstructure shows the presence of primary zinc. The performance ids studied using Tensile, resistance to wear, Hardness and density test methods. Tensile tests were carried out using universal testing machine. Wear Test behavior was studied by using computerized pin on disc wear testing machine. In both the testing cases it is observed that for all the tests such as tensile strength, Resistance to wear, hardness and density better performance with increase in Zinc percentage.

Keywords:- *Aluminum-zinc alloys, Tensile test.*

.

I. INTRODUCTION

Rapid development of Automobile, Marine and aeronautical industry the importance of research and development activities on composite materials become common practice. From past few decades most of the traditional materials are replaced by composite materials due to its superior properties such as higher specific high hardness, strength, high thermal resistance, high wear resistance and lower density[1][2]. Specifically aluminum metal matrix composites have preferred in industry such as automotive, aeronautics and marine industries for obtaining best result of mechanical properties. Most of the Composite materials are manufactured through either liquid metallurgy or solid method. In case of liquid metallurgy method, electromagnetic stir casting method, stir casting method, and in-situ method and centrifugal cast. Depending on the Matrix material, it can be classified as Polymer Matrix Composite (PMC), Metal Matrix Composite (MMC) and Ceramic Matrix Composite (CMC) [2][3][4].

Aluminum alloys are having good thermal conductivity with lightweight in nature. But, specifically for heat exchanger applications thermal conductivity of aluminum alone may not be suitable for manufacture. Hence to improve the thermal conductivity property one of the possible idea is Metal Matrix Composites (MMC) fabrication process with high thermal conductivity materials as reinforcement. Many authors Suggested copposite materials are good choice due to their inherent property of high strength-to weight ratio[1]-[5].

The fabrication techniques of MMC‘s play a major role in the improvement of the mechanical and Tribological properties. They will be distorted plastically and reinforced by a range of ways principally by obstructing the movement of linear defects referred to as dislocations on a microscopic scale. Once movements of dislocation are deadlocked, deformation rate is reduced that on the opposite hand leads to strengthening or strain hardening in order that the mechanical properties like tensile and compressive strengths, hardness, toughness, stiffness etc are improved. Metal matrix may be aluminum and its alloys, Copper and its alloys, titanium and its alloys, magnesium and its alloys and Nickel based super alloys etc. They're appropriate where the working temperatures are very harsh or high.

Many researchers shown Aluminium2024 Metal matrix composites (MMC‘s) provides better performance for heat treatment, reinforcing various ceramic material, and various manufacturing processes, various process parameters for improving the mechanical, thermal and corrosion related properties. Aluminium 2024 MMC‘s utilize ceramics like Al2O3, TiB2, TiO2,SiC, Tic, B4C, Graphite powder ,Carbon Nano particles ,E-glass fibers, Fly ash ,Red mud with individual and multiple primary CuAl2 b-phase in Al-40 Cu alloy. Development of microstructure during spray forming of Al—CU alloys is discussed it light of the solidification behavior of droplets and spray deposits. particulate reinforcements like Hybrid Metal matrix composites Al2024 MMC‘s reinforced in various Wt. % and various particle size.

Al2024 metal matrix composites shows various benefits over monolithic materials including higher specific strength, high strength to weight ratio and corrosion resistance, good wear resistance, higher thermal conductivity, lower coefficient of thermal expansion.

In this paper the study of mechanical properties and structural characterization of the Al-Zn alloy is discussed. The entire work is divided two parts. First preparation of the metal matrix composite by varying reinforcement particles 10%, 20% and 30% by using liquid metallurgy technique. Next characterize the prepared composite for their mechanical properties such as tensile test, hardness test, chemical composition wear and Density as per ASTM standards.

The rest of the paper is organized as follows: Section II discusses literature survey. In section III Methodology used to in the paper is discussed. Section IV discusses Various Testing procedure is discussed. Section V depicts the results and analysis. The paper concludes in Section VI.

