EVALUATION FOR THE EFFECTS OF SILICA ON MECHANICAL PROPERTIES OF TERNE

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ABSTRACT

Purpose: *This paper is focusing on the improvement of the mechanical properties such as hardness, tensile strength and wear rate etc. by varying Si content in the alloy of Pb-Sn-Si.*
Design/methodology/approach: *Three specimens have been prepared by casting for the various compositions of Pb-Sn-Si specifications have been given in Table no 3. Experiment has designed using Rockwell hardness Test, Brinell hardness Test, Tensile Test and Wear test.*
Findings: *We evaluate the effects of Si content on the mechanical properties of terne (Pb-80%, Sn-20%). Hardness test has shown that Maximum RHN for Specimen A (Pb-89%,Sn-10%,Si-1%,as cast) and BHN for Specimen B (Pb-79%,Sn-20%,Si-1%,as cast), maximum peak displacement and ultimate tensile strength for Specimen A (Pb-89%,Sn-10%,Si-1%,as cast) and maximum wear rate for Specimen A (Pb-89%,Sn-10%,Si-1%,as cast).*
Originality/value: *By this research it is found that the mechanical properties are enhanced. The results obtained by these studies will be useful to other researches for similar type of study and may be eye opening for further research on material properties.*

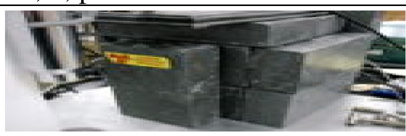
KEYWORDS: *Terne, RHN, BHN, Tensile test, Wear Test.*

I. INTRODUCTION

It is well known that particle volume, shape, size, surface characteristics and particle dispersion within the matrix have an influence on the mechanical properties of the alloy or composites [1, 2].The alloys of Pb-Sn are common but by adding Si to them change their properties and enhance their properties. The impact that they have on local environment are minimal. In recent years, lead-calcium-tin alloys have been widely used for producing lead/acid battery grids. In particular, lead-calcium-tin grids are usually employed for the positive grids of Valve-Regulated Lead Acid batteries (VRLA) or maintenance free storage lead/acid batteries [3, 4]. Indeed, Pb-Ca-Sn alloys present better mechanical and electrochemical properties considering Pb-Ca or Pb-Sb systems. In particular, the addition of tin to lead-calcium alloys dramatically improves the conductivity of corrosion products on the grid surface, allowing improved corrosion resistance and inhibition of the formation of non conductive layers at the grid-active material interface [5, 6]. Furthermore, tin increases the resistance corrosion in overcharge conditions because it leads to the rising of the oxygen overvoltage [14]. From a metallurgical point of view, the age-hardening process of the most commonly used ternary alloys Pb-Ca (0.08wt. %) Sn (2wt. %) proceeds by discontinuous or continuous precipitation of L12 phase {i.e. (Pb1-xSnx) 3Ca} from supersaturated α solid solution [15, 16]. Moreover, at room temperature, the residual tin and calcium super saturation of aged ternary alloys can lead to the over ageing appearance. The over ageing process of Pb-Sn alloys takes place in two stages [16]: first, a discontinuous precipitation of a coarse L12 phase, second, the lamellar coalescence of these latter precipitates. Globally, the beginning of the over ageing can be associated to the rapid decrease of mechanical and electrochemical properties of Pb-Ca-Sn alloys [15].

