iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VI **Month of publication:** June 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

High-Stress Abrasive Wear Response of Zinc-Based Alloy: A Comparison with Grey Cast Iron

Mohammad Mohsin Khan[1], Gajendra Dixit[2]
[1,2] Department of Mechanical Engineering, Maulana Azad National Institute of Technology, Bhopal

Abstract: ***The objective of the present study is to assess the high-stress abrasive response of zinc-based alloy and to compare their properties with a conventionally used grey cast iron. The zinc-based alloy has been synthesized by liquid metallurgy route while cast iron is procured from a commercial source. High-stress abrasive wear examination has been conducted on using a pin-on-disc wear tester as per ASTM G132-96 standard. The influence of abrading distance and applied load on the wear behaviour of the test materials have been studied. The zinc-based alloy exhibits dendritic structure comprising of α dendrites surrounded by $\alpha + \eta$ eutectoid and metastable ε phase in interdendritic regions. The $\alpha+\eta$ is a solid solution of zinc and aluminum in aluminum and zinc respectively are soft and ductile while ε phase is quite harder and transmits wear resistance to a slight range. In the case of cast iron, flakes of graphite were observed in the matrix; the latter comprised of (majority of) pearlite and (limited quantity of) ferrite. Wear rate and temperature rise increases with the increase in sliding distance and applied load. Moreover, cast iron exhibits less wear rate under all the test conditions while temperature rise was more in the case of the zinc-based alloy at lower load whereas at higher load opposite trend of variation was obtained.***
Keywords: ***Abrasive Wear, Zinc Aluminum Alloy, Lıquid Metallurgy, Grey Cast Iron,***

I. INTRODUCTION

Many authors have considered zinc compounds with a specific end goal to comprehend and enhance their tribological properties [1-4]. Many wear resistant components applied in different fields are already realized with zinc alloys. Components like casings/housings and wear plates are prone to abrasion in service due to sliding against hard particles [5-8]. In bearings, abrasion is caused due to the fragmented wear debris, contaminants of the lubricant and foreign hard particles in the surroundings. In a study, the abrasive wear response of a zinc-based alloy has been compared with that of a bronze in dry and lubricated conditions wherein the zinc-based alloy has been noted to be superior to bronze in specific conditions [7]. Moreover, the effect of alloy composition on the abrasive wear characteristics of some zinc-based alloys has been studied recently [9]. Cast irons, especially the gray irons, are widely used in wear related applications [10-12] wherein abrasive wear conditions are encountered in terms of contamination of foreign mass like dust and debris particles in the lubricant and/or from the surroundings during operation [7,13,14]. Some typical applications of the gray cast irons include automotive engine components [10,11], automatic moulding machines and moulds in casting industries, air pressure pumps and gas delivery pipes [12]. Despite a variety of the applications encountering abrasion, practically no information seems to be available pertaining to the abrasive wear response of gray cast irons. Available information suggests that the overall wear response of materials is controlled by factors like crack sensitivity, load carrying characteristics and such other features of material microconstituents [5,6,9,11,15–20]. In fact, the predominance of one set of parameters leading to improved wear behaviour over the other producing an opposite effect is very much responsible for a specific wear behaviour of materials. This, of course, is controlled by experimental parameters like load, speed, distance, abrasive particle size, shape etc. [5,6,9,11,15–20]. Effects of the mentioned parameters on wear response have been noted to be quite complex and synergistic in nature [20]. Accordingly, a systematic understanding of the same could enable to assess the working capability of the materials in identical conditions. The aim of this paper is to study the wear resistance of the zinc-based alloy in comparison with the commercial grey cast iron, in order to evaluate its competitiveness for tribological applications. In particular, the attention was focused on the high-stress abrasive behaviour.

II. EXPERIMENTAL

A. Material Preparation

The zinc-based alloy was prepared by liquid metallurgy route using graphite crucibles for melting. An electric furnace is used for melting the alloy while cast iron moulds were used for the solidification. The moulds were also preheated to around 200°C before pouring the melts. All the castings were made in form 20 mm diameter, 150 mm long cylindrical castings. Moreover, Grey cast iron is procured from Saurabh metal, Bhopal. Table 1 shows the chemical compositions of the sample materials.

