A Literature Review on Mechanical Properties of E- Waste Composites

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***Abstract* - E-waste accumulation has become a major concern for most of the environmental problems. The E-waste accumulation becomes an immediate environmental issue which can develop the human health hazards such as inflammation and oxidative stress precursor to cardiovascular diseases, cancer, skin diseases, and DNA damage etc. Recycling is the major way to dispose E-waste materials. Replacing the E-waste into the useful products is the major challenging process. Printed Circuit Board (PCB) which holds a majority share in E-waste is most hazardous when dumped into water, air and land. So we are in need to reuse or recycle the e-waste into some useful materials. In this paper, discussion about the recycling of Printed Circuit Board (PCB), Mechanical behavior of PCB with natural fibers, polymer matrices and also the combination of fibers with various materials along with various compositions are studied.**

Keywords- E-waste; Printed Circuit Board (PCB); Recycle;

I.INTRODUCTION

Electronic waste is also known as e-waste which is obtained from discarded electrical and electronic components or devices such as Mobile phones, Refrigerator, Computers, Compact disk, Printed circuit boards etc. E-waste is one of the fastest growing wastes in the world. In India, e-waste growth is increasing at the rate of 30% per annum. Most of the developed countries pull their e-waste into the developing waste like India due to the availability of cheap labour, absence of strict law and also due to the abrupt increase in the volume of e-waste. Because of this, the developing countries are facing critical issues like disposing of these wastes and also health hazardous to the human beings. To overcome this disposal problem, we are in need to reuse and recycle this waste into useful composite materials with various compositions.

Fibers: Fiber is a substance that is significantly longer than it is wide. Fibers are mostly used in manufacturing of other materials. The fiber may be natural or artificial/synthetic. In most of the engineering materials often incorporates fiber like carbon fiber, ultra-high molecular weight polyethylene.

Natural fiber

Natural fiber, raw material directly obtained from animal, vegetables or mineral sources and convertible into nonwoven fabrics such as feet or paper or after spinning the yarns into woven cloth. They can be classified based on their occurrence such as vegetable fiber, wood fiber, animal wood, mineral fiber, biological fiber.

Vegetable fiber: It is mainly based on arrangement of cellulose with lignin. Some of the examples of vegetable fibers are Jute, Cotton, Hemp, Banana, Flax etc. These fibers are employed in the manufacturing of papers and textile cloths.

Wood fiber: Wood fibers are naturally available in the cellulose elements of the tree. Woods are extracted from hard wood trees and soft wood trees. These fibers are mainly used for the manufacturing of paper. Wood fiber can be used as a composite with thermoplastics to leak proof, Outdoor furniture etc.

Animal fiber: This consists of proteins such as sea silk, spider silk, wool, fox, rabbit etc. These fibers can be used for textile clothes.

Mineral fiber: Mineral wood is also known as mineral fiber, mineral cotton, manmade mineral fiber etc. These fibers are formed by spinning or drawing molten minerals. These fibers are mostly used the thermal insulation, filtration, sound proofing and hydroponic growth medium.

Biological fiber: It consists of biologically relevant and biologically very important proteins, mutations or other genetics defeats. It can lead to diseases if it is used for applications.

Synthetic fiber:

Synthetic fibers are made from synthesized polymers or small molecules. They are mainly used for making clothes. The compounds that are used to make these fibers are taken from the raw materials such as petroleum based chemical or petrochemicals. These fibers may be synthetic or semisynthetic. Some of the semisynthetic fibers are rayon, which is made from natural polymers as a starting materials and the pure synthetic fibers like polyester, nylons, acrylics are purely made from chemicals.

II. LITERATUE REVIEW

Duan.Huabo et al. (2009) [1] Obtained TREPREG materials (PM) from waste printed circuit boards are used to produce polymetric composites with polypropylene (PP) as a bonding agent. This was produced by extrusion and injection process. It results in the increase of tensile strength, tensile modulus, flexural strength, and flexural modulus. The maximum amount of waste PM in polymetric composites was 30% wt, of which strength of tensile, flexural, impact could reach to 25.43 MPa, 48.30 MPa and 11.81 J/m respectively.