To delay the over ageing phenomenon, annealing treatments are usually performed. These treatments are issued from Transformation-Time-Temperature (TTT) diagrams of Pb-Ca-Sn ternary alloys [17]. Alloys are usually prepared to improve on the properties of their components. For instance, Steel is stronger than iron, its primary component. The physical properties of an alloy, such as density, reactivity and electrical and thermal conductivity may not differ greatly from the alloy's elements, but engineering properties, such as tensile strength, shear strength and Young's modulus, can be substantially different from those of the constituent materials. This is sometimes due to the differing sizes of the atoms in the alloy—larger atoms exert a compressive force on neighbouring atoms, and smaller atoms exert a tensile force on their neighbours. This helps the alloy resist deformation, unlike a pure metal where the atoms move more freely. Synergistic effects were found in the form of a further increase in wear resistance, stiffness, and fracture toughness and tensile and impact strengths by mixing nano and microparticles [22–23]. Unlike pure metals, most alloys do not have a single melting point. Instead, they have a melting range in which the material is a mixture of solid and liquid phases. The temperature at which melting begins is called the solidus, and that at which melting is complete is called the liquids. However, for most pairs of elements, there is a particular ratio which has a single melting point; this is called the eutectic mixture. Chemically, the fumed silica consists of amorphous SiO2 of variable purity [24], some physical properties and chemical composition are shown in Table 1.The fumed silica used here was obtained as a by-product of the silicon production in the top of large electrical melting furnaces, which is a non conventional production. Hence, the particle size and the purity of the fumed silica are variable, reflecting the furnace operation at the time it was collected. In any case, the silica weight proportion is greater than 95%. According to Schadler, three dimensional nanofillers are relatively equally-axed particles, with a length lower than 100 nm in their largest dimension [25].

Table 1- Properties of Lead and Tin

Material	**Lead**	**Tin**
	General Properties	
Name, Symbol, Number	lead, Pb, 82	tin, Sn, 50
Chemical series	poor metals	poor metals
Group, Period, Block	14, 6, p	14, 5, p
Appearance		
Standard atomic weight	207.2(1) g·mol−1	118.710(7) g·mol−1
Electron configuration	[Xe] 4f14 5d10 6s2 6p2	[Kr] 4d10 5s2 5p2
Electrons per shell	2, 8, 18, 32, 18, 4	2, 8, 18, 18, 4
	Physical properties	
Phase	solid	solid
Density (near r.t.)	11.34 g·cm−3	(white) 7.265 g·cm−3
Liquid density at m.p.	10.66 g·cm−3	(gray) 5.769 g·cm−3
Melting point	600.61K (327.46°C, 621.43°F)	6.99 g·cm−3
Boiling point	2022K (1749°C, 3180°F)	505.08K (231.93°C, 449.47°F)
Heat of fusion	4.77 kJ·mol−1	2875K (2602°C, 4716°F)
Heat of vaporization	179.5 kJ·mol−1	(white) 7.03 kJ·mol−1
Heat capacity	(25°C) 26.650 J·mol−1·K−1	(white) 296.1 kJ·mol−1
	Atomic properties	
Crystal structure	cubic face centered	Tetragonal
Oxidation states	(Amphoteric oxide)	(amphoteric oxide)
Electro negativity	2.33 (Pauling scale)	1.96 (Pauling scale)
Ionization energies (more)	1st: 715.6 kJ·mol−1	1st: 708.6 kJ·mol−1
	2nd: 1450.5 kJ·mol−1	2nd: 1411.8 kJ·mol−1
	3rd: 3081.5 kJ·mol−1	3rd: 2943.0 kJ·mol−1
Atomic radius	180 pm	145 pm
Atomic radius (calc.)	154 pm	145 pm

Covalent radius	147 pm	141 pm
Vander Waals radius	202 pm	217 pm
Miscellaneous properties		
Magnetic ordering	diamagnetic	no data
Electrical resistivity	(20°C) 208 nΩ·m	(0 °C) 115 nΩ·m
Thermal conductivity	(300K) 35.3 W·m−1·K−1	(300K) 66.8 W·m−1·K−1
Thermal expansion	(25°C) 28.9 µm·m−1·K−1	(25°C) 22.0 µm·m−1·K−1
Speed of sound (thin rod)	(r.t.) 1190 m·s−1	(r.t.) (rolled) 2730 m·s−1
Young's modulus	16 GPa	50 GPa
Shear modulus	5.6 GPa	18 GPa
Bulk modulus	46 GPa	58 GPa
Poisson ratio	0.44	0.36
Mohs hardness	1.5	1.5
Brinell hardness	38.3 MPa	51 MPa
CAS registry number	7439-92-1	7440-31-5

