Investigation of dry sliding wear behavior of hybrid composite (AA5083+cadmium+zirconia) fabricated by stir casting method

[1]Singaravelan M, [2]Rajavijay T
[1]Student, [2]Assistant Professor
[1]Alagappa Chettiar Government College Of Engineering And Technology, Karaikudi,
[2]Alagappa Chettiar Government College Of Engineering And Technology, Karaikudi

***Abstract* - In This work concentrates on the preparation of AA5083-(0, 2, and 2 Wt. %) Cadmium-(0, 3, and 5 Wt. %) zirconia aluminium metal matrix composites (AMCs) using stir casting and investigation of dry sliding wear behavior by means of pin-on-disc apparatus at room temperature. The successful incorporation of cadmium and zirconia particles into the aluminium alloy matrix. A proper distribution of cadmium and zirconia particles without segregation was achieved by using stir casting. Cadmium and zirconia particles refined the grains of the aluminium matrix and improved the hardness of the composite and reducing the wear rate. The result show that the increase in the percentage of addition of cadmium and zirconia increases the hardness and reducing the wear rate is observed for AA5083-2% Cd-5% ZrO2 hybrid alloy.**

***keywords* - Stir casting, pin-on-disc, cadmium, zirconia, dry sliding wear, hardness, wear rate.**

I. INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. Now a day's increasing demand of modern technology composites are most promising materials of recent interest. Metal matrix composites (MMC's) process significantly improved properties including high specific strength; specific modulus, damping capacity and Tribological behavior compared to unreinforced alloys.

AMC (Aluminium Metal Matrix Composites) are a combination of high specific stiffness, good fatigue properties, greater strength, light weight, low thermal expansion co-efficient, high thermal conductivity and the potential for relatively low-cost conventional processing. Ulhas .K.Annigeri et. al. [1] which is suitable method of employed in stir casting such as, how the base metal is melted, at what temperature and state it is to be maintained, what conditions the particulates are added and how the stirring time and stirring speed affect the final composite material. The effect of stirrer design and feeding mechanism has also been discussed. Bhaskar Chandra Kandpal et. al. [2] over all view of stir casting process, process parameter, & preparation of AMC material by using aluminium as matrix form and SiC, Al_2O_3 as reinforcement by varying proportion. Pranav Dev Srivyas et. al. [3] to review the role of different types of fabrication routes in the AMCs and also briefly discuss the major fabrication-synthesis techniques, properties characterization, applications and the future scope of AMCs. D. Prince Sahaya Sudherson et. al. [4] the wear behavior AA5083-cadmium alloy was investigated by varying the weight percentage of cadmium (0, 2.5, 5) their corresponding wear losses were measured through stir casting process. The results show that the increase in the percentage of addition of cadmium decreases the wear loss and the maximum wear resistant is observed for AA5083-5% cd alloy. Seyed Sajad Mirjavadia et. al. [5] multi-pass friction stir processing using zirconia nanoparticles was performed on AA5083 sheets to fabricate surface Nano composites it was found that iteration of FSP consistently improves tensile properties and micro hardness of the materials. Madhusudhan M et. al. [6] influence of reinforced particles ZrO2 on mechanical properties of aluminum alloy (AA7068) composites which are developed by stir casting technique. Pandiyarajan R et. al. [7] the metallurgical characterization of friction stir welded AA6061- ZrO2-C Hybrid MMCs fabricated by stir casting method and the microstructure of friction stir welded MMCs are produce maximum hardness value compare to base metal of MMCs. S. Roseline et. al. [8] the hardness and corrosion behavior of aluminium composites reinforced with Fused Zirconia Alumina 40 (FZA40) subjected to heat treatment was investigated. Aluminium composites reinforced with FZA in volume % of 0, 5, 10 and 15%, respectively, were manufactured using stir-casting techniques. The pits were getting shallower as the reinforcements increased. It can be concluded that the composites were stable in their structure as they maintained their corrosion resistance levels after heat treatment process.

II. MATERIALS AND METHODS

A. Materials and equipment

The under listed material and equipment were used for this research work; AA5083 ingot, cadmium micro powder, zirconia micro powder, weighting balance, stir casting machine, vernier caliper, bench vice, hack-saw, mixer, die, Brinell hardness testing machine, pin-on-disk machine, En33steel disk, lathe machine, emery papers of different grits.