Ganeshkumar.A.G et al.[2] discussed about the recycle of e-waste aluminum hybrid metal matrix composite reinforced with e-waste fiber and fly ash to prepare a new composite material. The experimental result shows that these composites have improved properties such as high tensile strength, hardness, low density, high stiffness and excellent wear when compared to other metal alloy. The e-glass fiber purchased by them was of 2-3 mm. The average particle size of fly size was 2-4 microns. This paper indicates that the tensile strength and compressive strength of the material increases with the increase in wt% of fly ash and its hardness decreases with increases in wt% of fly ash.

Muniyandi et al. (2013) [3] investigated that the nonmetals which are extracted from waste printed circuit board are used as a filler materials recycled HDPE(rHDPE) in the production of rHDPE/PCB composites. A good balance in stiffness, strength and toughness was achieved for the system containing 30% wt PCB. MAPE as a compatibilizer was used to increase the interfacial adhesion between nonmetallic PCB and rHDPE. Addition of 6 phr MAPE increases the flexural strength, tensile strength and impact strength, and impact strength by 71%, 98%, and 44% compared to non compatibilized composites, while the thermal properties of these composites were decreased.

Wang, Xinjie et al. (2010) [4] studied about the use of non metallic powders obtained from the printed circuits boards with additives to polyvinyl chloride(PVC) subtract and also they investigate the physical properties of PCB with PVC is analysed. With the composition of NMPCB with PVC increase the toughness of PVC but vicat softening temperature of the materials is not that much increase as compared to pure PVC. A composite of 20% wt of NMPCB have a average size of 0.08 mm with 80% wt of PVC, have a 7% increase in tensile strength and 23% increase in bending strength compare to pure PVC and also small size 0.08 mm of NMPCB added with PVC slight increase in the vicat softening temperature, but large size of NMPCB added with PVC decreases the vicat softening temperature. The method used by them was moulding process.

Zhou,Yihui, Qiu, Keqiang (2010) [5] found that WPCB's have lot of valuable materials with plenty of hazardous materials materials. In this research the author recycles materials from WPCB in centrifugal separation & Vaccum pyrolysis for Recover both solder and organic materials present in WPCB. First of all, centrifugal separation is done for separating solder from WPCB at 240^{o}c and the drum rotates at a speed of 1400 rpm for 6 minutes. Then the vaccum pyrolysis is done, it seperates type A of WPCB without solders havig a 69.5 wt% residue, 27.8 wt% of oil and 2.7 wt % of gas and type B WPCB without solders having 75.7 wt% of residue, 20 wt% oil and 4.3 wt% gas. This pyrolysis residue contain various metals glass fiber and other inorganic materials which can restored by further processing, These oils can also be used as fuel and these gases can be collected and combusted for pyrolysis self sustain.

Zheng,Yanhong (2009) et Al [6] Investigated that the flexural strength and flexural modulus of the PP composites is increased by filling with nonmetals recycled from PCB's. Nonmetals of PCB mostly contain 50-70% of glass fiber which has high length diameter ratio, low elongation and high elastic modulus. So addition of this nonmetallic waste with plastics like polypropylene leads to increase the strength of plastics. Based on the test results, the flexural strength of nonmetallic WPCB /PP is increases with increase in percentage of nonmetallic PCB from 10 to 30%. The maximum increment of flexural strength and flexural modulus is 86.5% and 133.0% respectively. And binding of NMPCB/PP is done by 1% of coupling agent KH-550(ɣ-Amino propyltriethoxysilane). This composites are mixed in high speed mixture and extruded by screw extruder.

Zhu,P et al. (2012) [7] Studied the extraction and recovery of useful materials from WPCB by removing hazardous materials using Ionic liquid (1-ethyl-3-methylimizadolium tetrafluoroborate $[EMIM^+][BF^-_4]$). The separation of solders from WPCB by heating it into 240^{o}c when $[EMIM^+][BF^-_4]$ solution contained WPCB is used. And that solution again reheated to 260^{o}c for separating coppers and glass fibers from WPCB and then allowed to water treatment with the used $[EMIM^+][BF^-_4]$ solution to generate solid residues are separated by filtration. These solution is verified with FT-IR analysis for dissolving bromine epoxy resins and H.NMR analysis indicates that the hydrogen bond is responsible for dissolving bromine epoxy resins into $[EMIM^+][BF^-_4]$ .This solution can be regenerated by vaporized rotatably under the decompression of the solution.

