Evaluation on Recycling of E-waste Aluminium in Metal Matrix Composite

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Abstract - *This paper presents a practical mechanical process of recycling E-wasted materials. The current investigations on environmentally sustainable solution to reduce the E-waste generation and to save environment and ecosystem by reducing pollution. The E-waste generated is not subjected to proper recycling and decomposition which in turn affect human beings and living things. In order to reduce the pollution created by E-waste and to make use of valuable materials like Aluminium, Copper, Zinc, Lead, Gold and other materials present in E-waste researches are being carried out for recycling of E-waste. The current project aims in the fabrication of composite materials with the help of recycled E-waste materials. The matrix are selected it is aluminium alloy which was recovered from heat sinks of PCB through manually. The matrix was reinforced with e-glass fibre and fly ash by varying weight percentage using stir casting method. The E-glass fibre is constant 3 wt. % and fly ash is varying such as (0, 3, 6 and 9 wt. %). The composite sample was fabricated using stir casting technology, the samples are namely sample 1, 2, 3 and 4. After the fabrication work the samples are analyzed its mechanical properties such as tensile, compressive, hardness, impact and the test specimen is prepared as per the ASTM standards. Based on test results the fly ash wt. % is increasing means the tensile, compressive, elongation and yield strength increased. But the hardness of the third sample is decreased then second sample and after increased in fourth sample. For the above result the third and fourth samples will be carried out the microstructure analysis and grain size of the samples using scanning electron microscope. Further chemical composition of the prepared will be studied through chemical testing lab. The test results will be compared to aluminium alloy base materials and further analysis will be made to apply the composite in engineering field such as machine component, automotive and aerospace components.*

Key Words**: Environmental impact assessment, electronic scrap, Heat Sink, e-glass fibre, fly ash, stir casting process, metal matrix composite, mechanical testings**

1.INTRODUCTION

In recent year there has been increasing concern about the growing volume of end-of-life (EOL).The electronic scraps and waste are enormous that couldn`t be normally disposed in to the agricultural land or any land because this contains more valuable metals and non-metals. There are also large amount of toxic materials present in it. The electronic scrap is very important subject of concern. All over the world, large amount of e-waste has been generated, with china & producing above 1000 million tons per year. At present the electronic wastes are subjected to recycling process adapting either mechanical process or chemical process. Japan Recycling processes are carried out to recover the materials from e-waste and segregate the materials in to metals and non-metals.

The chemical process yields high metal purity but involves high cost and need more safety. The mechanical process involves less cost, medium safety, but recovers high valuable metals. During the mechanical process toxic gasses are released which is very dangerous for the environment. The dumping of E-wastes spoils the fertility of the soil and causes lot of hazards to the ecosystem. These wastes can be reduced by properly recycling it and converting them into useful products. The use of electronic and electrical devices has increased significantly that lead to rapidly rising amounts of Waste Electrical and Electronic Equipment (WEEE), often called as E-waste throughout the world. E-waste is a highly complex waste stream as it contains both valuable as well as very toxic components. The processing of electronic waste causes serious health and pollution problems due to the fact that electronic equipment contains some very serious contaminants such as copper, aluminium, lead, cadmium, brominates and beryllium flame retardants. In the current work heat sink in PCBs from e-waste has been utilized and subjected to recycling for recovering aluminium alloy in composite materials. The extracted aluminium is extracted by heat sink in PCB. The extracted aluminum is a matrix material and the selected reinforcements are E-glass fibre and fly ash. It is fabricated by stir casting process at various Wt. % and analysis the mechanical properties such as tensile, compressive, hardness and impact strength.

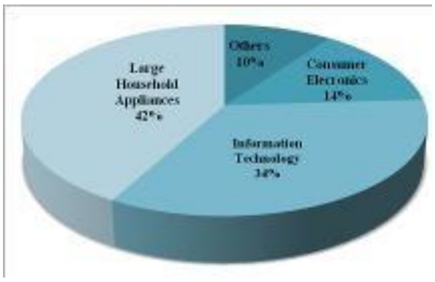


Fig -1: E-waste compositions

Table -1: Quantity of E-waste generated country wise, tones/year

E-devices	Brazil	China	India	South Africa	Mexico
PCs	96,800	300,000	56,300	19,400	47,500
Printers	17,200	60,000	4,700	4,300	9,500
Mobile phones	2,200	7,000	1,700	850	1,100
TVs	137,000	1,350,000	275,000	23,700	166,500
Refrigerators	115,100	495,000	101,300	11,400	44,700