Table 2 - Properties of Silica

General	
Other names	Silica
Molecular formula	SiO2
Molar mass	60.1 g/mol
Appearance	white or colourle solid (when pure)
CAS number	14808-60-7
Miscellaneous properties	
Density and phase	2.6 g/cm3, solid
Solubility in water	0.012 g in 100g of water
Melting point	1650 (±75) °C
Boiling point	2230°C

II. SPECIMEN PREPARATION

2.1 Preparation of Lead, Tin and Silica Alloy

The process of mixing the Lead, tin and silica consists of three main phases:
i. The purification of metal.
ii. The preheating of silica powder.
iii. Melting of lead and tin and mixing of silica powder.

Table 3 - Composition of lead, tin and silica

Specimens	Lead (Pb)	Tin (Sn)	Silica (Si)
Specimen A	89 %	10 %	01 %
Specimen B	79 %	20 %	01 %
Specimen C	90 %	10 %	-

2.2 Heat Treatment

After the tests have been performed on the as cast, annealing is done on the specimen and then again tested for comparison. Annealing is a term used to describe the restoration of a cold-worked or hot-worked or heat treated metal or alloy to its original properties, so as to increase ductility (formability), reduce hardness and strength, or modify the microstructure [20]. Annealing is a technique used to recover cold work and relax stresses within a metal. Annealing typically results in a soft, ductile metal. When an annealed part is allowed to cool in the furnace, it is called a "full anneal" heat treatment. When an annealed part is removed from the furnace and allowed to cool in air, it is called a "normalizing" heat

treatment. During annealing, small grains re-crystallize to form larger grains. In precipitation hardening alloys, precipitates dissolve into the matrix, "solutionizing" the alloy.
The purpose of annealing may involve one or more of the following aims:

i. To soften the steel and to improve machinability.
ii. To relieve internal stresses induced by some previous treatment (rolling, forging, uneven cooling).
iii. To remove coarseness of grain.
iv. The treatment is applied to forgings, cold-worked sheets and wire, and castings.
v. The operation consists of: Heating the steel to a certain temperature "Soaking" at this temperature for a time Sufficient to allow the necessary changes to occur.

III. RESULT AND ANALYSIS

3.1 HARDNESS TEST

Hardness is a property exhibited by all materials. Hardness is defined in different ways, depending upon the various hardness test used.

3.1.1 Rockwell hardness machine

When a metal is intended, it opposes indentation. The degree of resistance offered by the metal is commensurate with its hardness. If the hardness is more, the resistance to indentation is more and vice versa. Thus one will have small indentation with hard metals and larger indentation with soft metals. Based on the same phenomenon one can see that the depth of penetration is also inversely proportional to the material hardness. This can be utilized as the means of measuring the hardness. This concept was proposed in 1908 Ludwig at Vienna. Rockwell hardness tester is developed with the depth of penetration as the criterion for hardness of the metal.
Results:

At Load= 100kg

Table 4 Rockwell Hardness Machining Parameters

SPECIMEN	Trial1	Trial2	Trial3	Trial4	Average
Pure Pb-Sn (Pb-90%,Sn-10%,as cast)	67	65	64	66	65.5
Pure Pb-Sn (Pb-90%,Sn-10%, annealed)	54	60	60	58	58
Specimen A(Pb-89%,Sn-10%, silica-1%,as cast)	67	71	66	70	68.5
Specimen A (Pb-89%,Sn-10%, silica-1% annealed)	58	62	62	66	62
Specimen B(Pb-79%,Sn-20%, silica-1%,as cast)	64	71	69	64	67
Specimen B(Pb-79%,Sn-20%,silica-1%, anneale	64	64	65	65	64.5

3.1.2 Brinell hardness test

This test employs a diamond or hardened steel bar as indenter the specimen is placed suitably in the upper housing of Brinell hardness testing machine. This machine is called a push-pull button type machine because the indenting load is applied by pushing a bottom.
Results:

Load P = 250kg
Diameter of indent = 10mm
d = diameter of indentation

Table 5 Brinell Hardness Test Parameters

SPECIMEN	Trial1 d1	Trial2 d2	Trial3 d3	Trial4 d4	Average BHN
Pure Pb-Sn(Pb-90%,Sn-10%,as cast)	5.6	5.5	5.4	5.4	9.75
Pure Pb-Sn (Pb-90%,Sn-10%, annealed)	5.6	5.7	5.6	5.7	9.1
Specimen A(Pb-89%,Sn-10%, silica-1%, cast)	5.5	5.5	5.1	5.2	10.245
Specimen A(Pb-89%,S	5.6	5.6	5.5	5.6	9.28

10%,silica1%,annealed)					
Specimen B (Pb-79%,Sn-20%, silica-1%, cast)	4.8	4.8	4.8	4.8	12.96
Specimen B (Pb-79%,S 20%,silica1%,annealed)	5.9	5.2	5.3	5.4	9.81

Brinell hardness number,

$$BHN = 2P/ [\pi D (D-\sqrt{(D^2 - d^2)})]$$

P: load in kgs.
D: ball diameter in mm.
d: diameter of the indent in mm.

3.2 TENSILE TEST

Tensile test is conducted to determine the mechanical characteristics of the specimen. Here, we are concentrating on the behaviour of specimens under tensile loads [21]. The parameters that are determined from the test are peak load, break load, ultimate tensile stress, peak displacement, break displacement etc.