B. Microstructure Studies

Specimens (10 mm diameter, 15mm long) for microstructural analysis were prepared by cutting and machining the cast cylindrical rods. The samples were polished metallographically and etched suitably. Diluted aqua regia was used for etching the samples of zinc-based alloy while cast iron was etched with nital. Microstructural studies were carried out by using a scanning electron microscopy.

TABLE I
CHEMICAL COMPOSITION OF THE TEST MATERIALS

Test Material	Element wt. %								
	Al	Cu	Mg	Zn	P	Si	Mn	C	Fe
Zinc-based Alloy	27.5	2.5	0.03	*	-	-	-	-	-
Grey Cast Iron	-	-	-	-	0.08	2.32	0.56	3.35	*

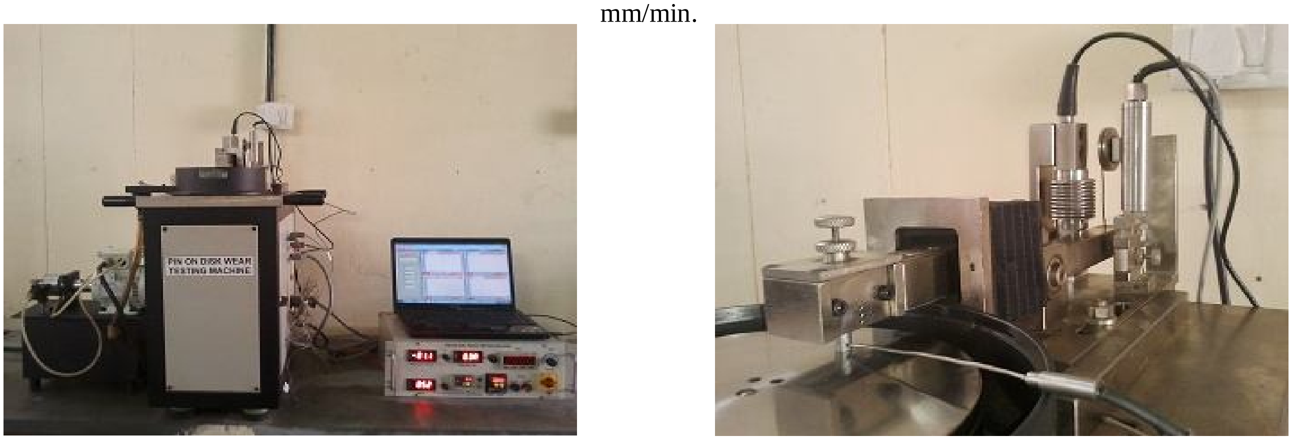
"*" Remainder

C. Phase Identification

X-Ray diffraction analysis of the test materials was carried out using Rigaku (Model Miniflex-2) X-ray diffractometer to find out the phases present in the sample. The solid sample was packed on a sample holder of size 10 mm x 10 mm rectangular cavity having the depth of 2 mm. The samples were scanned at a scanning speed of 5 degrees (2θ) per minute in the diffraction angle (2θ) range of 35 to 47^0 for zinc-based alloy 35 to 90^O for grey cast iron, the measurement was done at an applied voltage of 30 kV and current of 15 mA.

D. Measurement of Physical and Mechanical Property

Hardness measurements were carried out on metallographically polished samples using a Vickers hardness tester. The applied load, in this case, was 294 N. density of the samples was determined by water displacement technique. A Mettler microbalance with a precision level of 0.01 mg was used for weighing the samples in water and air. An average of five observation has been taken Tension test were conducted on 10 mm diameter, 50 mm G.L. specimens as per ASTM E8/E8M − 15a. The tests were performed at room temperature using Instron make computerized tension testing machine. The strain rate or cross head speed used was 0.5 mm/min.