2.LITERATURE SURVEY

Dora Siva Prasad[1]. aluminium alloy A356.2 matrix and reinforcement of rice husk ash and Silicon carbide added at equal ratio of 2,4,6,8 wt.% is fabricated by double stir casting process. While increasing of reinforcements wt.% the porosity, hardness, yield strength and ultimate strength was increased in the composite and the density is decreased. **Kenneth Kanayo Alaneme[2]** Aluminium alloy (Al-Mg-Si), RHA and Alumina (Al_2O_3) reinforcement at used with various combinations to fabricate the composite such as 0:10, 2:8, 3:7, 4:6 wt.% by using double stir casting method. In this composite was investigated as showed percentage elongation and fracture toughness was increased of the 2:8 wt.% sample and it containing low hardness, ultimate tensile strength and yield strength while increasing the reinforcements. So that the single alumina reinforcement only got higher than others samples. **S.D. Saravanan. [3]** aluminium alloy (Al-Si-10Mg) and Rice Husk Ash reinforcement in ratio of 3,6,9,12 wt. % using stir casting method fabricate the composite material. The tensile strength, compression strength and hardness was increased and the ductility gets decreased with increase in RHA weight fraction reinforcements. **Abhishek Kumar. [4]** Aluminium alloy A359 and reinforcement with Al_2O_3 at different wt.% such as 2,4,6,8 wt.% was fabricated by electromagnetic stir casting method. The tensile and hardness strength of the composite was increased that increasing the reinforcement Al_2O_3% while comparing with unreinforcement alloys. **C.H.Chen.[5]** waste e-glass fibre particles are utilized in cement concrete mixer inert fillers at different percentage and different ageing days such as 17, 27, 43 wt. % and 28, 91, 365 days. The e-glass fibre size is 38 to 300μm 40% of e-glass fibre is less then 150μm. Based on the properties the hardened concrete, optimum e-glass content was found to be 40-50 wt. % and having excellent chloride –ion penetration resistance. **Prabhakar Kammer.[6]** Aluminium 7075 matrix and reinforced with Fly ash and E-glass Short fibres composite is fabricated by stir casting at various weight fraction like E-Glass fibre 1%,3%,5% constantly with each ratio of fly ash (2,4,6,8%). The test result the 8% of fly ash and 5% of e-glass fibre sample was get high tensile and compressive strength. So the reinforcement Wt. % is increasing the properties is increased. **Anilkumar.H.C.[7]** aluminium alloy 6061 and reinforced with flyash was fbricated the composite by using stir casting method at different particle size and different percentage in weight fraction such as (4-25, 45-50, 75-100 μm) and (10, 15, 20 wt.%). The particle size is increased the tenisle and compressive strength is decreased. The wt.% percentage of fly ash is increased the tensile and compressive strength is increased at the same time the ductility is decreased. **Deepak Singla. [8]** Aluminium 7075 matrix and reinforced with Fly ash and Magnesiun composite is fabricated by stir casting at four various weight fraction like S1,S2,S3,S4. The samples are subjected to mechanical testing the S2 sample was higher strength at toughness, tensile, hardness strength and the grain size was decreased. So the amount of fly ash is increased up to S2 weight, that properties is increased. **Sachin Malhotra. [9]**the effect of reinforcement (Zirconia + Flyash) with aluminium alloy 6061 matrix is fabricated at fixed percentage of flyash (10%) and varying percentage of Zirconia (5% and 10%) in weight fraction by using stir casting method. From the result (fly ash10% + zirconia 10%) containing sample was having high tensile and hardness strength and the percentage elongation was decreased while comparing unreinforced alloy. **Vivekanandan.P [10]** the wastage of fly ash is utilized in MMCs at aluminium matrix is fabricated at stir casting method at different weight fraction (flyash 5%,10%,15%,20%). The 20% of flyash sample is got high hardness and decreased in frictional forces and wear rates. So they increasing of fly ash % that the hardness is increased.

3. EXPERIMENTAL WORK

3.1 Heat Sinks

In electronic systems, a heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. In computers, heat sinks are used to cool the PCB. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the basic device is insufficient to moderate its temperature. The heat sinks are found in all electronic and automation systems (i.e.) TV, DVD Player, Washing Machine, CPU…etc. The electronic equipments and systems containing large size heat sink is made by aluminium alloy material using casting process. Heat sink is majorly placed in the PCB`s (PRINTED CIRCUIT BOARDS) to reduce heat and cool the circuit boards with the help of fans. Heat sinks are the heat exchangers such as those used in refrigeration and air conditioning systems.