Guo,Jie et al. (2009) [8] replaced wood flour in the wood plastic composite (WPC) by non metallic wastes from PCB. And they evaluate the durability property of WPC against weather conditions and also they investigate the effects of accelerated aging process on the properties of WPC. There test result shows that the filling of nonmetals obtained from PCB in wood plastic composite in the place of wood flour which increases the flexural strength and tensile strength and also reduces the screw withdrawal strength. The composition of this composite is 15% of nonmetals with WPC [H-15-WPC] undergoes aging process and it had a flexural strength of 25.8 MPa, tensile strength of 9.8MPa, a charpy impact strength of 3.4 KJ/sq.m and face/edge screw withdrawal strength of 121 or 115 N/mm. This test also shows decreases in flexural strength with the increase of accelerated aging cycles and their effects of aging in impact and tensile strength is minor. Above results of this paper shows that the strength of the WPC is increased if the wood flour is replaced by PCB's nonmetallic waste.

Guo, Jie et al. (2010) [9] discussed about the new kind of wood plastic composite was produced by combination of wood flour, recycled high polyethylene (HDPE), Waste Printed Circuit Boards (WPCB) and their additives. This study shows the combination of 40% of nonmetallic PCB with wood plastic composite by conical counter rotating twin screw extruder. This study results shows the flexural strength was 23.4 MPa, tensile strength was 9.6MPa , impact strength was 3.303J/sq.m and screw withdrawal strength was 1755 N. This composite was prepared by the following steps, First of all the mixture of nonmetals and wood was decomposed at 260^{o}c to 380^{o}c, then decomposition of HDPE was obtained at 440^{o}c to 500^{o}c.

Nestore,Olga et al. (2013) [10] discussed about the composite materials of LLDPE with waste textile fiber (Hemp). In this study they add upto 30 wt% of hemp fiber to the LLDPE which increase the tensile strength of the composite and also they add 10 wt% of filler material to that mixture which rapidly decreases the elongation nature at the break point. The hemp fiber influences the physical and mechanical properties of LLDPE was somewhat as predicted. The highest values of strength(both tensile and bending) was obtained in this composition of length upto 1mm, then the metal flow index of the LLPDE matrix with fiber (LLPDE with hemp fiber of 30 wt%) was decreased (from 4.4dg/min for LLPDE to 0.05-0.14 dg/min) . And further process of this component was done by manual method like extrusion.

Sapuan, S.M et al. (2003) [11] investigated about the tensile and flexural properties of composite which consist of coconut shell filler particle and epoxy resin. In this composite they used to study three different composition (viz:5%,10%,15%) of coconut shell fiber with epoxy resin. The size of the coconut shell filler particle was 50 to 200 µm in diameter which has a density of 1.60g/cm^{2}and it is mixed with epoxy resin 3554A having a density of 1.15g/cm^2. The result shows that the tensile and flexural properties of composites were increased with the increase in percentage of coconut shell filler particle.

Agunsoye, J Olumuyiwa et al. (2012) [12] studied the effect of using 5% -25% of volume fraction of coconut shell particle in the low density polyethylene matrix and they also observed that the mechanical and morphological properties of coconut shell reinforced polyethylene composite. They prepared the composite by mixing five different compositions of coconut shell particle (5% to 25%) with LDPE. They were blended together in two roll rheomixture with rotating speed of 60 rpm at 50^{o}c. Then the result shows that the hardness of the composite increases with the increase in coconut shell content in that matrix, but their modulus of rigidity, ductility, tensile strength and impact energy are decreases with increase in coconut shell content in the composites. The Scanning Electron Microscopy (SEM) of the composite shows that there is a poor interfacial bonding between coconut shell particle and low density polypropylene matrix.