(a) (b)

Fig. 1 (a) Photographic view of the wear testing machine (b) Enlarged view of the pin-disc assembly

E. Abrasion Test

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Abrasive wear tests were carried out as per ASTM G132-96 using Ducom (Bangalore) make a pin-on-disc machine (model TR-20 LE). Photographic view of the wear tester is shown in Fig. 1. Cylindrical samples of 8 mm diameter, 27 mm long and 1.5 mm diameter hole made near the contacting surface of the sample for abrasion wear tests were prepared from the cylindrical castings. The abrasive medium used in this study was a polishing/emery paper having 50 µm (average particle size) SiC abrasive particles firmly bonded on a strong paper base. The abrasive medium was fixed firmly on the disc of the machine. The sample was held against the rotating abrasive medium with the help of a specimen holder. Load on the sample was applied through a cantilever mechanism with the help of dead weights. The sliding speed was fixed at 5m/s (corresponding to 955 rpm and 50 mm track radius) while the applied load was varied over a range of 5-20 N in the step of 5N. The samples were polished metallographically, cleaned with acetone and weighed using the microbalance prior to testing. The tested samples were once again cleaned with acetone and weight loss taken at an interval of 25 seconds corresponding to a traversal distance of 125 m. The temperature at a distance of 1.5mm from the contacting surface of the specimen was also monitored during the tests by inserting a chromel–alumel thermocouple in a 1.5mm diameter hole made therein. An average of three observations has been considered in this study.

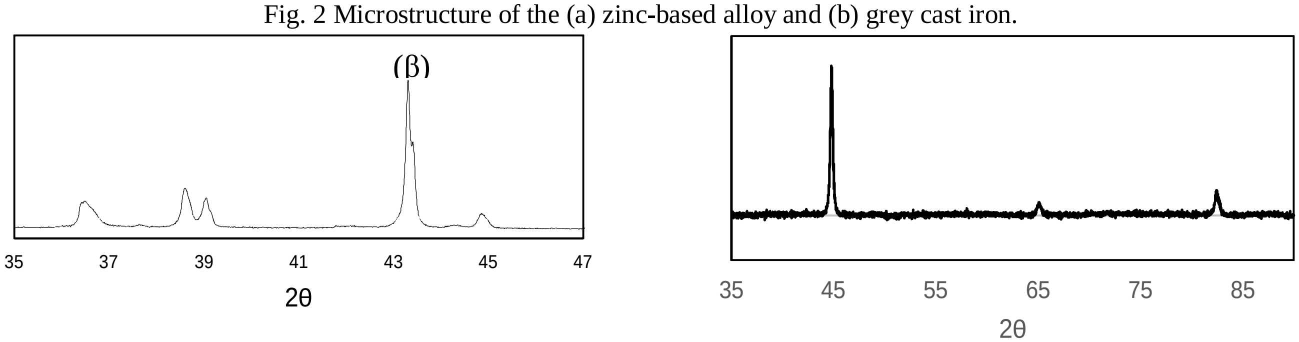
III.RESULT & DISCUSSIONS

A. *Microstructure and Phase Analysis*

Fig. 2 represents the microstructure of the samples whereas Fig. 3 confirms the phases present in the test materials. The matrix alloy revealed primary dendrites of α and eutectoid $\alpha + \eta$ and $\in$ phases in the interdendritic region (Fig. 2a). The α phase being face-centered cubic (FCC) has load bearing capability and deferability. The η phase has a hexagonal structure with c/a ratio greater than that of an ideal hexagonal closed packed (HCP) crystal. The somewhat hard ε phase offers to wear resistance to the alloy system. However, the (zinc-based) matrix alloy has low melting point, in general, causing the phases to play their positive rates at low operating temperatures. The cast iron showed graphite in the matrix of pearlite and a limited quantity of ferrite. The cast iron consisted of graphite in a matrix of pearlite and some ferrite (Fig. 2b). Graphite acts as a solid lubricant causing better sliding and abrasive wear resistance in [22,23]. However, being a soft phase it also acts as weak points in the material [10,24,25]. Moreover, despite nucleating and growing from within the matrix, the graphite phase/matrix interfacial regions are relatively weaker and serve as easy centers for the nucleation and propagation of cracks [10,25] in view of poor compatibility with the matrix [24]. Ferrite is soft and ductile while the hard cementite in pearlite offers abrasion resistance [25]. The mentioned factors greatly control the wear behaviour of cast iron.

(a) (b)

Fig. 2 Microstructure of the (a) zinc-based alloy and (b) grey cast iron.



a) (b)

Fig. 3 XRD Analysis of (a) zinc-based alloy and (b) grey cast iron.