Fig – 2: Heat Sinks (Aluminium alloy)

Heat Sink Cutting process: The heat sinks are large sizes it is contains little amount in the crucible either it is cut a small pieces the crucible contains large amount of heat sinks.

Fig – 3: Heat Sink cutting Process

Table – 2: Chemical Composition of Aluminium alloy

Si	**Fe**	**Cu**	**Mn**
0.29%	0.073%	0.0002%	0.006%
Mg	**Zn**	**Ti**	**Cr**
0.49%	0.015%	0.019%	0.0002%
Ni	**Pb & Sn**	**Na**	**Ca**
0.0001%	0.002%	0.0002%	0.00003%
B	**Zr**	**V**	**Be**
0.0005%	0.0003%	0.002%	0.00004%
Sr	**Co**	**Cd**	**Sb**
0.00003%	0.006%	0.0003%	0.002%
Ga	**P**	**Li**	**Al**
0.008%	0.002%	0.00002%	**99.0%**

3.2 E-glass fibre

Fiber reinforced composite materials consist of fibers of high strength and modulus embedded in or bonded to a matrix with distinct interfaces between them. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. E-Glass or electrical grade glass was originally developed for standoff insulators for electrical wiring. It was later found to have excellent fibre forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as e-glass fibre.

Fig – 4: E-glass fibre

3.3 Flyash

Fly ash is a waste product from the combustion of pulverized coal in electricity power plants. Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Here are two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The Cao wt. % is less than 20% ash is called class f type fly ash and more than 20% ash is called class c type fly ash. The grain size of the fly ash was used in the composite is below 63 micron only.

Fig – 5: class F type and class C type fly ash

3.4 Stir Casting

Stir casting is a liquid state method of composite material fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The stir casting arrangements is shown in figure 6. It is effectively mixing the reinforcements with the matrix material (Al–alloy) and doesn't damaged the reinforcements while stirring.

Table – 3: Chemical composition of Fly ash

SiO_2	31.0%	MgO	2.8%
Al_2O_3	9.0%	Fe	5.7%
Fe_2O_3	8.15%	Na_2O	0.30%
CaO	**6.0%**	K_2O	0.20%

Fig – 6: Stir Casting Setup Arrangements

3.5 Composite Material composition

According to the following literature studies we prepared the composite materials samples at various wt. %. The composite material composition is shown in the table.4

Sample	Aluminium alloy (wt %)	E-glass Fibre (wt %)	Fly ash (wt %)
1	97%	3%	0%
2	94%	3%	3%
3	91%	3%	6%
4	88%	3%	9%

Table – 4: Chemical composition of Fly ash

3.6 Methodology

The following above literature studies we prepared the methodology of the metal matrix composites by using stir casting process. Shown in figure.7