II. LITERATURE SURVEY

In [1] Author provides idea of Aluminum–Graphene Nano platelets composite based casting process is discussed. They used semi-powder method with hot extrusion method. They used 0.25%, 0.5%, 1% of weight of aluminum is mixed with grapheme. The result shows GNP Nano- particle integration provides better performance for tensile, hardness test. In [2] Metal Matrix Composites (MMC) of Graphene /aluminum based method is proposed. They used Friction Stir Processing(FSP) for fabrication process. The result shows using FSP graphene aluminum matrix composite successfully mixed. Also thermal conductivity of graphene/ aluminum mixture is increased compared to aluminum matrix. In [3] stir casting method based production of particulate composite plate method is discussed. They used Al alloy as a matrix phase and reinforcement is alumina (Al2O3). The results shows better performance. In [4] Aluminum and Silicon alloy based scheme is discussed. In [5] friction stir alloying based bulk aluminum-graphene nano platelets composite fabrication process is discussed. They fabricated channel on surface of cross section of the aluminum plate and filled with graphene nano platelets Further, cross-sectional surface is covered by same size of another aluminum plate, The friction stir alloying method is used. The results of tesile and hardness test provides better performance.

In this paper Aluminum -Zinc alloy based structural characterization and mechanical properties are studied. The various metal matrix composite for the dfferent reinforcement particles 10%, 20% and 30%. Further to study the performance tests such as tensile test, hardness test, chemical composition wear and Density tests are carried out as per ASTM standards

III. METHODOLOGY

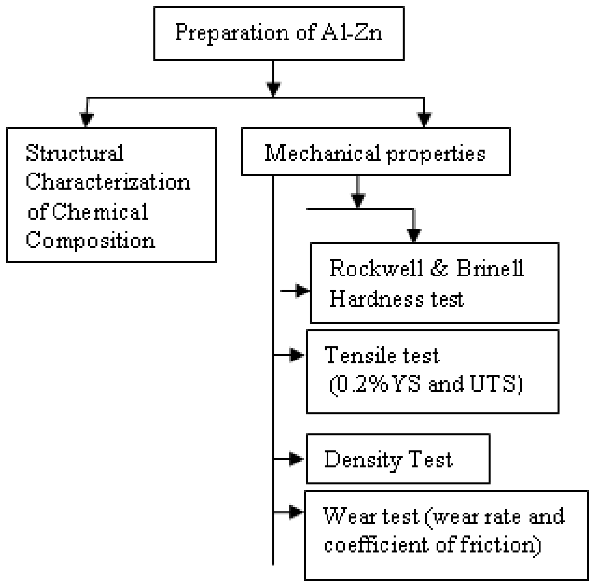

Fig 1:- The methodology of the whole experiment involves

Fig 1 shows Methodology used in the works. Initially AI-Zn is prepared. Then Test such as Rockwell and Brinell hardness test, Tensile test, density test, wear test is carried out.

IV. SAMPLE PREPARATION

The process of casting starts with placing empty crucible in the furnace. Then in order to maintain homogeneous mixture temperature of the heater is gradually increased up to 800°C. In the pre processing dust particles present in Aluminum alloy removed and weighed, charged in the crucible for melting. Further required quantities of reinforcement Zinc are weighed on the weighing machine. Reinforcements are heated for 45 minutes at a temperature of 500°C. When matrix was in the semisolid stage condition at 650°C, some amount of D gas master alloy can be added weighed by weight is use as wetting agent. After five minutes alloy forms completely dissolve of impurity on liquid surface which to be removed. Each melt was stirred for 30s after the addition of the modifier, held for 5 min and then poured into a cubical graphite mould surrounded by fireclay bricks. Heater temperature is then gradually increased to 800°C. At this heater temperature stir sometimes is started and continued for five minutes. as Casting and Centrifugal Casting .

Sl. No.	Material Composition	Al (in gms)	Zn(in gms)
1	Al - 10% Zn	900	100
2	Al - 20% Zn	800	200
3	Al - 30% Zn	700	300

Table 1:- Composition of Al-Zn alloy

ISSN No:-2456-2165

➢ *Cutting:*

After obtaining the composition from the casting process, specimen of desired dimension is prepared to conduct the testing process by using some with the help of cutting tools. Further the specimen of composition of alloy fixed in the lathe to remove the material and to get the desired shape to conduct the test. The cast samples used are approximately of same width, length and height .

➢ *Tensile specimen:*

The casting samples were prepared by some dimension of squared shaped pieces. By using EDM cutting machine, the tensile specimens were prepared to conduct the tensile properties. Below figure shows the specimen dimension required to conduct the test.

