Tribological Behaviour of ZA – 27 Metal Alloy Composites for Bearing Races:An Overview

Viresh Payak[1], Swati Gangwar[2]

[1]M.Tech research scholar, [2]Assistant Professor

Department of Mechanical Engineering,

Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh,(India)

ABSTRACT

Over the past decade rapid progress has been done in the field of composites due to its capability to replace the monolithic or conventional materials. Composite materials have many strong properties such as high structural strength, mechanical properties, durability, wear resistance, resistance to corrosion etc. For the particular engineering application, we need to see that what are the essential qualities and accordingly the selection of right reinforce particle in the monolithic material produces high performance composite material. Zinc – Aluminum alloy (ZA – 27) and its composites used due to the better quality and performance in various areas such as automotive, electronics industry, industrial fittings and hardware, sleeve bearings, Bearing races and wear plates. Graphite, Al_2O_3, SiC particles have been used in Zinc – Aluminumalloy as reinforcement. It provides the best properties for high load small sliding speeds. Now a day, the trend of hybrid reinforcements has increased because the performance and quality of hybrid reinforcements are better than a single reinforcement.

KEYWORDS -ZA-27 alloy, Hybrid Composites, Tribological characteristics.

I.INTRODUCTION

Composite material is the combination of two or more than two materials which give better properties than the individual components, the one constituent is known as matrix and other one as reinforcement [1].The matrix asmonolithic or individual material into which fibers or metallic/non-metallic particlesgets embedded,for an example zinc–aluminum alloy, magnesium and titanium, provide better support for the reinforcement and the reinforcements are the strong metallic or non-metallic material which incorporated in the matrix to provide the better properties [2].In metal matrix composite (MMC), we use a metal or an alloy as matrix material and reinforcement may or may not be metallic as desired. These composite have several properties like thermal conductivity, strain resistance, modulus of elasticity, better stiffness to weight and strength to weightratio, because of these properties metal matrix composites have various applicationslike marine, nuclear power station,aerospace, automotive and sports industries [3].The hybrid composite materials are the combination of different reinforcement in to a base matrix to enhance the mechanical as well as tribological properties of the composites.

A zinc alloy used as most adaptable material for engineering applications, as they provide the better characteristics of strength, toughness, rigidity, high wear resistance and thus shows better bearing performance. Economicaland conventional methods can be adopted for casting zinc alloy metal matrix composites due to low casting temperature. These alloys have small amount of copper, can be substitute for a different kind of non - ferrous and ferrous alloys regarding cost and energy, because of their better strength, lower wear rate and casting temperature. ZA alloy composites are critical bearing materials particularly responsible for low speed and high load operationbecause of high hardness, low weight, better machining and tribo–mechanical attributes. Lower elevated temperature, lack of dimensional stability at temperature greater than 100 °C and some mechanical properties are the major limitation of these alloy system.ZA composites (generally ZA – 27) are capable to be a substitute of aluminum cast composites and bearing bronzes [4 – 5], these alloys reduce 25 – 50 % cost for aluminum and 40 – 75% cost for brass alloys [6]. The ZA – 27 alloys come in the group of ZA alloy, have high strength utilized in bearing and busing function as a substitution of bronze bearing because of its low cost and better performance[7 – 8].In the markets, these alloysare famous for bearings, bearing races, wear resisting part, valves, sheaves, pulleysand used in some other application also such as in the component of electrical, automotive, industrial, firm and thin wall casting [9]. This paper attempts to review the effect of micro reinforce embedded ZA – 27 alloy metal matrix and hybrid composites on mechanical and tribological properties.

II.LITERATURE REVIEW

This literature review gives the various information of zinc – aluminum alloy (ZA – 27) composites, existing on mechanical and tribological characteristics and also effort to review the different combination of reinforcement employed in the development of zinc-aluminum alloy matrix material.