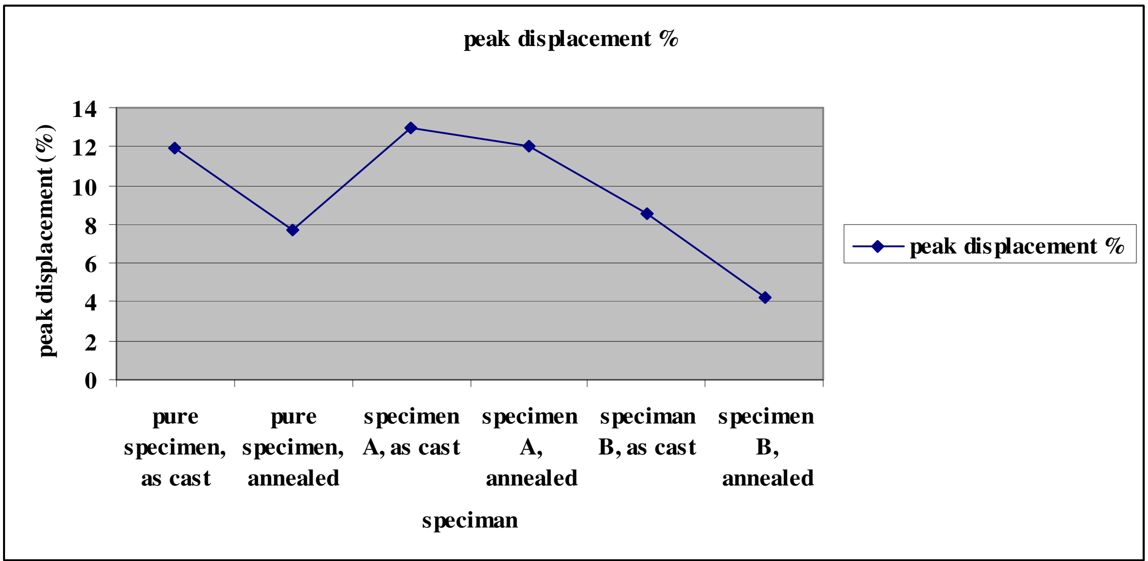


Figure 1 - Peak displacement v/s Specimen

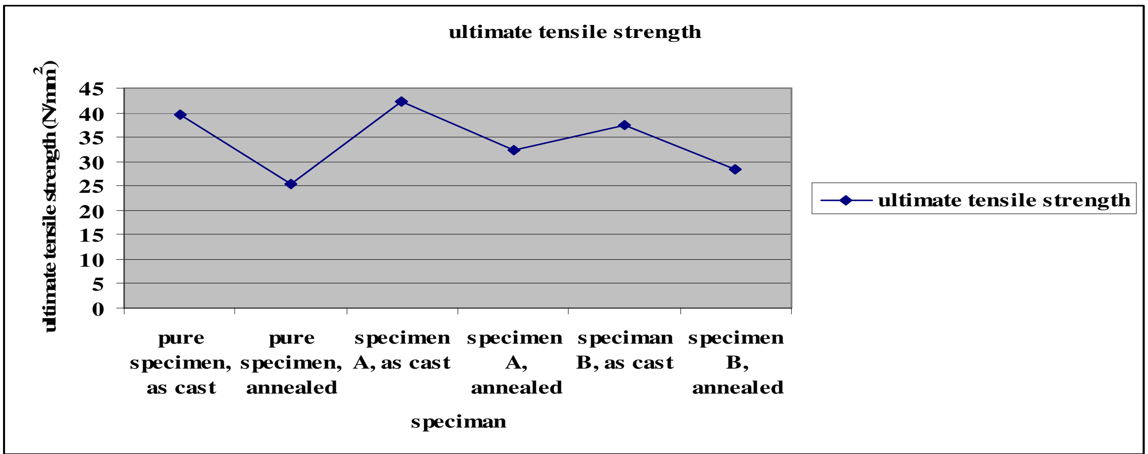


Figure 2 - Ultimate tensile strength v/s Specimen

3.3 WEAR TEST

WEAR- A material cannot remain the way it is through the years of use. The continuous usage of material results in loss of the material at the surface that is exposed. This renders unpolished, blunt, unsmooth and irregular surface.

Apparatus: Wear and friction monitor, electronic balance.

Table 6 - Pure lead tin alloy (as cast, Pb-90% Sn-10%), Initial wt. = 13.22gms

Run time(min)	10	10	10	10	10
Dist. Covered(kms)	1.398	1.398	1.398	1.398	1.398
Cumulative dist(kms)	1.398	2.796	4.194	5.592	6.99
Weight of spec.(gms)	12.783	12.352	11.856	11.404	10.589
Weight loss(gms)	0.437	0.431	0.496	0.452	0.446
Specific wear rate (mm3/N-m) 10-3	5.83	5.75	6.61	6.03	5.95
Cumulative wear rate (mm3/N-m) 1 3	5.83	11.58	18.19	24.22	30.17

Table 7 - Pure lead tin alloy (annealed, Pb 90% Sn 10%), Initial wt. = 19.830gms

Run time(min)	10	10	10	10	10
Dist. Covered(kms)	1.398	1.398	1.398	1.398	1.398
Cumulative dist(kms)	1.398	2.796	4.194	5.592	6.99
Weight of spec.(gms)	19.022	18.196	17.377	16.547	15.736
Weight loss(gms)	0.808	0.826	0.819	.830	0.811
Specific wear rate (mm3/N-m) 10-3	10.78	11.02	10.92	11.07	10.82
Cumulative wear rate (mm3/N-m) 1 3	10.78	21.8	32.72	43.79	54.61

Table 8 - Specimen A (as cast, Pb 89% Sn 10% Si 1%), Initial wt. = 30.157gms

Run time(min)	10	10	10	10	10
Dist. Covered(kms)	1.398	1.398	1.398	1.398	1.398
Cumulative dist(kms)	1.398	2.796	4.194	5.592	6.99
Weight of spec.(gms)	29.917	29.637	29.387	29.097	28.867
Weight loss(gms)	0.24	0.28	0.25	0.29	0.23
Specific wear rate (mm3/N-m) 10-3	3.22	3.75	3.35	3.89	3.08
Cumulative wear rate (mm3/N-m) 1 3	3.22	6.97	10.32	14.21	17.29