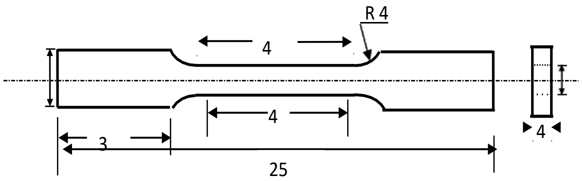

Fig 2:- Tensile test specimens in cm

➢ *Wear Test:*

The casting samples were prepared by some dimension of squared shaped pieces. By using Cutting tools or by turning lathe the specimen were prepare to conduct the wear properties. Test samples are prepared as per ASTM standards. AISI1020 round rods of diameter 1cm and 10cm are taken and cut in to cylinders of required lengths as per ASTM standards. Below figure shows the specimen dimension required to conduct the test.

➢ *Hardness Test:*

The casting samples were prepared by some dimension of squared shaped pieces. By using milling machine or by cutting tools to polish the face of all the surface of the specimens by using sandpaper were prepare to conduct the Hardness test. Test samples are prepared as per ASTM standards. AISI1020 length is 5cm and width is 2cm are taken as per ASTM standards.

➢ *Density Test:*

The casting samples were prepared by some dimension of squared shaped pieces. By using milling machine or by cutting tools to polish the face of all the surface of the specimens by using sandpaper were prepare to conduct the Density test. Test samples are prepared as per ASTM standards. AISI1020 length is 5cm and width is 2cm are taken as per ASTM standards. Below figure shows the specimen dimension required to conduct the test.

V. RESULTS AND DISCUSSION

➢ *Various Testsconducted*

The following tests were conducted to assess the properties of the composites produced:

- Density test-to determines the weight in Air and weight in water.
- Hardness test-to determines the hardness of the prepared specimen by using Rockwell & Brinell's hardness test.
- Wear test- to determine wear on the prepared specimens by using pin on disc wearing test machine.
- Tensile test- to determine tensile strength.

➢ *Chemical Composition*

The equipment of Chemical analyzer instrument used to identify, quantify and characterize the samples of gas, liquid, and solid comical components. Chemical analysis instruments are used in wide verity of applications such as materials analysis, nanotechnology, environmental and clinical chemistry etc. chemical composition of a material analysis accuracy provides better understanding of the information of component and helps solving chemical problem, Research and Development. It also helps to ensure the quality of a chemical formulation.

Table 2 Shows weight percentage of different element present in the Al-Zn samples. The list indicates both as casting and centrifugal casing to determine average value of AI and average value of Zn. Figure3 shows Al -10%, 20%and 30% Zn As Casting Samples.

Al-Zn Alloy			
Sl.No	**As casting**	**Average value of Al**	**Average value of Zn**
1	Al90% Zn 10%	90.83	8.68
2	Al80% Zn 20%	82.66	>16.82
3	Al70% Zn 30%	74.26	>25.18
Centrifugal casting		**Average value of Al**	**Average value of Zn**
1	Al90% Zn 10%	90.95	8.56
2	Al80% Zn 20%	82.66	>16.82
3	Al70% Zn 30%	72.27	>26.31

Table 2:- Average value of aluminum and zinc for the Weight percentage of Al-Zn samples

ISSN No:-2456-2165

Fig 3:- Al -10%, 20%and 30% Zn as Casting Samples

➢ *Density Test*

It is relationship between the die preheating temperature and density of composites. The density of reinforced composite of aluminum and zinc particles is greater than the density of unreinforced Al alloy at 35°C die preheating temperature. Further, the density of composites increased with an increase in weight fractions of reinforcements. The density of Al alloy and composites decreased on increasing the die preheating temperature due to slower cooling rates. At lower cooling rate, dendrite arm spacing of matrix was increased which resulted in reduction of density. This causes increase in porosity of aluminum alloy composites. The density of aluminum and zinc weight ratio particles reinforced composite decreased by composition which was equal to weight on increasing the die preheating temperature from 35 to 250°C. This could be attributed to increasing in the size of eutectic silicon phase because of the longer solidification time. The porosity of Al alloy and composites increased with an increase in die preheating temperature. A decrease in density of Al alloy and composites resulted in increased porosity level on increasing the die preheating temperature. The low porosity level was observed for Al alloy compared to composites at all the temperatures studied.