2.1 Mechanical and Tribological properties

Mechanical property is thebehavior of materials under external loads [10], some useful example of its are hardness, ultimate tensile strength (UTS), Young's modulus, ductility, impact strength, tensile strength. The ability of materials to resist localized plastic deformation (such as dent or scratches) is known as hardness [11]. The amount of strain produced by a given stress is measure by ductility [12], is the ability of material to drawn into a wire without failure.The material strength under a simple stretching action is known as tensile strength and below the elastic limit stress to strain ratio is Young's modulus [13]. The strength of material to withstand at maximum stress is called UTS and the resistance offered by a material for a rapidly applied load is termed as impact [14].Tribology originated from the Greek word, "tribos", signifying "rubbing" or "to rub" and the word "ology" signifies "the investigation of" so, Tribology is the investigation of rubbing or the investigation of things that rub, it consists the study of wear, friction and lubrication [15].Wear is a gradually loss of solid surface because of the relative movement and contacting substance between that surfaces. Friction resisting the tangential force acting between two contact surfaces when these surfaces tend to move in respect to each other, the magnitude of this force for solid surface is known as friction coefficient [16]. The ratio of tangential friction force to the perpendicular or normal force is known as the coefficient of friction [17], lubricant reduces the friction and wear by making a film between the contacting surfaces of two substances [18].

2.2 Review on Mechanical and Tribological properties of ZA – 27 alloy composites filled reinforcement-

1. Shanta Sastry et. al. investigated the damping behavior and dynamic young's modulus over a temperature range 30 °C to 300 °Cof composite formed by the combination of ZA – 27 alloy and 1 – 4 wt.% of aluminite particles in the step of 1% by weight and found that during the increase in temperature, damping capacity of material increases butdynamic modulus decreases. The damping capacity is known as the potential of a material to convert mechanical vibration energy into thermal energy. The dynamic modulus is useful in the study of creep, thermal and inter–atomic potential, comes under the dynamic loading [19].

2. K.H.W Seah et. al. investigated the mechanical properties of composite formed by ZA – 27 alloy with 0 – 5 weight percentage of graphite particle and found that increase in the Gr particle increases the compressive strength, Young's modulus, ductility and UTS but monotonic decreases in the hardness. Fig. 1 and Fig. 2 shows the effect of Gr reinforcement on compressive strength and UTS respectively, the compressive strength increased by about 44% and UTS increased by about 25% by increases the Gr particles from 0 - 5 weight percentage. The maximum value of compressive strength is obtained 1128.96 Mpa and the UTS is 375.54 MPa with 5 wt.% of Gr particles [20].

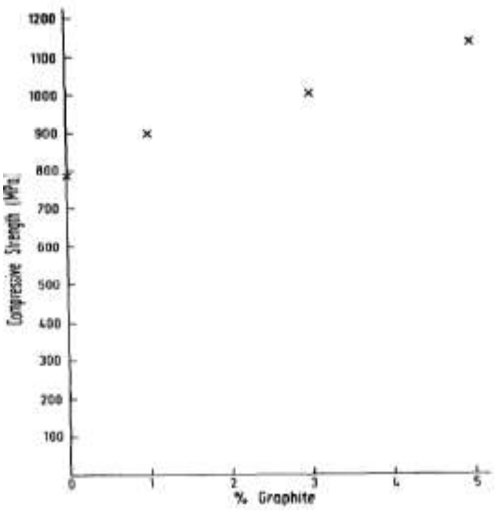

Fig. 1: Effect of compressive strength vs. graphite content [20]

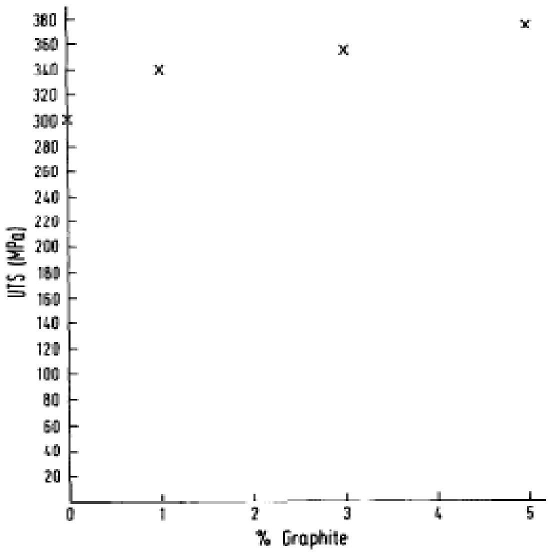

Fig. 2: Effect of UTS vs. graphite content [20]