B. Method

The methodology adopted to carry out these research essentially involved alloy preparation by melting and casting techniques. The alloying element zirconia were added in concentration of 3-5% by weight to molten AA5083-2%Cd alloy, stirred and casted by using gravity die casting method. Subsequently, specimens obtained from the casting were subjected to machining and tribological investigation such as pin-on-disk test and Brinell hardness test.

III. EXPERIMENTAL PROCEDURE

A) **Preparation of AA5083-cadmium-zirconia alloy**

In this work 2%, 2% cadmium and 3%, 5% zirconia is alloyed with Aluminium AA5083 through stir casting process which is represented in Fig. 1 and their chemical constituents are given in Table 1. In addition to Aluminium, it consist small amount of Manganese (Mn), Iron (Fe), Magnesium (Mg), Silicon (Si), Zinc (Zn), Titanium (Ti), Chromium (Cr) and Copper (Cu). Initially, Aluminium AA5083 alloy is converted into molten state at 1023 K using gravity stir casting process and it is quenched to keep the atmospheric in the semi-solid state in which the stirring process was carried out at 300 rpm. The cadmium and zirconia micro piratical was preheated at 473 K is added manually with the vertex at a constant temperature of 1023 K. Finally, the mixture is poured into the mound cavity and quenched at room temperature and the different weight fractions of AA5083-cadmium- zirconia alloys are formulated.

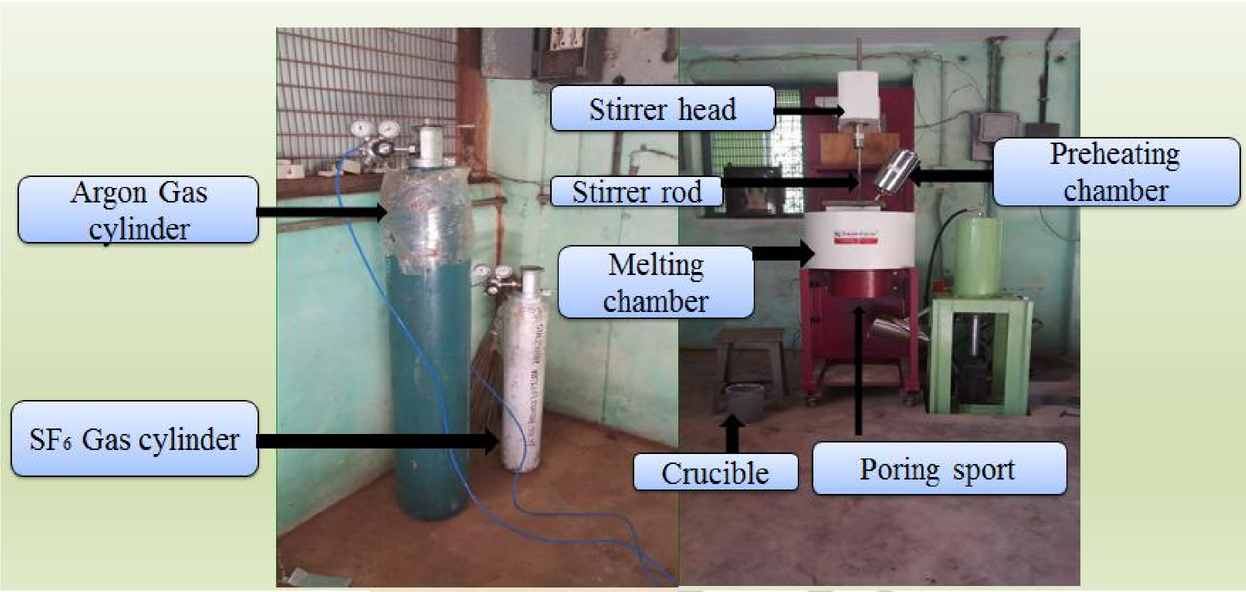

Figure. 1. Stir casting setup

Table 1. Chemical composition of AA5083-cadmium-zirconia alloy (wt %).