Composition Alloy	Trial No.	Weight in AIR	Weight in WATER	Density	Average density
Al 70 %-Zn30% As Casting	1	14.515	10.234	3.3906	3.388
	2	12.338	8.693	3.3849	
Al 80 %-Zn20% As Casting	1	12.025	7.628	2.7348	2.803
	2	13.058	8.511	2.8718	
Al 90 %-Zn10% As Casting	1	11.645	6.466	2.2485	2.31
	2	11.799	6.823	2.3712	
Al 70 %-Zn30% Centrifugal Casting	1	13.733	9.625	3.343	3.338
	2	13.246	9.272	3.3332	
Al 80 %-Zn20% Centrifugal Casting	1	12.863	8.321	2.832	2.792
	2	13.638	8.681	2.7513	
Al 90 %-Zn10% Centrifugal Casting	1	11.854	6.823	2.3562	2.298
	2	11.458	6.342	2.2396	

Table 3:- Average value of aluminum and zinc for the Weight percentage of Al-Zn samples.

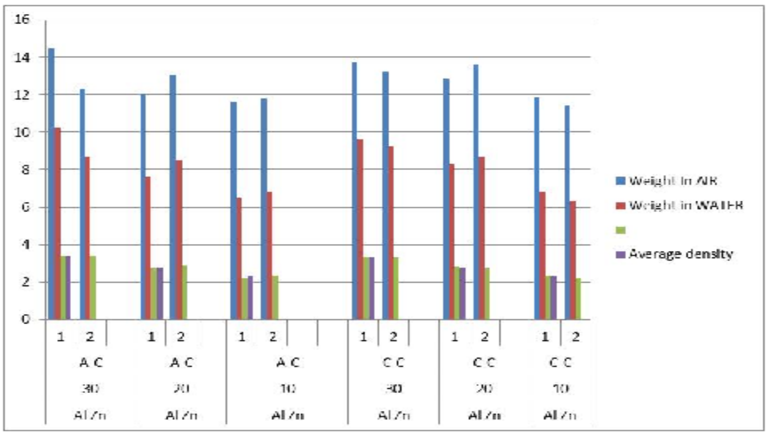

Fig 4:- Histogram showing values of YS for different Al-Zn alloys

➢ *Hardness Test*

The Brinell hardness tester used to test hardness the material. The ASTM E8 standard used with the specifications of ball indenter diameter 10mm, load of 500 kg and 30 seconds is applied. The test is performed in room temperature (30°C to 32°C) and hardness measurements is taken from five different places on each sample and then average hardness value is considered.

Illustration of Hardness test can be obtained by

$$\text{Ball} \quad \frac{2P}{\pi D\left(D-\sqrt{D2-d2}\right)}$$

D = Ball diameter (here D=10mm is cosidered)
d = impression diameter
F = load
BHN = Brinell Hardness Number

Composition		Sl.No	Trails	BHN
Al-10%Zn	As Casting	1	1	63.9983
		2	2	
		3	3	
Al-20%Zn	As Casting	1	1	93.46929
		2	2	
		3	3	
Al -30%Zn	As Casting	1	1	108.9091
		2	2	
		3	3	
Al-10%Zn	Centrifugal Casting	1	1	67.60236
		2	2	
		3	3	
Al-20%Zn	Centrifugal Casting	1	1	99.27509
		2	2	
		3	3	
Al -30%Zn	Centrifugal Casting	1	1	117.3351
		2	2	
		3	3	

Table 4:- Test of Brinell hardness number of different Al-Zn alloys.

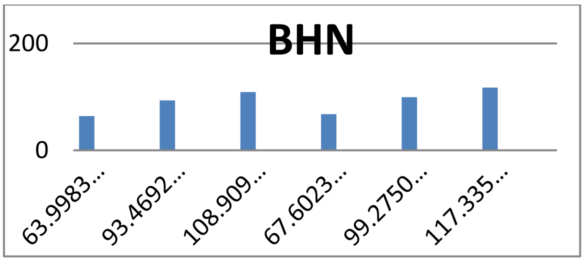

Fig 5:- shows the variation of hardness number of Al-10% Zn, Al-20% Zn and Al-30% Zn with zinc percentage.