Table 9 - Specimen A (annealed, Pb 89% Sn 10% Si 1%), Initial wt. = 25.153gms

Run time(min)	10	10	10	10	10
Dist. Covered(kms)	1.398	1.398	1.398	1.398	1.398
Cumulative dist(kms)	1.398	2.796	4.194	5.592	6.99
Weight of spec.(gms)	24.683	24.251	23.787	23.302	22.833
Weight loss(gms)	0.47	0.432	0.464	0.485	0.469
Specific wear rate (mm3/N-m) 10-3	6.3	5.79	6.22	6.5	6.29
Cumulative wear rate (mm3/N-m) 10-	6.3	12.09	18.31	24.81	31.1

Table 10 - Specimen B (as cast, Pb 79% Sn 20% Si 1%), Initial wt. = 27.455gms

Run time(min)	10	10	10	10	10
Dist. Covered(kms)	1.398	1.398	1.398	1.398	1.398
Cumulative dist(kms)	1.398	2.796	4.194	5.592	6.99
Weight of spec.(gms)	26.985	26.528	26.091	25.645	25.169
Weight loss(gms)	0.47	0.457	0.437	0.446	0.476
Specific wear rate (mm3/N-m) 10-3	6.52	6.34	6.06	6.19	6.61
Cumulative wear rate (mm3/N-m) 10-	6.52	12.86	18.92	25.11	31.72

Table 11 - Specimen B (annealed, Pb 79% Sn 20% Si 1%), Initial wt. = 29.085gms

Run time(min)	10	10	10	10	10
Dist. Covered(kms)	1.398	1.398	1.398	1.398	1.398
Cumulative dist(kms)	1.398	2.796	4.194	5.592	6.99
Weight of spec.(gms)	28.483	27.885	27.276	26.666	26.06
Weight loss(gms)	0.602	0.598	0.609	0.61	0.606
Specific wear rate (mm3/N-m) 10-3	8.35	8.3	8.45	8.46	8.41
Cumulative wear rate (mm3/N-m) 10-	8.35	16.65	25.1	33.56	41.97