B. *Hardness, Density & Tensile Strength*

Volume 5 Issue VI, June 2017
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

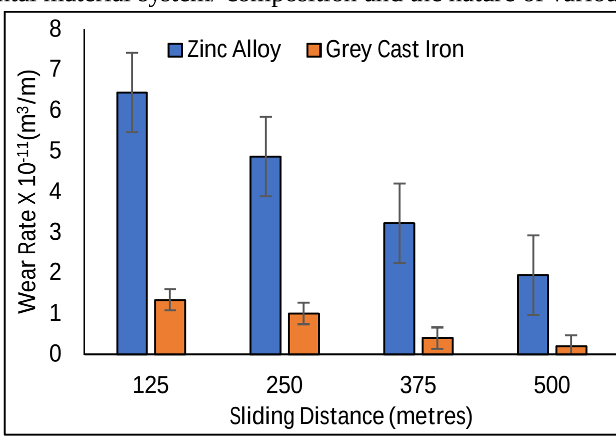
Table 2 represents various properties of the test materials. The grey cast iron attains higher density and hardness but lower tensile strength than the zinc-based alloy due to quite ductile nature of the zinc-based alloy.

TABLE III
PHYSICAL & MECHANICAL PROPERTIES OF THE TEST MATERIALS

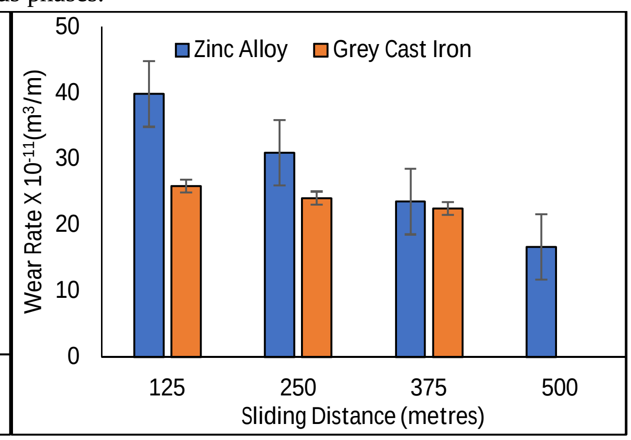
Type	Vickers Hardness (HV)	Density g/cm^3	Tensile Strength (MPa)
Zinc Alloy	130	4.97	305
Grey cast iron	220	7.24	276

C. Abrasive Wear Behaviour

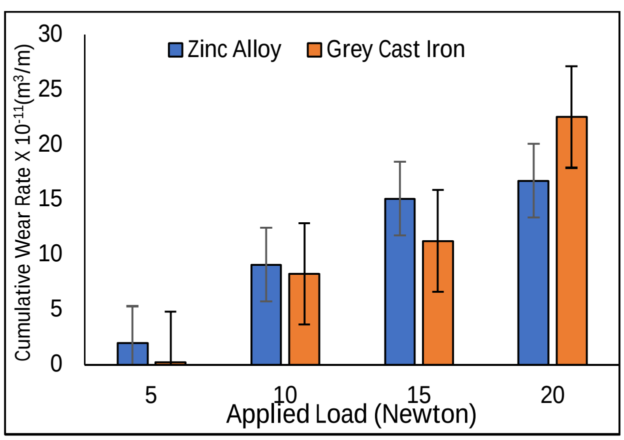
Fig. 4a and b depicted the wear rate of the samples tested against the abrasive as a function of abrading distance at an applied load of 5N and 20 N respectively while the influence of applied load on the cumulative wear rate at an abrading distance of 500m is shown in Fig 4c. The wear rate decreased with abrading distance for both the test materials irrespective of the applied load. Moreover, the zinc-based alloy delineates higher wear rate to that of cast iron. Furthermore, wear rate increased with load regardless of the specimen materials. Wear resistance under severe conditions also improves because of improved thermal stability while ambient temperature properties deteriorate over the matrix alloy due to enhanced cracking tendency introduced by the thermally stable micro-constituents. Coming to the experimental conditions affecting the wear response of materials, applied a load directly influences the property i.e. larger the load greater the wear rate. Abrasion resistance relies on various factors relating to the experimental material system/ composition and the nature of various phases.