Samples	Mg	Fe	Mn	Si	Zn	Ti	Cr	Cu	Cd	ZrO2	Al
AA5083	4.9%	04%	1%	0.4%	0.25 %	0.15 %	0.25 %	0.1%	-	-	balance
AA5083-2%Cd-3%ZrO2	4.9%	04%	1%	0.4%	0.25 %	0.15 %	0.25 %	0.1%	2%	3%	balance
AA5083-2%Cd-5%ZrO2	4.9%	04%	1%	0.4%	0.25 %	0.15 %	0.25 %	0.1%	2%	5%	balance

B. Machining

The machining operation was carried out using a three jaw chuck lathe machine. The samples to be machined were firmly clamped on the machine and facing, turning and shaping operations were done on the clamped samples with the aid of a cutting tool mounted on the post of lathe machine. Eventually the required dimensions for pin-on-disk and hardness test samples.

C. Brinell hardness test

This test was conducted using a Brinell testing machine model B2000 (H). The specimen each 20mm in diameter were polished, placed on an adjusting table below the control panel separately, the table was raised to the focus of the microscope which helped to determine the exact spot for indentation. On pushing the start button on, the microscope returned automatically to its resting position and the spherical indenter was carefully placed on the specimen surface. A specified force was applied and maintained for about 15seconds after which the indenter bounced back to its formal position. The indentation was clearly seen on the monitor of the Brinell testing machine, the diameter of the indentation was obtained by placing four metric lines on the edges of the indentation using hand control knob. The diameter obtained and the force applied was used by the machine to calculate the Brinell hardness of the work piece. Brinell hardness result was displayed on the bottom left hand corner of the monitor. Three indentations were taken on each specimen and the mean was obtained.

D. Dry slide wear behavior test

The wear test is conducted by pin-on-disc wear tester according to ASTMG99 standard in which EN31 steel is used as counter material. Before and after the each wear test, the sliding surface of pin and disc are cleaned thoroughly by using acetone. At constant speed (110 rpm), the wear test is carried out by varying load (10 N, 20 N, 30 N, 40 N), sliding velocity and sliding distance both are constant. The contour face disc was cleaned with an organic solvent to remove the traces obtained during each test. During the wear test, the circular disc is rotated and the pin specimen is kept stationary and normal to the rotating disc. A cylindrical rod of 8 mm in radius and 40 mm in length samples are prepared for wear test. The wear loss is estimated by weighing the weight of the samples before and after the wear test by using an electronic weighing machine with the precision of 0.0001 g. Further, the density of cast samples is calculated using the following formulas.

1. Area
   Cross sectional Area, $A = \pi r^2$
2. Volume loss
   Volume loss = Cross sectional Area x Height loss
3. Wear rate
   Wear rate = Volume loss / Sliding distance
4. Wear resistance
   Wear resistance = 1/ Wear rate
5. Specific wear rate
   Specific wear rate = Wear rate/load

IV. RESULTS AND DISCUSSION

A. Brinell hardness test

Results of Brinell hardness test responses by the test specimens are displayed in Table 2 and Figure 2. From Table 2 and Figure 2, it could be observed that addition of all the elements within the studied range of composition improved material hardness.

Table 2. Brinell hardness experimental results.

Material Composition	Diameter Of ball "mm"	Load "kg"	Diameter of indentation "mm"			Average Indentation "mm"	Area	BHN
			T1	T2	T3			
AA5083	10	500	2.9	2.7	3.1	2.9	13.5005	74
AA5083+Cd (2%)+ZrO2(3%)	10	500	2.65	2.3	3.15	2.7	11.6778	86
AA5083+Cd (2%)+ZrO2(5%)	10	500	2.7	2.8	2.45	2.65	11.2317	89