3. S. Mitrovic et. al. investigated the tribological characteristics of ZA – 27 alloy composite reinforced by

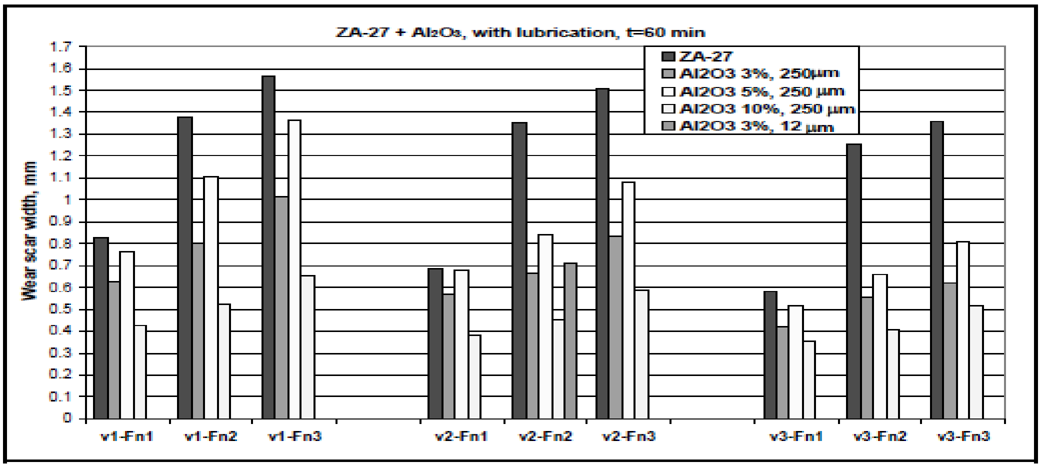

Fig. 3: Wear scar width - ZA-27 + $Al_2O_3$with lubrication [21]

12 µm and 250 µm particle size of $Al_2O_3$with 3, 5 and 10 wt.% and observed tribological characteristics with load (2 daN, 5 daN, 8 daN) and sliding speed (0.26 m/s, 0.50 m/s, 1.0 m /s), have been found highest wear resistance at 10 wt.% of $Al_2O_3$with lubrication and at 5 wt.% without lubrication. Fig. 3 and Fig. 4 represent the wear scar width of composite material for different wt. % of Al_2O_3particles with and without lubrication respectively, from the both figures it is clear that normal load and sliding speed affect the wear rate. In the present of lubrication, wear rate increases by the increase of normal load and it decreases by the increase of sliding speed, the effect of normal load was almost same at maximum and minimum sliding speed but in the case of without lubrication wear scar width increases with the increase of both sliding speed and normal load and found the largest value of it at the highest sliding speed and load. The wear scar width is decreased by almost 50% at lower load without lubrication and 76 % with lubrication for 5 and 10 wt.% of 250 µm Al_2O_3particle size reinforced composite respectively [21].