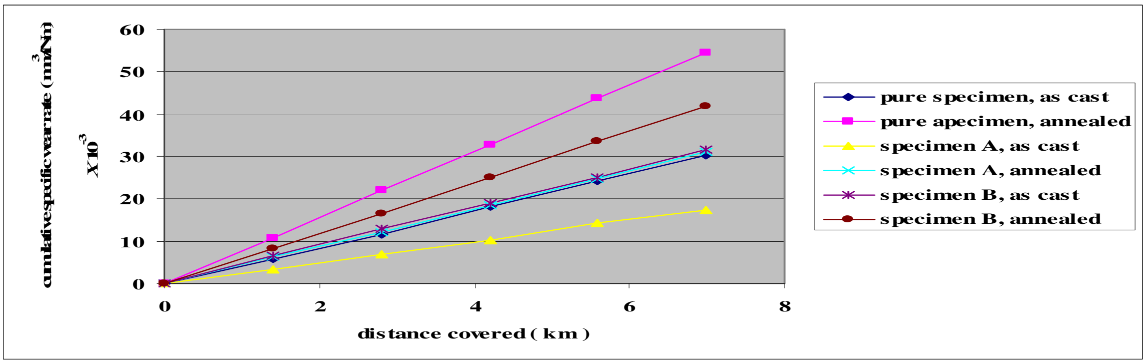


Figure 3 - Cumulative specific wear rate v/s Distance covered

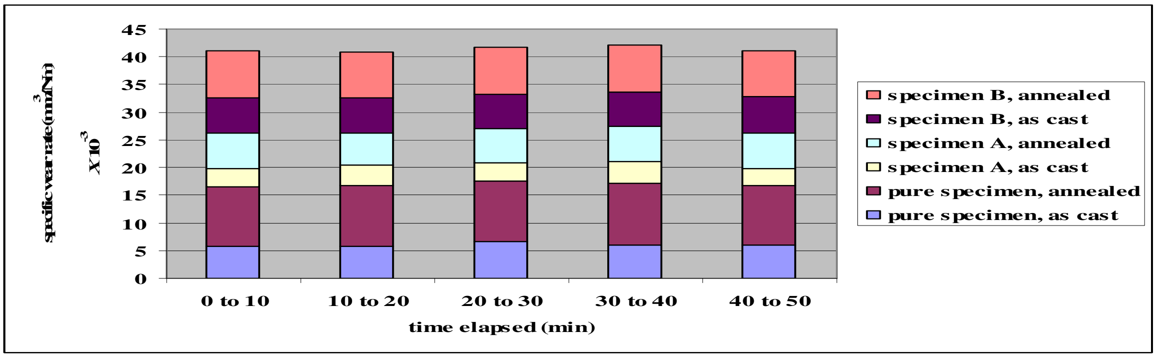


Figure 4 - Specific wear rate v/s Time elapsed

Formulae used:

Specific wear rate = weight loss/(density * distance covered * load)
Density of lead = 11.34 gms/cm3
Density of tin = 7.625 gms/cm3
Density of silica = 2.6 gms/cm3
Density of specimen = (% of lead * 11.34 + % of tin * 7.625 + % of silica* 2.6)/100 gms/cm3

IV. CONCLUSION

The research paper focused on the development of a new alloy which has enhanced properties at current stage. The cost of constructing such an alloy is low because of easily availability of silica abundance in nature. It does not require any special treatments of pressure and temperature. It is found by varying the percentage of the silica with composition of lead and tin the mechanical properties are enhanced. On the bases of the hardness, Tensile and wear test following conclusions are found.

The following are conclusions drawn based on the tests conducted

1. From the Table 4, average value of maximum RHN value 68.5 for the specimen A(Pb-89%,Sn-10%, Si-1%,as cast) and maximum BHN 12.96 for Specimen B (Pb-79%,Sn-20%, Si-1%,as cast), that shows value of hardness increases when traces of silica are added to the pure specimen and value of hardness decreases when specimen is annealed.

2. From figure 1 and 2, maximum peak displacement and ultimate tensile strength for Specimen A (Pb-89%, Sn-10%, Si-1%,as cast), that shows value of maximum peak displacement and ultimate tensile strength increases when traces of silica are added to the pure specimen.

3. From figure 3 and 4, maximum wear rate for Specimen A (Pb-89%,Sn-10%, Si-1%,as cast) The wear decreases when traces of silica are added to the pure specimen and The wear rate increases when the specimen is heat treated.

REFERENCES

[1] Fu S-Y., Feng X-Q., Lauke B., Mai Y-W.: Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate-polymer composites. Composites Part B: Engineering, 39, 933–961 (2008).

[2] Lee A., Lichtenhan J. D.: Thermal and viscoelastic property of epoxy-clay and hybrid inorganic-organic epoxy nanocomposites. Journal of Applied Polymer Science, 73, 1993–2001 (1999).

[3] Giess, H. the influence of calcium, tin and grid thickness on corrosion induced grid growth. J. power Source, 53, (1995) pp. 31-43

[4] Bagshaw, N.E., Lead alloy: past, present and future. J. power Source, 53, (1995) pp. 25-30.

[5] Miraglio L., Albert L., Ghachcham A. E1., Steinmentz J., Hilger J. P., Passivation and corrosion phenomena on lead-calcium-tin alloy of lead/acid battery positive electrodes. J. power Source, 53, (1995) pp. 53-61.

[6] Takahashi K., Yasuda Y., Hagegawa H., Horie S., Karatsuki K., Eight years of experience with valve-regulated batteries for automotive use. J. Power Sources, 53 (1995) pp.137-141.

[7] Knowles L.M., Thermal analysis of the system PbBr2-PbO, J. Chem. Phys., 19 (1951) pp.1128- 1130.