Kumar, G Ganesh et al. (2016) [13] investigated the huge quantity of e-waste produced every year because of fast growing technologies in the world. So they tried to reuse the waste in useful form (ie) safety helmet. Especially they focused on their for the transformation of discarded PCB into required light weight safety helmet. This helmet was made up of carbon fiber, PCB powder of 80 micron size and epoxy resin as a bonding agent. Based on these materials, they made three test specimens of different compositions such as 48% carbon & 52% PCB ,50% carbon & 50% PCB and 52% carbon &48% PCB. These specimens are made by hand layup process. The mechanical properties were tested on these specimens and their results shows that the third specimen(52% carbon & 48%PCB) had more tensile strength, flexural strength, impact strength and shear strength when compared to other two specimens. The flexural strength of 48% carbon & 52%PCB and 52% carbon & 48% PCB are obtained to be the same. Based on their results they used third composite specimen (52% carbon & 48% PCB) for making of safety helmet with the help of compression moulding process.

Xing,Mingfei., Zhang,Fu-Shen (2013) [14] studied the degradation of brominated epoxy resin present in the WPCB and metal recovery from residue. Both the process occurred at the same time with the help of sub/supercritical water treatment method. In this method they tested the 10 gram of WPCB kept in batch type reactor with 30-40 ml of water at 200^{o}c to 400^{o}c for 30-240 minutes. During this time the brominated epoxy resin could be decomposed under sub/supercritical water condition and bromination rate was 97.8% which can be controlled by adding 40 ml of water in it at 400^{o}c for 130 minutes. Then their result shows that the bromine was completely changed into HBr and balance 97.7% of water was released and also some main components such as phenol (58.5%) and 4-(1-methylethyl)-phenol (21.7%) was obtained. After the water treatment, the residue of glass fiber and copper foil is precipitated. Further these residue can be crushed by high speed universal crusher for separating metals.

Salmah, H et al. (2013) [15] found that there is a improvement in the properties of the coconut shell powder (CSP) when it is combined with poly lactic acid (PLA) bio composites. The CSP/PLA bio composites was prepared by using plastograph mixer at 180^{o}c with rotor speed of 50 rpm. The average particle size of CSP was 38 µm which is dried at 80^{o}c for 24 hours and the time taken for the mixing of bio composites was 8 minutes and then the mixture is compressed for 1 minutes with preheating of 180^{o}c and subsequent cooling under pressure for 5 minutes. With this combination tensile strength was decreased and have low elongation at break, but the modulus of elasticity was increased. When the treated PLA/CSP bio composite is added with acrylic acid, tensile strength and modulus of elasticity was increased but lower elongation at break. The

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thermal stability of the composite is increased when compared to untreated bio composite. The Scanning Electron Microscopy (SEM) shows that there is a strong interfacial bonding between the CSP/PLA matrix.

Singh,Alok et al. (2013) [16] observed the properties of polymer matrix composite using coconut shell powder in different composition. The different weight percentages of coconut shell powder such as 20%, 30%, and 40% with material matrix having epoxy resin and hardener in the ratio of 5:4. This mixture is moulded into mould cavity at room temperature for 24 hours without any air bubbles and the result shows that the maximum tensile strength of the composite is obtained by having 20% of CSP and the maximum flexural strength of the composite is obtained with 30% of CSP. The density of the composite is maximum between 30% and 40% of CSP and less water absorption capacity of the composite is agreed with 20% of CSP. So the overall result shows that the optimum percentage of CSP for polymer matrix composite was 20% to 30% and it is applicable in the field of automobile and the interior parts of aircraft.

Pradhan, Siddhartha K et al. (2004) [17] observed that the strength of the composite materials remained tough when the content of CSP was 20-30 vol% which was observed by notch impact test & fractography studies, but the compressive strength of Ultra High Molecular Weight Polyethylene – Coconut Shell Powder (UHMWPE-CSP) composite decreased rapidly beyond 20 vol% CSP. This composite was prepared with polymer matrix using coconut shell powder as a filler material. They obtained the properties of the composite with different volume fraction of CSP such as 20%, 30% & 40%. These combinations were taken in a plastic jar of 300 cm^3 and is rotated for 10 hours in a ball mill for the efficient blending. The typical processing temperature, load and total time were 200^{o}c, 2 metric tons and 5-6 hours respectively.