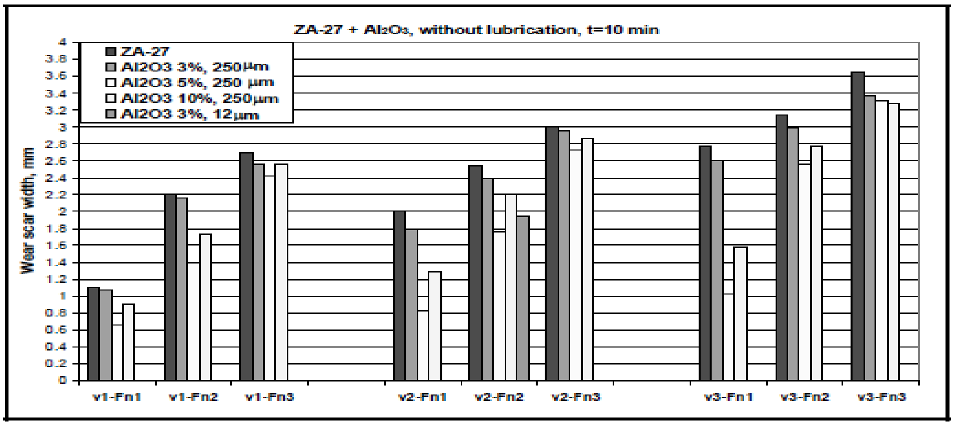

Fig. 4: Wear scar width: ZA – 27 + Al_2O_3without lubrication [21]

International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.01, April 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

4. S.C. Sharma et. al. investigated the mechanical characteristics of ZA – 27 alloy composite reinforced by 0 – 5 weight percentage of glass fibers and found that increase in the reinforcement particles increases the hardness, Young's modulus and UTS but decreases the impact strength and ductility [22].
5. S.C. Sharma et. al. investigated the unlubricated sliding wear characteristics of ZA – 27alloy composite reinforced by 1 – 5 wt.% of SiC particle in the step of 2% by weight and found that the hardness increases and wear rate decreases by increasingthe SiC particles [23].

The table 1shows various classes of reinforcements ingrained with zinc – aluminum alloy(basically ZA – 27) in different ratios, different methods used for their fabrication, testing'sperformed on the fabricated ZA – 27 metal matrix composite as desired depending on the area of application and the results showing the effect of added reinforcements on the final ZA – 27 metal matrix composite.

TABLE 1: Effect on tribo – mechanical behavior of ZA – 27 alloy composite filled reinforcement

S. No.	Alloy	Reinforcements	Wt.%	Fabrication Technique	Testing's	Results	Ref. No.
1	ZA-27	Al_2O_3	1, 2, 3, 4	Compo - casting	Damping capacity and dynamic modulus	Increasing the weight percentage of Al_2O_3increases the dynamic modulus and damping capacity of material	19
2	ZA-27	Gr	0, 1, 3, 5	Liquid metallurgy	UTS, compressive strength and hardness	Monotonic increases in compressive strength and UTS but monotonic decreases in hardness with increasing in graphite particles	20
3	ZA-27	Al_2O_3	3, 5, 10	Compo - casting	wear	Highest wear resistance obtained at 10 wt.% of $Al_2O_3$with lubrication and at 5 wt.% without lubrication	21
4	ZA-27	Short glass fiber	1, 3, 5	Compo - casting	Hardness, UTS, Young's modulus, ductility andimpact strength	Young's modulus, Hardness and UTS increases but ductility and impact strengthdecreases with increasing in the wt.% of reinforcement	22
5	ZA-27	SiC	1, 3, 5	Liquid metallurgy	wear and hardness	Wear and hardness increases with increasing in wt.% of SiC particles	23
6	ZA-27	Al_2O_3	5, 10, 15, 20, 25	Centrifugal casting	Wear rate	Normal load was most influencing factor at 15 wt.% of Al_2O_3 Wear rate decreases with optimum casting and wear parameter	24

7	ZA-27	Mn	0.2, 0.5, 1, 5	Gravity die casting	Impact strength, hardness, UTS, volumetric wear rate	Impact strength and hardness are increases whereas UTS and volumetric wear rate decreases with increasing in Mn content up to 1%	25
8	ZA-27	CaO (quicklime)	0, 2.5, 5, 7.5, 10	High temperature gravity casting	Coefficient of friction and specific wear rate (SWR)	SWR and coefficient of friction decreases with increases of filler content	26
9	ZA27-TiB2	TiB2	1, 3, 5	Situ fabrication	Wear rate and hardness	Wear resistance and hardness increases with increases of TiB_2 particles	27
10	ZA-27	Fly ash or Al_2O_3	0, 2, 4, 6	Stir casting	Corrosion	Corrosion rate decreases with increasing in reinforcement particles	28