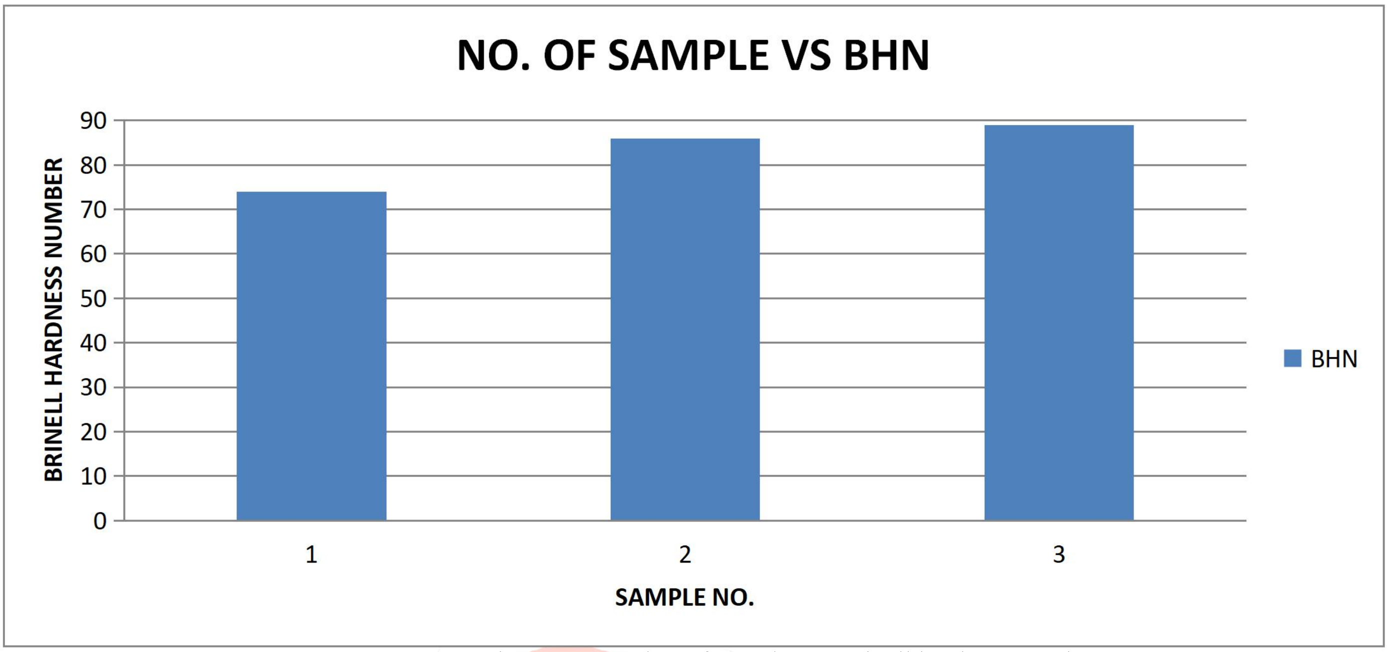

Figure. 2. Number of samples vs Brinell hardness number

B. Dry slide wear behavior test

The wear rate of different concentrations of AA5083-cadmium-zirconia alloy is estimated through pin on disc wear test. The weight loss observed from the wear test samples are shown in the table 3 and Fig. 3 in which wear loss decreases with increase in the percentage of addition of zirconia content. Enrichment of hardness and lower wear rate was proved due to the reduction in weight loss of the samples.

Table 3. Wear rate experimental results.

s.no	Specimen Composition	Wear rate (mm^3/m)			
		Load 10N ($1*10^{-4}$)	Load 20N ($1*10^{-4}$)	Load 30N ($1*10^{-4}$)	Load 40N ($1*10^{-4}$)
1	AA5083	4.4081	6.9797	9.1837	12.123
2	AA5083+2% Cd+3%ZrO2	3.1108	5.1857	6.9141	9.3332
3	AA5083+2% Cd+3%ZrO2	2.4182	4.1457	5.5279	7.6018

Table 4. Wear resistance experimental results.

s.no	Specimen Composition	Wear resistance (m/mm^3)			
		Load 10N	Load 20N	Load 30N	Load 40N
1	AA5083	2268.55	1432.73	1088.89	824.88
2	AA5083+2% Cd+3%ZrO2	3214.61	1928.42	1446.32	1071.44
3	AA5083+2% Cd+3%ZrO2	4135.31	2412.14	1809.01	1315.48

Table 5. Specific wear rate experimental results.

s.no	Specimen Composition	Specific wear rate (mm^3/Nm)			
		Load 10N	Load 20N	Load 30N	Load 40N
1	AA5083	4.4081	3.4899	3.0612	3.0308
2	AA5083+2% Cd+3%ZrO2	3.1108	2.5928	2.3047	2.3333
3	AA5083+2% Cd+3%ZrO2	2.4182	2.0729	1.8426	1.9005

The wear behavior of different concentrations of AA5083- cadmium- zirconia alloy at 10 N, 20 N, 30 N and 40 N normal loading conditions are displayed in the Fig. 3-5. The each point in the curve is the average value of wear loss obtained from the test samples and the wear loss of AA5083 is compared with the constant percentage of addition cadmium and various percentage of zirconia alloyed samples for all the above four loads. It is clear that low wear was observed in the AA5083-cadmium (2%)- zirconia (5%) alloy. Hence, the percentage of an increase in the cadmium content reduces the wear loss whereas the wear loss also increases with increasing the magnitude of normal load.