Fig 6:- Aluminum -Zinc Alloy of As Cast & Centrifugal Casting Specimens trails for Brinell hardness test

From the calculation and graphs, it is clear that there is an increase in the hardness of the aluminum–zinc metal alloy composite. So, as the percentage of Zinc reinforcement increases the hardness of the composites also increases and this is useful for aerospace application and automobile industries.

ISSN No:-2456-2165

Composition	Sl.No	Trails	RHN
Al -10%Zn As Casting	1	40	40
	2	39	
	3	41	
Al -20%Zn As Casting	1	51	59.7
	2	61	
	3	67	
Al -30%Zn As Casting	1	62	64
	2	64	
	3	66	
Al -10%Zn Centrifugal Cast	1	46	48.3
	2	50	
	3	49	
Al -20%Zn Centrifugal Cast	1	60	61
	2	61	
	3	62	
Al -30%Zn Centrifugal Cast	1	61	65.7
	2	67	
	3	69	

Table 5:- Rockwell Hardness number of different Al-Zn alloys

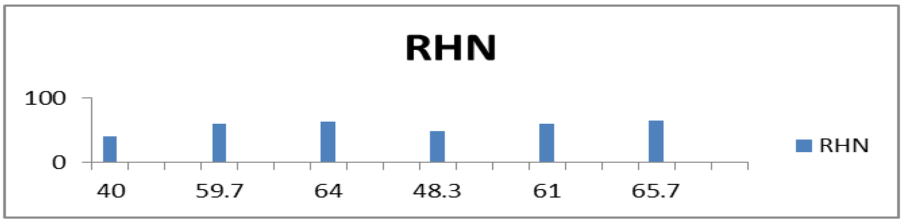

Fig 7:- variation of hardness number of Al-10% Zn,Al-20% Zn and Al-30% Zn with zinc percentage.

Fig 8:- Al-Zn Alloy of As Cast & Centrifugal Casting specimens trails for Rockwell Hardness Test

➢ *Wear Test*

Two specimens are essential to perform pin-on-disk wear test. First, a pin with a radius used tip, is positioned perpendicular to the other, usually a flat circular disk. A ball, rigidly held, is often used as the pin specimen. The test machine causes either the disk specimen or the pin specimen to revolve about the disk centre. In either case, the sliding path is a circle on the disk surface. The plane of the disk may be oriented either horizontally or vertically.

Composition	Co-efficient M3/Nm	Average Co-efficient
Al -10%Zn As Casting	7.01E-08	1.51E-07
	3.50E-08	
	3.47E-07	
Al -20%Zn As Casting	1.82E-07	2.62E-07
	3.19E-08	
	5.73E-07	
Al -30%Zn As Casting	1.21E-07	6.69E-08
	3.82E-08	
	4.14E-08	
Al -10%Zn Centrifugal Cast	1.94E-07	3.85E-07
	3.79E-07	
	6.69E-08	
Al -20%Zn Centrifugal Cast	2.74E-07	2.17E-07
	7.01E-08	
	3.06E-07	
Al -30%Zn Centrifugal Cast	9.56E-08	7.01E-08
	7.65E-08	
	3.82E-08	

Table 6:- Experimental values of wear of Zn alloys at different applied loads

Fig 9:- Variation Al-Zn alloys with Wear rate

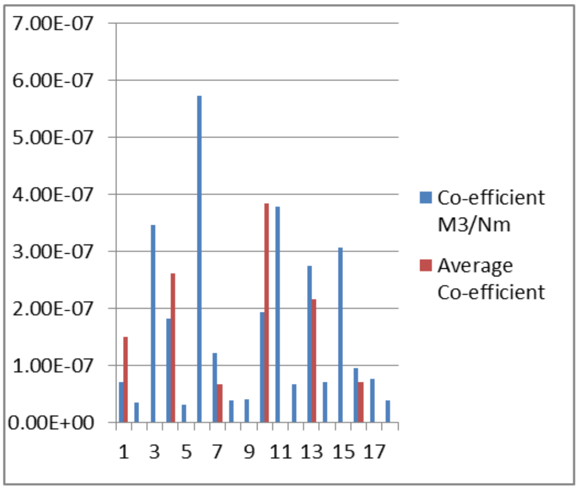

Fig 10:- Al-ZnAs Casting Wear Rate

➢ *Tensiletest*

The tensile test is one of the most widely used of the mechanical tests. The tensile tests were carried out according to the ASTM E8 standard by universal testing machine to determine the amount of tensile strength to withstand during fracture. A tensile test of a material is performed on ductile materials.