2.3 Review on Mechanical and Tribological properties of ZA – 27 alloy composites filled with hybrid reinforcements –

1. Mohammed Almomani et. al. investigated the tribological properties of Zamak alloy reinforced by 0-6 wt.% of fly ash and alumina particles in the step of 2% by weight, have been observed that increasing the reinforcement particle increases the hardness and wear resistance. Fig. 5 represent the effect of fly ash and Al_2O_3reinforcement (up to 6 wt. %) on the wear rate of composite material, found that the wear rate is reduced by the addition of these reinforcement. The addition of Al_2O_3particles slightly improves the wear resistance than the fly ash particles for similar wt. % because fly ash composite have higher porosity percentage, reduces the wear rate[3].

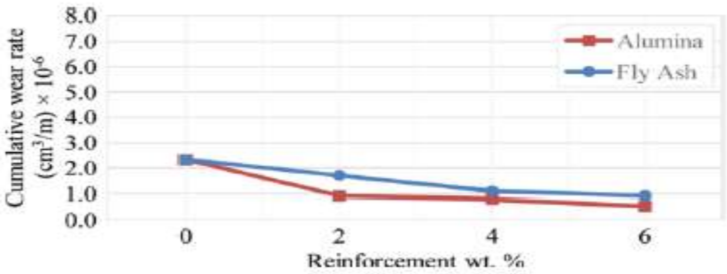

Fig. 5: Effect of fly ash and Al_2O_3weight fractions on the wear rate of ZA – 27 [3].

2. T.S. Kiran et. al. investigated the dry sliding wear characteristics of ZA – 27 alloy composite reinforced by 9 wt.% of SiC and 3wt% of Gr and found thatincreasing the applied load and sliding speed increases the wear volume loss (WVL) but decreases while increase in the sliding distance [29].
3. T.S. Kiran et. al. investigated the dry sliding wear characteristics of heat treated ZA – 27 alloy composite reinforced by constant 3 wt.% of Gr and 0, 3, 6, 9 wt.% of SiC, have been observed that onincreasing the

sliding speed, sliding distance and normal load,there is increase in the WVLbut wear rate decreases with increases of SiC and graphite content [30].

The table 2 shows effect of different classesof hybrid reinforcements (i.e. when two or more than two reinforcements are ingrained within the matrix material then it is known as hybrid reinforcement and the composite is known as metal matrix hybrid composite) on the mechanical and tribological characteristics of the fabricated ZA – 27 metal matrix and hybrid composites.

Table 2: Effect on tribo-mechanical behavior of ZA – 27 alloy composite filled hybrid reinforcement

S. No.	Alloy	Hybrid Reinforcement	Wt.%	Fabrication Technique	Testing's	Results	Ref. No.
1	ZA-27	Al_2O_3	0,2,4,6	Compocasting	Hardness and wear	Wear rate decreases and hardness increases by increasing the wt.% of reinforcement particles.	3
		Fly ash	0,2,4,6				
2	ZA-27	SiC	9	Stir casting	Wear	Gr and SiC improve wear resistance by forming a ceramic mixed mechanical layer	29
		Gr	3				
3	ZA-27	SiC	3,6,9	Stir casting	Wear	The increasing in wt.% of SiC particles increases the wear resistance	30
		Gr	3				
4	ZA-27	SiC	5	Compocasting	Wear volume loss	WVL increases with the increasing of sliding speed, sliding distance and normal load	31
		Gr	3				
5	ZA-27	SiC	10	Compocasting	Wear volume loss	WVL increases with the increasing of sliding speed, sliding distance and normal load	32
		Gr	1				
6	ZA-27	Fly ash	5	Stir casting	Hardness, tensile strength, wear	The increasing in wt.% of Gr particles decreases the wear depth whereas hardness and tensile strength increases by adding the 5 wt.% of fly ash particles	33
		Gr	2,4				