(a)



(b)



(c)

Fig. 4 Wear rate versus abrading distance at an applied load of (a) 5 N, (b) 20 N & (c) wear rate versus applied load at an abrading distance of 500 meters

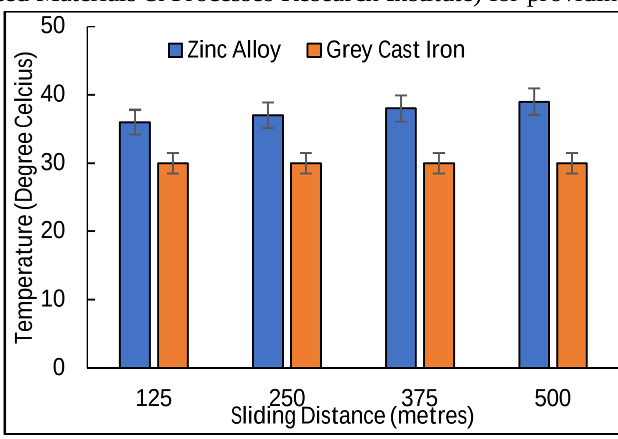
Frictional heating adjacent the contacting surface of the test material during abrasion testing at 5N and 20 N loads have been plotted as a function of test duration/distance in Fig. 5a and b respectively. The effect of load on frictional heating can also be proven within the Fig. 5c. The frictional heating elevated with abrading distance for the entire experiment materials. at lower load, the zinc-based alloy experienced higher frictional heating than the cast iron while at higher load cast iron delineates the maximum. Frictional heating led to increases with the increase in applied load regardless of the test material. Higher frictional heating with increasing load may be ascribed to a higher depth of penetration on the surface of the test material by the abrasive particles.

IV. CONCLUSIONS

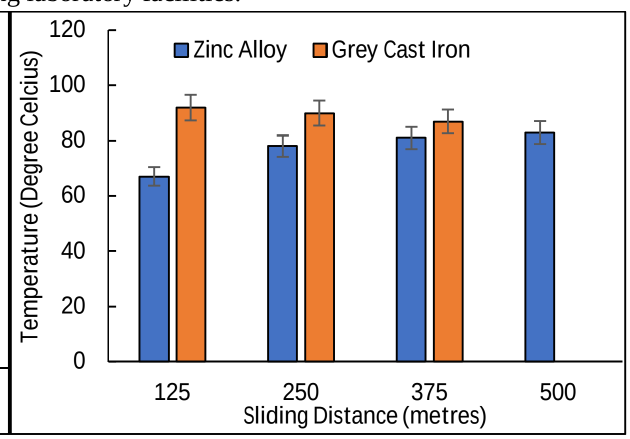
Pertaining to the observations made in the present study, it can be concluded that the matrix alloy contained primary α, eutectoid α+η and ∊ while in the case of cast iron, flakes of graphite were observed in the matrix; the latter comprised of (majority of) pearlite and (limited quantity of) ferrite. Moreover, the Abrasive wear rate of the test materials increased with test duration and applied load. The zinc-based alloy exhibited higher wear rate took after by the grey cast iron. Furthermore, the frictional heating was rise was more in the case of the zinc-based alloy at lower load whereas at higher load opposite trend of variation was obtained. Also, the frictional heating enhanced with load and test distance, the frictional heating elevated at a greater rate at first followed via a shrink rate of broadening at longer test distance.

V. ACKNOWLEDGMENT

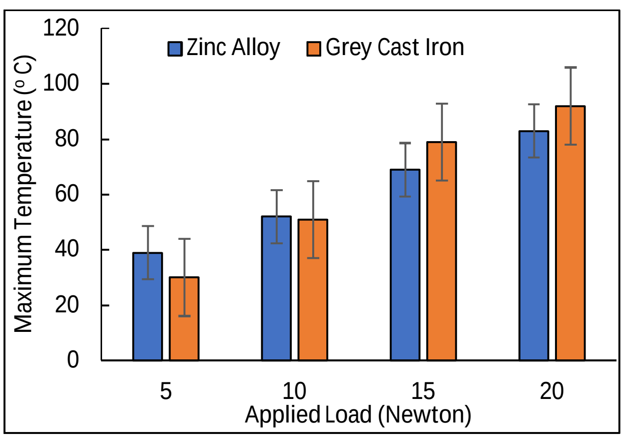
The authors would like to be obliged to Maulana Azad National Institute of Technology, Bhopal, and CSIR-AMPRI, Bhopal (Advanced Materials & Processes Research Institute) for providing laboratory facilities.