A. Aluminum reinforced with 10% Zinc Centrifugal Casting

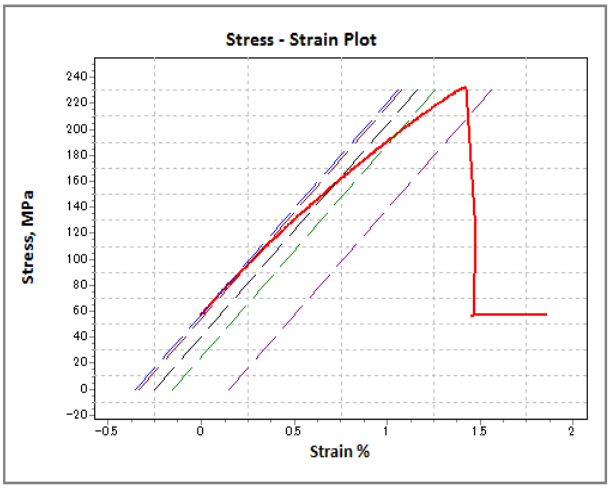

Fig 11:- Stress vs Strain for 10% Zn with Aluminium Alloy.

Test	Results
Area	16 sq-mm
Gauge Length	25 mm
Width	4 mm
Thickness	4 mm
Peak Stress	208.374MPa
Peak Load	3.334kN
0.2% Offset Yield Stress	155.617MPa
Yield Strain	0.50%
Yield Load	2.49kN
0.02% Offset Yield Stress	77.307MPa
0.1% Offset Yield Stress	116.082MPa
0.5% Offset Yield Stress	177.173MPa
Modulus	34.576GPa
Upper Yield Point	155.617MPa
Lower Yield Point	181.701MPa

Table 7:- UTM Results for Al-10%Zn Centrifugal Casting

B.Aluminum reinforced with 20% Zinc As Casting

The ultimate tensile strength and total elongation for the Al-10% Zn were found to be 208.374MPa and 5 % respectively. The ultimate Strength was calculated to be 77.307.

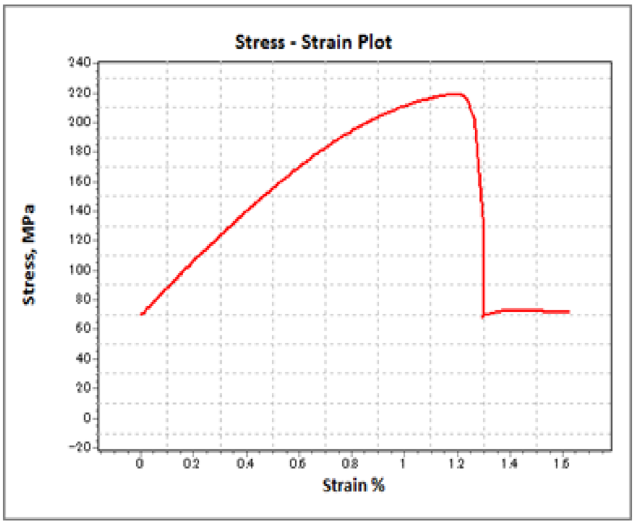

Fig 12:- stress vs Strain for 20% Zn with Aluminium Alloy

Test	Results
Area	16 sq-mm
Gauge Length	25 mm
Width	4 mm
Thickness	4 mm
Peak Stress	219.212 MPa
Peak Load	3.507 kN
0.2% Offset Yield Stress	0 MPa
Yield Strain	0%
Yield Load	0 kN
0.02% Offset Yield Stress	0 MPa
0.1% Offset Yield Stress	0 MPa
0.5% Offset Yield Stress	0 MPa
Modulus	0 GPa
Upper Yield Point	0 MPa
Lower Yield Point	0 MPa

Table 8:- UTM Results for Al-20%Zn As Casting

The ultimate tensile strength and total elongation for the Al-20% Zn were found to be 219.212 MPa and 16.24 % respectively. The ultimate load was calculated to be 3.507 KN.