Table 4 and figure 4 shows the wear resistance as a function of time for the AA5083 and composites reinforced with cadmium and zirconia particles of size ranges (200 meshes) at a load of 10, 20, 30, 40 N and total time is 5 minutes. It is observed that wear resistance increased. Table 5 and figure 5 shows the specific wear rate as a function of time for the AA5083 and composites reinforced with cadmium and zirconia particles of size ranges (200 mesh) at a load of 10, 20, 30, 40 N and total time is 5 minutes. It is observed that specific wear rate of hybrid MMC AA5083 decreased.

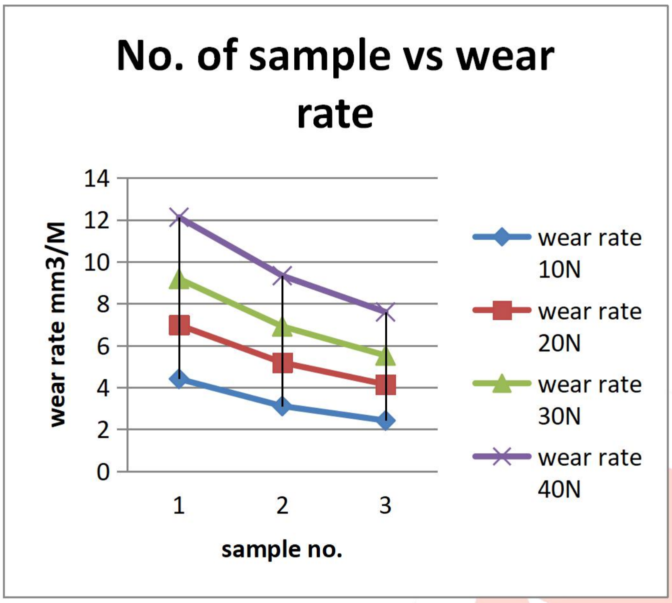

Figure. 3. Number of samples vs wear rate

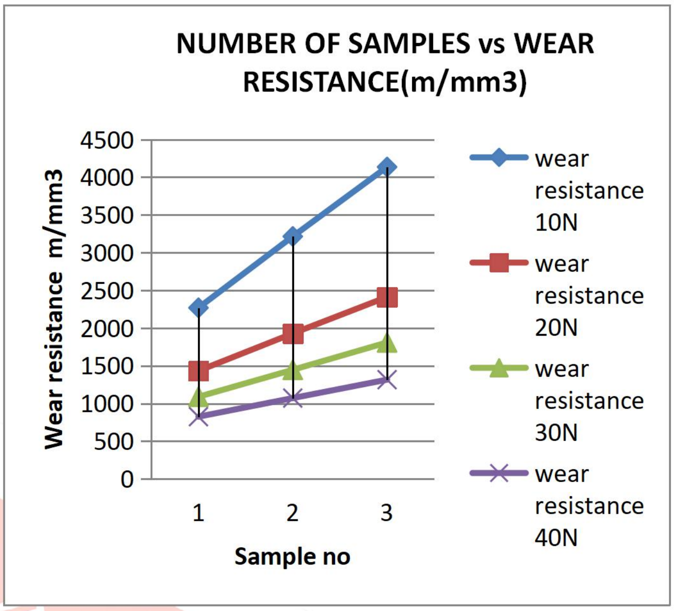

Figure. 4. Number of samples vs wear resistance

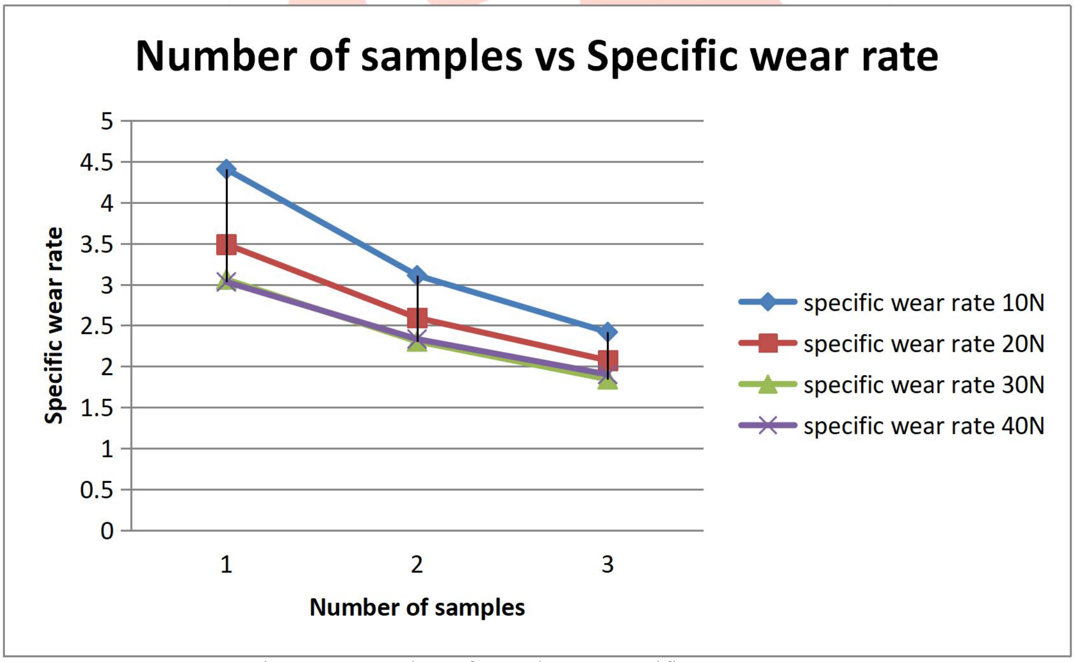

Figure. 5. Number of samples vs Specific wear rate

V. CONCLUSION

The wear characteristics of AA5083-cadmium-zirconia hybrid alloy made by gravity stir casting process are experimentally investigated. The wear resistance of the composites is significantly higher than that of aluminum alloy (AA5083). The addition of cadmium and zirconia with the AA5083 alloy developed a wear resistant oxide layer in the all concentrations of AA5083-cadmium-zirconia hybrid alloys. The wear resistance and hardness of AA5083 alloys are increases with constant percentage of cadmium content addition and increase the percentage of zirconia content addition. Since the investigation parameters sliding velocity, sliding distance is constant and increases the applied normal load. Hence the wear resistant behaviors of AA5083 alloys are enhanced due to the addition of cadmium and zirconia content.