IV.CONCLUSION

This paper presents that ZA – 27 alloy composites have various appealing properties such as high hardness, elasticity, low melting point, good cast-ability, improved machining, low formation cost, excellent bearing and wear resistance, high strength and low density. ZA – 27 alloy composites have ability to be substitute of aluminum metal matrix composites and bearing bronzes, due to low cost, predominant bearing and wear properties. The reinforcement like Al_2O_3, fly ash, SiC increases several mechanical and tribological property of

ZA – 27 alloy compositessuch as Gr increases the Young's modulus, UTS, ductility and compressive strength because it acts as a barrier to dislocation in the microstructure.

REFERENCES

[1] F.C. Campbell, "Structural Composite Materials", ASM International,2010.

[2] Nachiketa Tiwari,"Introduction to Composite Materials and Structures", Indian Institute of Technology Kanpur.

[3] Mohammed Almomani, Mohammed T. Hayajneh and Majd Draidi, "Tribological Investigation of Zamak Alloys Reinforced with Alumina ($Al_2O_3$and Fly Ash", Particulate Science and Technology an International Journal,2015.

[4] Srimant Kumar Mishra, Sandhyarani Biswas and Alok Satapathy, "A study on processing characterization and erosion wear behavior of silicon carbide particle filled ZA-27 metal matrix composites", Materials and Design 55, 2014, 958–965.

[5] Miroslav Babic, Mitrovic Slobodan, Dragan Dzunic, Branislav Jeremic and Bobic Ilija,"Tribological behavior of composites based on ZA-27 alloy reinforced with graphite particles", Tribol Lett,37,2010,401–10.

[6] C. Dominguez, M. V. Moreno Lopez and D. Rios-Jara, "The influence of manganese on the microstructure and the strength of a ZA-27 alloy", J Mater Sci,37, 2002,5123–7.

[7] G. Ranganath, S.C. Sharma, M. Krishna, and M.S. Muruli,"A Study of mechanicalproperties and fractography of ZA–27/titanium–dioxide metal matrix composites", JMEPEG,11,2002,408–13.

[8] S. C. Sharma, B.M. Girish, Rathnakar Kamath and B.M. Satish,"Graphite particles reinforced ZA-27 alloy composite materials for journal bearing applications", Wear,219, 1998,162–8.

[9] Yuanyuan Li, Tungwai Leo Ngai, Wei Xia and Wen Zhang,"Effects of Mn content on the tribological behaviors of Zn–27% A1–2% Cu alloy", Wear,198, 1996,129–35.

[10] ME Mechanical Team, "Mechanical properties of materials", Engineering materials, Dec 16, 2015.

[11] Introduction to Materials Science, "Mechanical Properties of Metals", University of Tennessee, Dept. of Materials Science and Engineering, Chapter 6.

[12] Dr. M. Medraj, "Ductility", Mech. Eng. Dept. - Concordia University, Mech 221, lecture 12/4.

[13] Adam Zaborski, "A handout on Tensile test for Afghans".

[14] Narinderpal, "Experimental study and parametric design of impact testing methodology", Department of Mechanical Engineering, Thapar University Patiala (Panjab), June 2009.

[15] SJ Shaffer, "Introduction to the Basics of Tribology", Tribology 101, Bruker-TMT.

[16] Raymond G. Bayer, "Tribological and wear testing", Tribology Consultant, Vestal, NY, USA.

[17] Raja K. Sivamani, Jack Goodman, Norm V. Gitis and Howard I. Maibach, "Coefficient of friction: tribological studies in man – an overview", Skin Research and Technology, 9, 2003, 227-234.

[18] G. J. Johnwon, R. Wayte and H. A. Spikes, "The Measurement and Study of Very Thin Lubricant Filmsin Concentrated Contacts", Tribology Transactions, Volume 34, 2, 1991, 187-194.