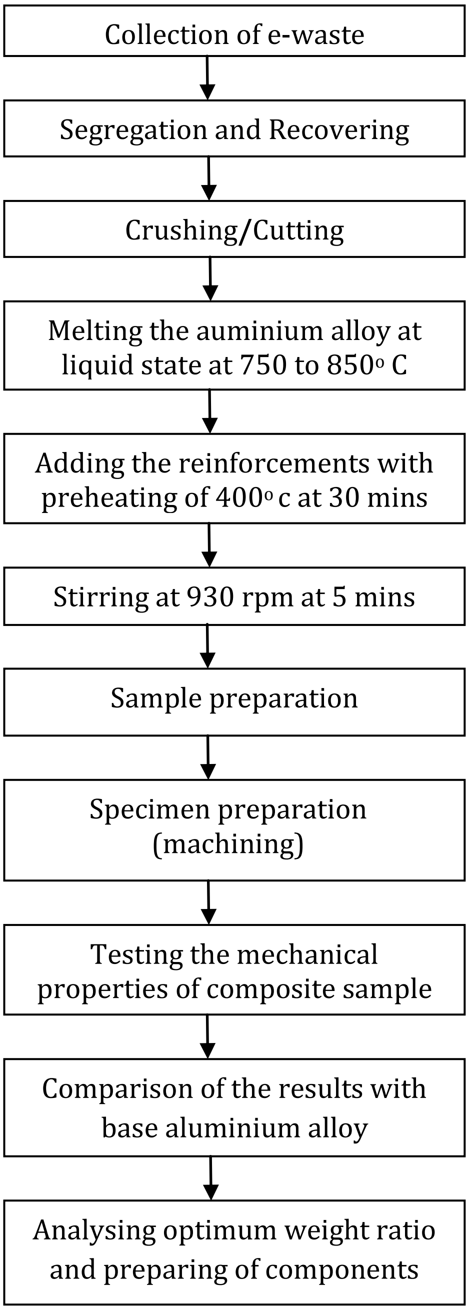


Fig – 7: Composite Materials Fabrication Process

4. FABRICATION WORK

The e-wasted heat sinks is collected at require amount in Kg and segregation, cutting, is a primary process of the experimental work. The secondary process of the project is the small pieces of heat sink is melted in stir casting furnace at 750ºC to 800ºC at 1 hr by crucible and the stirrer is set inside the melted aluminium and add the reinforcements e-glass fibre and fly ash was preheated in pre-heating furnace at 400ºC for 30 minutes. After adding the reinforcements with the degassing tablet powder (HEXACHLORA ETHANE TBLET) and stirrer is switch on rotated at 800 to 900 rpm at 5-7 minutes. After stirring it is lifted in to the furnace and crucible is take out in to the furnace and pouring in to the die and fabricate the composite materials samples this process is followed at remaining samples.

Fig – 8: fabrication of composite materials samples

5. RESULTS AND DISCUSSIONS

After completion of the fabrication work the composite samples are machined for preparing test specimens as per the ASTM standards and analyzed the mechanical properties such as tensile strength, yield strength, % elongation, compressive strength, hardness strength (BHN) and impact strength (CHARPY TEST). Is shown in figure.9 and the results are shown in table. 5

5.1 Tensile Strength

The tensile strength is an ability of the materials it is tested by UTM - 40 tonn capacity machine (universal Testing Machine). The test specimen is prepared by as per the ASTM E8M-13a dimension it is shown in figure 9. The tensile test is conducted at room temperature 28ºC. The tensile strength of the composite materials samples results is shown in chart–1.

5.2 Yield Strength

The yield strength is an ability of the materials it is tested during the tensile test the yield point is yield strength of the composite materials results it is shown in chart–2.

5.3 Percentage of Elongation

The percentage of elongation is also calculated during the tensile strength test process it is a ability of the materials elongated in the breaking point the percentage of elongation of the composite samples results is shown in chart–3.

5.4 Compressive Strength

The compressive strength is an ability of the materials it is used to analyze the compressibility of the materials. The compressive strength is conducted in UTM machine and the test specimen is prepared as per the ASTM-E9 standards. The compressive strength of the composite materials samples results is shown in chart–4.

5.7 Hardness strength

The hardness strength is an ability of the materials it is a hardness of the materials it is tested by hardness machine there are three types of hardness tester such as Brinell, Rockwell, and Vickers hardness. The test specimen is prepared as per the ASTM. In this project the Brinell hardness testing machine is used to analyze the hardness strength. The hardness strength of composite materials test results is shown in chart –5.

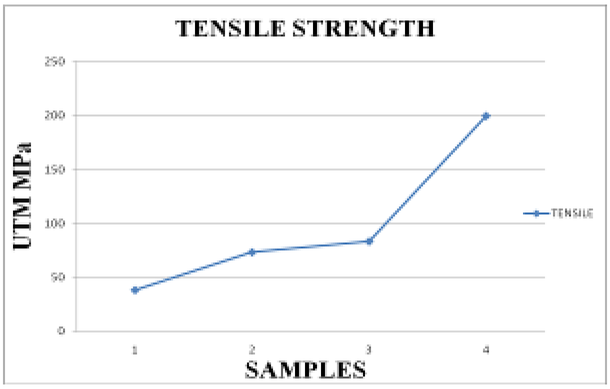
5.8 Impact Strength

The Impact strength is an ability of the materials it is used to analyze the toughness of the materials it is tested two types Charpy and Izod test. By this project the Charpy test is carried out in the impact testing machine with V-notch. The test specimen was prepared as per the standard dimensions. The impact strength of the composite materials samples result is shown in chart–6.

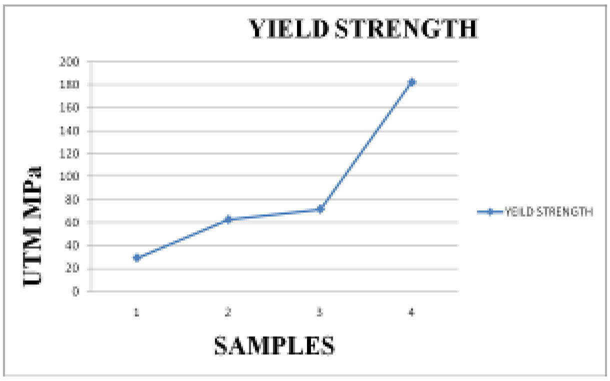
Fig – 9: Tested Specimens

Table – 5: Test results of the MMCs samples

SAMPLES	1	2	3	4
Tensile, (Mpa)	38.325	73.368	83.392	199.698
Yield, (Mpa)	29.099	62.579	71.682	182.55
Elongation (%)	1.10	2.53	2.20	3.40
Compressive (Mpa)	343.757	349.649	390.941	432.678
Hardness	57.5	71.3	62.8	79.3
Impact (J)	3.0	1.0	2.3	2.0