REFERENCES

[1] Method of stir casting of Aluminum metal matrix Composites: A review Ulhas .K. Annigeria, G.B. Veeresh Kumar. Materials Today: Proceedings 4 (2017) 1140–1146.
[2] Aluminium-based metal matrix composites by stir casting: a literature review. Bharat Kumar, Jyoti V. Menghani. Int. J. Materials Engineering Innovation, Vol. 7, No. 1, 2016.
[3] Manufacturing and technological challenges in Stir casting of metal matrix composites– A Review. Bhaskar Chandra Kandpal, Jatinder Kumar, Hari Singh. Materials Today: Proceedings 5 (2018) 5–10.
[4] Role of Fabrication Route on the Mechanical and Tribological Behavior of Aluminum Metal Matrix Composites – A Review. Pranav Dev Srivyasa, M.S. Charoob. Materials Today: Proceedings 5 (2018) 20054–20069.
[5] Dry sliding wear behavior of novel AA5083-cadmium alloy prepared by stir casting process. D. Prince Sahaya Sudherson, J. Sunil. Materials Today: Proceedings 5 (2020).
[6] Surface metal matrix composites of Al5083 - fly ash produced by friction stir processing. G.V.N.B. Prabhakar, N. Ravi Kumar, B. Ratna Sunil. Material today: Proceedings (2018).
[7] Mechanical properties and characterization of zirconium oxide (ZrO2) and coconut shell ash (CSA) reinforced aluminium (Al 6082) matrix hybrid composite. K. Ravi Kumar, T. Pridhar, V.S. Sree Balaji (2018). S0925-8388(18)32298- 9.
[8] Corrosion behavior of heat treated aluminium metal matrix composites reinforced with fused zirconia alumina 40. S. Roseline, V. paramasivam. Journal of alloy and compounds 799(2019) 205-215.