[8] Régnier C., Tristant P., Desmaison J., Remote microwave plasma-enhanced chemical vapour deposition of insulating coatings (SiO2) on metallic substrates: film properties, Surface and Coatings Technology, 80 (1996) 18-22.

[9] Cooper A., The Brite–EuRam lead-acid electric-vehicle battery project—progress report. J. Power Sources, 73 (1998) pp.127-145.

[10] Subramanian R., Ramachandran S., Electrodeposition of Lead-Tin alloy for Use as Anodes, Metal Finishing, (1996) pp.53-56

[11] Maître A., Vilasi M., Synthesis, Sintering Behaviours and Mechanical Properties of Lead-Ceramic (Nano-) Composites for Acid Battery Grids. Advances in Composite Materials for Medicine and Nanotechnology, pp. 315-342.

[12] Albert L., Chabrol A., Torcheux L., Steyer Ph., Hilger J.P., Improved lead alloys for lead/acid positive grids in electric-vehicle applications. J. Power Sources, 67, (1997) pp.257-265.

[13] Brochin F., Devaux X., Ghanbaja J., Scherrer H., Study of BiSb-SiO2 nanocomposite powders produced by an arc plasma processing. NanoStructured Materials, 11(1999) pp. 1-8

[14] Bui, N., Mattesco P., Simon P., Steinmetz J., Rocca E., The tin effect in lead-calcium alloys. J. Power Sources, 67 (1997) pp.61-67.

[15] Bouirden L., Hilger J.P., Hertz J., Discontinuous and continuous hardening processes in calcium and calcium—tin micro-alloyed lead: influence of 'secondary-lead' impurities. J. Power Sources, 33 (1991) pp.27-50.

[16] Maître, A., Bourguignon G., Fiorani J.-M., Ghanbaja J., Steinmetz J. Precipitation hardening in Pb–0.08wt.%Ca–x%Sn alloys—the role of the pre-ageing. Materials Science and Engineering A, 358 (2003) pp.233-242.

[17] Hilger J.-P., Bouirden L., New representation of the hardening processes of lead alloys by transformation-time-temperature (TTT) diagrams. J. Alloys and Compounds, 236 (1996), pp.224-228.

[18] Tilman M.M., Crosby R.L., Desy D.H., Dispersion strengthening of lead by co precipitation, U.S., Bur. Mines, Rep. Invest (1971).

[19] Cartigny Y., Fiorani J.M., Maître A., Vilasi M., Pb-based composites materials for grids of acid battery. Materials Chemistry and Physics, 103 (2007) pp.270-277.

[20] Kalpakjian S., Schmid S. R., Manufacturing processes for engineering materials, Pearson Education, IE, (4)2007, pp. 240-242 .

[21] Shackelford J. F., Muralidhara M. K., Introduction to Materials Science For Engineers, Pearson Education, IE, (6)2009, pp. 169.

[22] Wetzel B., Haupert F., Zhang M. Q.: Epoxy nanocomposites with high mechanical and tribological performance. Composites Science and Technology, 63, 2055–2067 (2003).

[23] Han J. T., Cho K.: Nanoparticle-induced enhancement in fracture toughness of highly loaded epoxy composites over a wide temperature range. Journal of Materials Science, 41, 4239–4245 (2006).

[24] Saavedra J. Tarrío, Beceiro J. López , Naya S, Gracia C., Artiaga R. "Controversial effects of fumed silica on the curing and thermo mechanical properties of epoxy composites" eXPRESS Polymer Letters Vol.4, No.6 (2010) 382–395

[25] Schadler L. S.: Polymer-based and polymer-filled nanocomposites. in 'Nanocomposite Science and Technology' (eds.: Ajayan P. M., Schadler L. S., Braun P. V.) Wiley, Weinheim, 77–135 (2003).

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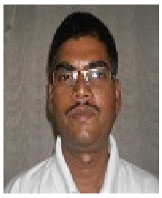

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