Chart–1: Tensile Strength test results



Chart–2: Yield Strength test results

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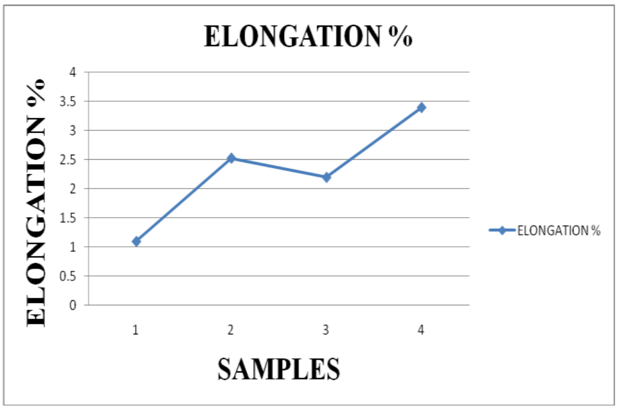
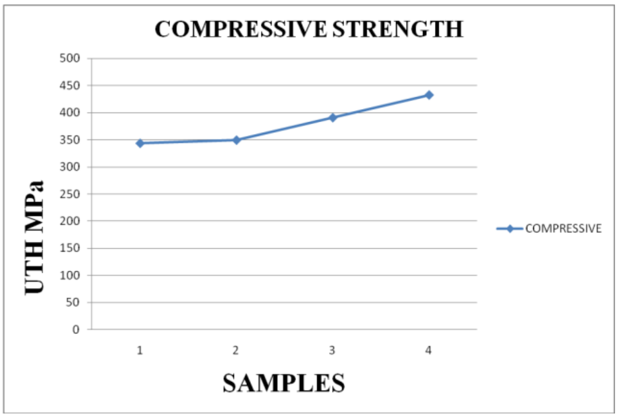
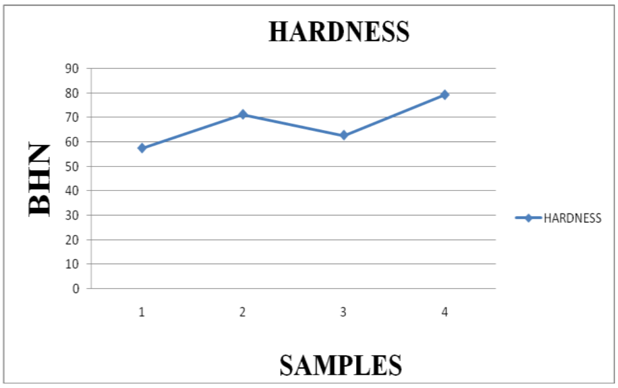


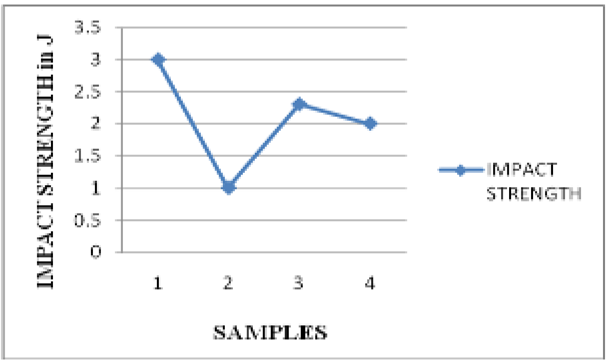
Chart–3: % of Elongation test results



Chart–4: Compressive Strength test results



Chart–5: Hardness Strength test results



Chart–6: Charpy test results

6. CONCLUSIONS

From the above practical and theoretical work we successfully fabricated the composite materials. The samples are analyzed the mechanical properties and all over discussed above sections. Now we concluded based on the test results the tensile strength, yield strength and compressive strength are increased gradually at all the four samples only the fly ash wt. % increasing. But the hardness and % elongation is increased up to the first and second sample after the third sample it is decreased and the fourth sample is increased while the percentage of fly ash increasing. The impact strength is different it's only increasing the first and third samples and second and fourth samples are decreased while the fly ash wt. % is increased finally the fourth sample is the optimum composite sample it will be use in the engineering application like machine components and aero space industry.

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