C. Aluminum reinforced with 30% Zinc As Casting

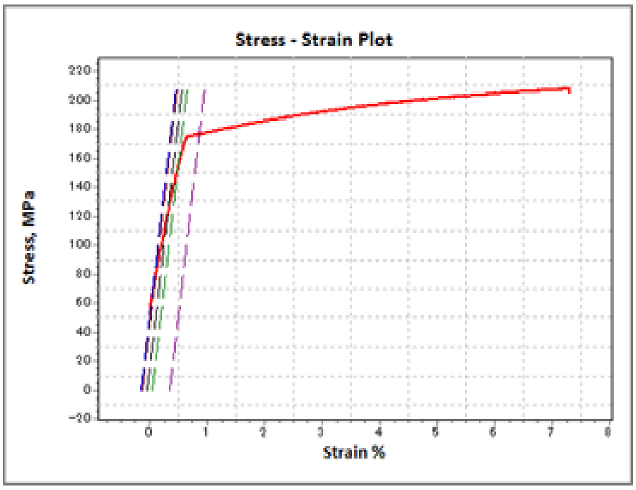

Fig 13

Test	Results
Area	16 sq-mm
Gauge Length	25 mm
Width	4 mm
Thickness	4 mm
Peak Stress	231.928MPa
Peak Load	4.639kN
0.2% Offset Yield Stress	197.609MPa
Yield Strain	1.06%
Yield Load	3.952kN
0.02% Offset Yield Stress	103.653MPa
0.1% Offset Yield Stress	157.571MPa
0.5% Offset Yield Stress	120.218MPa
Modulus	16.286GPa
Upper Yield Point	197.609MPa
Lower Yield Point	56.88MPa

Table 9:- UTM Results for Al-30%Zn As Casting

The ultimate tensile strength and total elongation for the Al-30% Zn were found to be 231.928 MPa and 10.6 % respectively. The ultimate strength was calculated to be 103.653MPa.

Fig 14:- Al-10% Zn Centrifugal Casting

Fig 15:- Al-20% Zn as Casting

Fig 16:- showsAl-30% Zn as Casting

VI. CONCLUSIONS

In this paper Aluminum 2024 alloy reinforced with Zinc synthesized by As casting and Centrifugal casting process with different weight fraction of 10%, 20% and 30% is discussed. The mechanical properties such as tensile strength, hardness test, density and wear test. And some chemical composition by using scanning electron microscope test were obtained and analyzed. Result shows Zinc of 10%, 20%, 30% reinforced with Al2024 composites hardness value maintaining optimum value. The results show that wear loss of the Al-Zn composite decreases and the damaged surfaces look smoother with increasing the Zinc particle size. Also the wear rate of Al-Zn composites initially decrease slightly by increasing sliding speed and after a critical speed, wear rate changes dramatically.

REFERENCES

[1]. Muhammad Rashada, FushengPana, AitaoTanga, Muhammad Asifd “Effect of Graphene Nanoplatelets addition on mechanical properties of pure aluminum using a semi-powder method” Progress in Natural Science Materials International, 2014, Volume 10, Issue. 1016

[2]. Chi-Hoon Jeon, Yong-Ha Jeong, Jeong-Jin Seo, Huynh Ngoc Tien, Sung-Tae Hon, Young-Jin Yum, Seung-Hyun Hur and Kwang-Jin Lee “Material properties of graphene/ aluminum metal matrix composites fabricated by friction stir processing”, International Journal of Precision Engineering and Manufacturing, · June 2014 Volume:15, PP 1235-1239.

[3]. Dattatraya N. Lawate, Shriyash S. Shinde, Tushar S. Jagtap “Study of process parameters in stir casting method for production of particulate composite plate” volume 3, jan.-2016.

[4]. K.V.Ojha, ArunaTomar, DevendraSingh, G. C. Kaushal “Shape, microstructure and wear of spray formed hypoeutectic Al—Si alloys” Materials Science and Engineering: A Volume 487, Issues 1–2, 25 July 2008, PP 591-596

[5]. Abhishek Sharma, Vyas Mani Sharma, Jinu Paul, “Fabrication of bulk aluminum-graphene nano composite through friction stir alloying” Journal of Composite Materials, June - 2019 https://doi.org/10.1177/0021998319859427