(a)



(b)



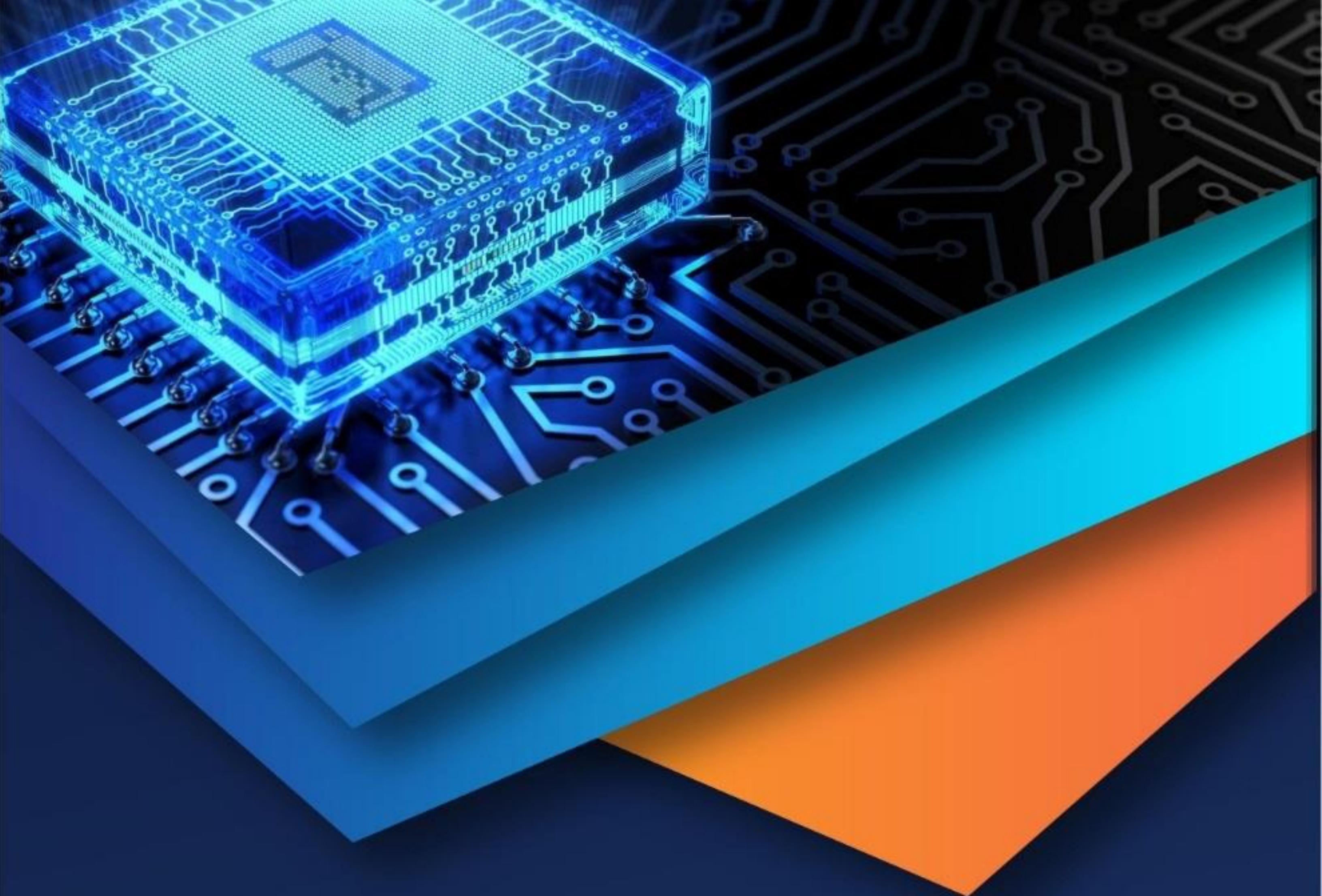
(c)

Fig. 5 Temperature rate versus abrading distance plots at an applied load of (a) 5 N, (b) 20 N & (c) Maximum Temperature versus applied load at an abrading distance of 500m

REFERENCES

[1] Türk, Ahmet, Can Kurnaz, and Hüseyin Şevik. "Comparison of the wear properties of modified ZA-8 alloys and conventional bearing bronze." Materials & design 28.6 (2007): 1889-1897.