[19] Shanta Sastry, M. Krishna, and Jayagopal Uchil, "A study on damping behavior of aluminate particulate reinforced ZA-27 alloy metal matrix composites", Journal of Alloys and Compounds, 314, 2001,268–274.

[20] K. H. W. Seah, S. C. Sharma and B. M. Girish, "Mechanical properties of cast ZA-27/graphite particulate composites", Materials & Design, Volume 16, Number 5, 1996.

[21] S. Mitrovic, M. Babic and I. Bobic, "ZA-27 Alloy Composites Reinforced with Al_2O_3Particles", Tribology in industry, Volume 29, No. 3&4, 2007.

[22] S. C. Sharma, K. H. W. Seah, M. Satish and B. M. Girish, "Effect of short glass fibers on the mechanical properties of cast ZA-27 alloy composites", Materials & Design Volume, 17, Number 5/6, 1997.

[23] S. C. Sharma, B.M. Girish, Rathnakar Kamath and B.M. Satish, "Effect of SiC particle reinforcement on the unlubricated sliding wear behavior of ZA-27 alloy composites", wear, 213, 1997,33-40.

[24] Jyothi P N, Jagath M.C and Channakeshavalu K, "Wear Characteristics of ZA-27/Al_2O_3Composites Processed by Centrifugal Casting", International Journal of Materials Science and Engineering, 2015.

[25] Veeresha G, "Some tribological investigations on zinc base alloy", International Journal of Research in Engineering and Technology, 2016.

[26] Swati Gangwar, Amar Patnaik and IK Bhat, "Tribological and thermomechanical analysis of CaO (quicklime) particulates filled ZA-27 alloy composites for bearing application", Journal of Materials: Design and Applications, 2015, 0(0) 1–15.

[27] Fei Chen, Tong-min Wang, Zong-ning Chen, Feng Mao, Qiang Han and Zhi-qiang Cao, "Microstructure, mechanical properties and wear behavior of Zn−Al−Cu−TiB_2 in situ composites", Trans. Nonferrous Met. Soc. China, 25, 2015,103−111.

[28] Mohammed Almomani, Mohammed T. Hayajneh and Majd Draidi, "Corrosion Investigation of Zinc Aluminum Alloy Matrix (ZA-27) Reinforced with Alumina (Al_2O_3) and Fly Ash", an International Journal of Particulate Science and Technology, 2016.

[29] T.S. Kiran, M. Prasanna Kumar, S. Basavarajappa, and B.M. Viswanatha, "Dry sliding wear behavior of heat treated hybrid metal matrix composite using Taguchi techniques", Materials and Design, 63, 2014,294–304.

[30] T.S. Kiran, M. Prasanna Kumar, S. Basavarajappa, and B.M. Viswanatha, "Effect of heat treatment on tribological behavior of zinc aluminum alloy reinforced with graphite and SiC particles for journal bearing", Industrial Lubrication and Tribology, Volume 67, Number 4, 2015,292–300.

[31] S. Mitrovic, M. Babic, N. Miloradovic, I. Bobic, B. Stojanovic, D. Dzunic and M. Pantic, "Wear Characteristics of Hybrid Composites Based on Za27 Alloy Reinforced with Silicon Carbide and Graphite Particles", Tribology in Industry, Vol. 36, No. 2, 2014,204-210.

[32] N. Miloradovi and B. Stojanovi, "Tribological Behaviour of ZA27/10SiC/1Gr Hybrid Composite", Journal of the Balkan Tribological Association Journal of the Balkan Tribological Association, Vol. 19, No 1, 2013,97–105.

[33] Veera Brahmam, T. Vivekananda Swamy and Abdul Khurshid, "Characterization of Za27-Fly Ash Graphite Particulate Reinforced Hybrid Composites", Journal of Material Science & Manufacturing Technology, Volume 2 Issue 2, 2017.