Yazici,EY.,Deveci,H [18] used to investigate the extraction of nonmetals from WPCB by using sulphate solution and chloride solution in two forms such as presence and absence of Mno_2, usually WPCB contained 86 g/t Au, 694 g/t Ag, 97 g/t Pd and 18.5% Cu. In chloride test the chloride solution (1 M Hcl,1 % W?N solids, 80^{o}c, 47 g/L cl^-)used for extraction of metals from WPCB. The presence of Mno_2(10g/L) for 120 minutes leads to improvement in leach performance of Cu present in WPCB compared with negligible extraction of copper(ie <=1.4%) for 30 minutes with absence of Mno_2. The copper of 14.7% is obtained over a period of 120 minutes. But addition of Mno_2 does not affect the extraction rate of precious metal (Au, Ag, Pd). In Fluoride test, the fluoride solution (1.2 M H_2So_4, 80^{o}c, 5% W/V solids and 2L Mno_2) are used for extraction of metal. The presence of $NaNo_2$ for 60 minutes lead to improvement in extraction of copper from 28.2% to 67% but no significant improvement in extraction of precious metals compared to absence of $NaNo_2$. Thus the results obtained from chloride and fluoride test suggest the presence of Mno_2 and $NaNo_2$ respectively leads to significant amount of extraction of copper from WPCB.

Tomczak, Fabio et al. (2007) [19] investigated the effect of change in diameter and change in length of fiber affects, the properties such as stress strain curves, tensile properties and thermal behavior. In this study, they used a coconut fiber of defect density 1106 Mp/m^3 and fiber exhibits crystallinility at 22^{o}c wit crystallinity index of 57%. Their test results suggests, the tensile strength decreases from 275 MPa to 50MPa, young modulus decreases from 3.6GPa to 1.2GPa and % strain at break is constant about 30, when the diameter is increased from 0.040 mm to 0.40 mm. And also suggests increasing length of the fiber from 5mm to 25 mm effects the young modulus increases from 1.27 GPa to 2.7GPa, the tensile strength decreases from 142.6 MPa to 118.3MPa and strain at break decreases from 23.8% to 12.5%. Then their results are discussed in the form of X-ray diffraction and microscopic observation.

Raghavendra,SN et al. (2006) [20] investigated the grinding characteristics and hydration properties of coconut residue based on the calculation of work index, Bond's constant, Kick's constant and Rittinger's constant. In this research they used to study about the disintegrated coconut grating (residue) which is obtained from coconut after the extrusion of milk. Then the taken sample of coconut residue undergoes a hexane treatment for 9 hours to remove hexane and kept in a solvent extracter to remove fat, then kept in hot air for 3 hours at 55^{o}c. The hexane removed removed residue undergoes grinding operation to obtain different particle size and it is separated based on size. The hydration properties of coconut residue of different particle size was studied and then absorption property can be studied by mixing the residue particles in water and centrifuged at 10000 rpm for 30 minutes. Then the grinding characteristic study result shows that, the grinding operation results in honey comb physical structure and resulted in a flat ribbon type structure and by providing higher surface area for fat and water absorption. The hydration property varies with particle size variation and then there is a decrease in particle size upto 550µm resulted in high hydration property, below that size the hydration property id decreased. Finally small size particle has high fat absorption because of increase in theoretical surface area, structural modification and increase in pore volume.

III.CONCLUSION

From the research discussed, it is clear that e-waste and fibers are suitable for various engineering applications. The e-waste materials from domestic applications like Refrigerators, Televisions, Mobile phones, IT products like Computers, PVC cables, LED's etc and fibers like waste coconut husk fiber, carbon fiber, wood fiber are used for the replacement of common plastics. Based on the study of various research papers, the e-waste and fibers have various physical and mechanical properties in various combinations. Depending upon the properties of composite, we can reuse that material for various applications. As disposal of waste is a major problem in the today's world due to limited landfill space as well as hazardous to human health by utilization of waste in various engineering applications.

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