[2] Hanna, M. D., J. T. Carter, and M. S. Rashid. "Sliding wear and friction characteristics of six Zn-based die-casting alloys." Wear 203 (1997): 11-21.
[3] El-Khair, MT Abou, A. Daoud, and A. Ismail. "Effect of different Al contents on the microstructure, tensile and wear properties of Zn-based alloy." Materials Letters 58.11 (2004): 1754-1760.
[4] Yan, Shuqing, et al. "Influence of different Al contents on microstructure, tensile and wear properties of Zn-based alloy." Journal of Materials Science & Technology 26.7 (2010): 648-652.
[5] Prasad, B. K., et al. "Abrasive wear characteristics of Zn–37.2 Al–2.5 Cu–0.2 Mg alloy dispersed with silicon carbide particles." Materials Transactions, JIM 36.8 (1995): 1048-1057.
[6] Prasad, B. K., et al. "Factors controlling the abrasive wear response of a zinc-based alloy silicon carbide particle composite." Composites Part A: Applied Science and Manufacturing 28.4 (1997): 301-308.
[7] M. MacNeill, E. Laufer, J. Masounaive, in: G.R. Kingsbury (Ed.), Proceedings Conference on Wear Resistance of Metals and Alloys, Chicago, IL, USA, ASM International, Materials Park, OH, USA, 24–30 September 1988, pp. 55–63.
[8] Kid Creek Mines Ltd., Zinc Casting Alloys Pamphlet #262.1, 1984.
[9] Choudhury, P., S. Das, and B. K. Datta. "Effect of Ni on the wear behavior of a zinc-aluminum alloy." Journal of materials science 37.10 (2002): 2103-2107.
[10] Metals Handbook, vol. 18, 10th ed., ASM International, Materials Park, OH, USA, 1992, pp. 695–701.
[11] Xing, Jian-Dong, et al. "Effect of phase stability on the wear resistance of white cast iron at 800° C." Wear 252.9 (2002): 755-760.
[12] Dai, W. S., Li-Hui Chen, and Truan-Sheng Lui. "A study on SiO 2 particle erosion of flake graphite and spheroidal graphite cast irons." Wear 239.1 (2000): 143-152.
[13] Lee, Pekwah Pearl, Temel Savaskan, and Emmanuel Laufer. "Wear resistance and microstructure of Zn-Al-Si and Zn-Al-Cu alloys." Wear 117.1 (1987): 79-89.
[14] Prasad, B. K. "Abrasive wear characteristics of a zinc-based alloy and zinc-alloy/SiC composite." Wear 252.3 (2002): 250-263.
[15] Wu, Wen-Zhong, Jian-Dong Xing, and Jun-Yi Su. "An investigation on three-body abrasive wear test at elevated temperature." Wear 210.1 (1997): 299-303.
[16] Lerner, Y. S., and G. R. Kingsbury. "Wear resistance properties of austempered ductile iron." Journal of Materials Engineering and Performance 7.1 (1998): 48-52.
[17] B.V. Kovac, Mod. Cast. (March) (1990) 38–41.
[18] J.R. Keough, Foundry Manage. Technol. (November) (1995) 27–31.
[19] R. Gundlach, J. Janowack, in: Proceedings of the 2nd International Conference on Austempered Ductile Iron, University of Michigan, USA, 17–19 March 1986, pp. 23–30.
[20] P. Prasad Rao, J. Mater. Charact. 76 (1995) 47–51 (Institution of Engineers (I)).
[21] Yu, S. Y., H. Ishii, and T. H. Chuang. "Corrosive wear of SiC whisker-and particulate-reinforced 6061 aluminum alloy composites." Metallurgical and Materials Transactions A 27.9 (1996): 2653-2662.
[22] Das, S., S. V. Prasad, and T. R. Ramachandran. "Microstructure and wear of cast (Al-Si alloy)-graphite composites." Wear 133.1 (1989): 173-187.
[23] Cenna, A. A., et al. "Effects of graphite particle addition upon the abrasive wear of polymer surfaces." Journal of materials science 36.4 (2001): 891-900.
[24] Majumdar, B. S., A. H. Yegneswaran, and P. K. Rohatgi. "Strength and fracture behaviour of metal matrix particulate composites." Materials Science and Engineering 68.1 (1984): 85-96.
[25] Metals Handbook, vol. 9, ninth ed., ASM International, Materials Park, OH, USA, 1985, pp. 242–255.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY