Materials Physics and Mechanics 47 (2021) 896-904
Research article

Received: May 11, 2021
Accepted: November 22, 2021

STUDY OF MECHANICAL PROPERTIES OF COPPER SLAG REINFORCED PARTICULATE POLYMER COMPOSITE

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Abstract. Copper slag is one of the by-products that is extracted from the copper waste, during the smelting process. It is an environmentally friendly material that also, has some industrial benefits too. The composite prepared using this copper slag improves the mechanical strength of the products. From this, an idea to promote over some of the waste to enhance the strength of the composite for effective mechanical applications. In this paper, the tensile, flexural, and impact mechanical strength of the copper (Cu) slag powder in different weight percentages as 5wt. %, 10wt. %, 15wt. %, and 20wt. % were analyzed. The composites were fabricated with hand layup techniques. The mechanical properties of the composites were tested using the universal testing machine for tensile and flexural tests and Izod impact tester for an impact study. These results show the different mechanical behaviours of the varying copper weight percentage in the composites was observed with enhanced mechanical properties. SEM analysis gives information about the poor bonding, micropores, and lack of copper inclusion in the various weight percentage copper slag reinforced in the polyester composite.

Keywords: copper slag, polyester resin, particulate composite, mechanical properties, SEM morphology.

***Acknowledgements**. No external funding was received for this study.*

Citation: Arunprasath K., Amuthakkannan P., Manikandan V., Kavitha S., Radhkrishnan B. Study of mechanical properties of copper slag reinforced particulate polymer composite // Materials Physics and Mechanics. 2021, V. 47. N. 6. P. 896-904. DOI: 10.18149/MPM.4762021_9.

1. Introduction

The exploitation of industrial and agricultural waste materials for the improvement of Polymer matrix composites, providing through a well-judged analysis of a sample and varied references source from the oldest to the newest ones an approaching into the challenges and opportunities for the exploitation to their full potential uses. The apposite use of industrial and agricultural waste materials entails acquaintance generation as a qualification for incubation of pilot-plant and industrialization stages, culminating with all related benefits to humanity.

http://dx.doi.org/10.18149/MPM.4762021_9

There is no longer introduction which is not incorporate the success and failures of fabricated polymer samples to the analysis of various testing's and their form of application-oriented outputs. This research mainly initiates the conversion of waste into some useful things the wide choice of materials, today's engineers are posed with a big challenge for the right selection of a material and as well as the right selection of a manufacturing process for an application. Powered reinforced composites are a relatively new material among all the engineering materials. This can use in the field of mechanical, automobile, aerospace, and some other engineering applications due to its property resistance and its considerable inflexibility. One of the most important criteria is forged ability by which the workability of the material can be unwavering. The scenery of distribution of reinforcing phase in the matrix greatly influenced the properties of Particulate Composites. The consequence of the isolated particles on the composite properties depends on the particles dimensions of large dispersed phase particles have a low strengthening effect but they are capable to share load applied to the material, resulting in an increase of stiffness and decrease of ductility. Two important mechanical properties of any resin system are its mechanical properties. It must be understood that the adhesive properties of a resin system are important in achieving the full mechanical properties of a composite. The sticking together of the particulate reinforcement is used as a core material in squash in construction is important also used as additional material for some of the application and daily used products. This literature investigation is a collection of ideas and exposes the wide knowledge with the proposal of our work initiation with these references of reputed international journals related with our work by the preparation of metal matrix composites from agricultural and industrial wastes like aluminum with reinforced fly ash, Si, Ni, Cu with reinforced bamboo, red mud, and eggshell. The composite is prepared by ultrasonic cavitation technique and the morphological structure is analyzed by using scanning electron microscopy (SEM). A mixture of copper with steel aramid fibers and cellulose fi-Bers-Graphite, antimony sulfide, coke, barium sulfate, potassium feldspar, chromium iron mine, and various other particles. Shows better hardness value which is measured using a plastic Rockwell hardness instrument and the value is 63.6 HRL. The impact strength of the copper slag reinforced composite was measured using an impact tester and the result is 3.59(kJ/m^2) and the density is 2.35(g/cm^3), while compared to other combinations this shows some good results [1].

Zhanhong Wang et al. [2] reported that the matrix form of Epoxy Urea formaldehyde waste is a matrix material and the composite is prepared by compression moulding method. The bending stress and bending modulus are defined by using a universal testing machine and the values are 106MPa and 2.13GPa, these results show that incorporation of filler copper slag is responsible for these types of observation. Nurcan Calis Acikbas et al. [3] discussed the composite of coir fiber and Alumina fiber composite, the composite preparation is with conventional hand layup technique. The surface morphology is done by SEM. Epoxy (85 wt.%)/ Coir fiber (3 mm)/ (5 wt.%)/ Al_2O_3 (10 wt.%) after the addition of filler material in the composite increases the mechanical properties. Geetanjali Das et al. [4] prepared a composite with nylon, aluminium reinforced with aluminum oxide composite is produced by stir casting techniques. Then, the experimentation was done on thermal analysis by using TGA (thermogravimetric analysis) and the result is 460c.K.S, this better output is obtained after the addition of 5 wt. %copper slag in the composite.

Boparai et al. [5] study electrical resistivity and conductivity of the metal matrix composite of copper and titanium alloy with different proportions. The values are 1.562×10^{-7}[Ω. m] and 640×10^{-7}[Ω. m] respectively, the changes in the conductivity of the composite are observed after the incorporation of copper slag in the composite. Burdzik et al. [6] did research on geopolymer and silicon carbide composites. The samples are taken in three different ratios and their XRD and thermal conductivity show the presence of pyrene material in the geopolymer increases the 35 % strength of the composite. Fei-Peng Du et al. [7] studied the composite of Aluminum MMC composites is reinforced with ceramic/ stainless steel/ 30 wt. % of copper slag. The improved mechanical results were noted. Especially, the tensile strength, porosity, surface morphology, and hardness properties are excellent in this composite.

Shirvanimoghaddam [8] et al. studied, the composite of Acicular ferrite (AF) and steel of MMC. The impact toughness is calculated from the specimen and the average values tabulated in that result, the SEM shows the morphology of failure that occurs through the uneven application of load [9]. In fiber-reinforced polymer composite, the hand layup technique is used to prepare the composite very easily. The mechanical results obtained through this fabrication technique, also very good compared to the vacuum bag technique [9,10].

A composite of aluminum with fly ash, clay graphite composite is used and the impact, hardness was tabulated as per the ASTM. The values are 92BHN and 103KN after the addition of powdered fly ash the improved mechanical properties were noted [11]. In the mixture of fly ash and epoxy of different concentrations, the addition of the various percentage of fly ash particles supports the reinforcement with the epoxy matrix. The composite manufacturing from industrial and agricultural waste like aluminum, silicon, copper slag. Agricultural wastes like eggshell, and red mud always performs well in different mechanical loading conditions, and morphology is evaluated using SEM [12]. Bahramia et al. [13] said that particle reinforced polymer composites with copper slag is reinforced with polypropylene have better mechanical properties. After the addition of copper slag in the composite responses for these kinds of interventions.

The copper slag particle reinforced with polymer composite shows enhanced mechanical properties, and the application of these composite products is also utilized for many applications to get very good performance [14,15]. From the literature evidence, the enhanced mechanical properties are noted for waste powdered materials used in different applications and this research work focus on the study of the mechanical properties of various weight percentage of copper slag reinforced with polyester matrices. And SEM (Scanning Electron Microscopy) was used to study the morphology of the mechanical properties.

2. Materials and Methods

In this research work, the copper slag is obtained from a renowned copper extraction company in Tamilnadu, India. Polyester resin is purchased from Vasavibala resins, Chennai. Various percentages of copper slag are used as a reinforcement material and polyester resin as a matrix material. The composite preparation is done using the hand layup method with the square mold in the dimension of (200mm×200mm). The matrix material (polyester matrix) is 500ml constant throughout the composite fabrication with the varying weight percentage of copper slag. Table 1 represents the various percentage of copper slag content and their specimen code.

Table. 1 Percentage of copper (Cu) Slag and its composite code

S. No	Weight Percentage Cu-slag (wt. %)	Polyester Resin (ml)	Specimen code
1	0	500	S1
2	5	500	S2
3	10	500	S3
4	15	500	S4
5	20	500	S5

3. Result and Discussion

Tensile strength. Tensile Strength is the resistance of a material to breaking under tension and this evaluation helps to study the axial load acting on the prepared composite material using copper slag. In this research work, tensile specimens are prepared with the ASTM D638 and with the dimension of (165×13×3mm). The test is performed in a universal tensile tester machine and an average of five trials of results are used to study all the mechanical behaviours of the various percentage of copper slag polyester composites. The tensile strength comparison graph is shown in Fig. 1.

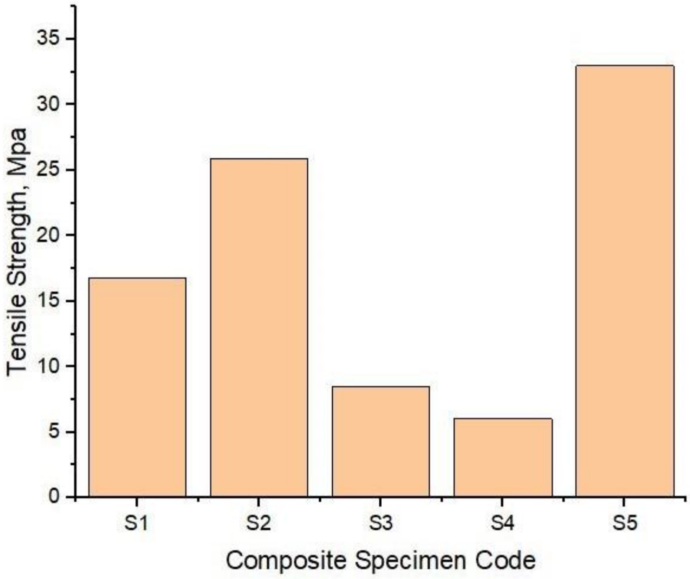

Fig. 1. Tensile strength comparison of various weight percentages of Cu-slag

The specimens of different weight percentage show different values. The 0 wt. % Cu-slag given 16.75MPa of tensile strength, for 5 wt. %, 10 wt. %, 15 wt. %, 20 wt. % the values are differing slightly 25.84Mpa, 8.4994Mpa, 6.03Mpa and 32.98Mpa. The tensile strength difference between 0 and 5 wt. % specimens are nearer to 9 MPa like that the difference between 5wt. % and 10 wt. % are 17 MPa but the difference between the next two concentrations is 2MPa, finally the difference between the 15 wt. % and 20 wt. % Cu content specimens are nearly 26MPa the maximum tensile strength is attained by 20 wt. % of Cu-slag content. Figure 2 shows the specimen before and after the examination of the tensile test. Enhanced tensile strength is seen after the mixing of more weight percentage (20 wt. %) of copper slag in the composite. This result shows that increasing the weight percentage of copper slag improves the bonding nature between the copper slag and matrices [16]. And this bonding act as a very good interface between the reinforcement and matrix for better behaviour of the composite, during the tensile condition of axial pull.

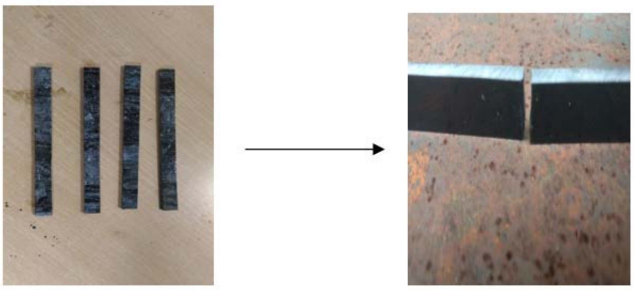

Fig. 2. Before and after tensile tested specimen

Flexural Strength. Stress at failure in three-point bending represents the maximum yield of the composites. The flexural strength of the Cu-slag composite represents the significance of copper slag in mechanical properties. The specimen is prepared for the flexural test with respected to the ASTM D790 standard and followed by the dimension as (127×13×3mm). The test is carried out using a three-point bending fixture in the universal testing machine. The prepared specimens are tested for flexural and the values are started from 205 MPa for 0 wt. % Cu-slag by comparing with 5 wt. % values are larger. On comparing with 10 wt. % Cu the value is increases and the value slightly increases. The difference of 30 MPa in between 0 wt. % and 5 wt. % of Cu samples for the next two the difference is similarly 30MPa but the difference between 10 wt. % and 15 wt. % contents are nearly 60 MPa the 20 wt. % specimen is 40MPa lesser than 15 wt. % specimen 15 wt. % has better strength than others.

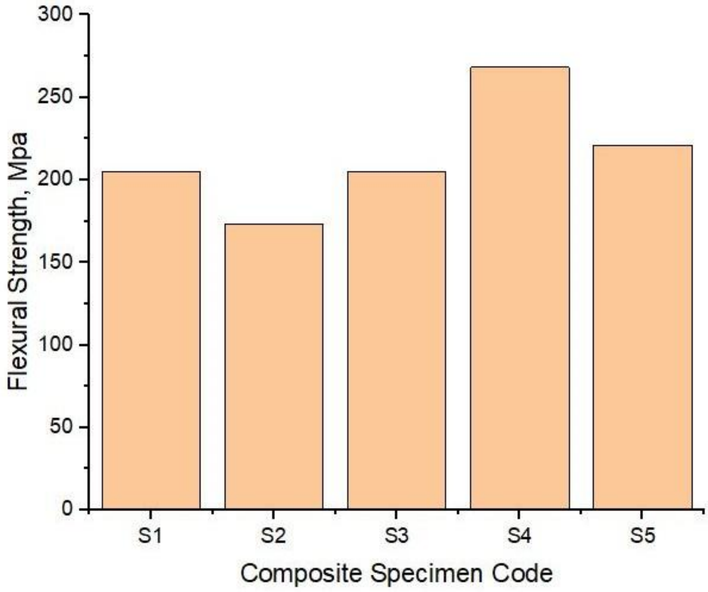

Fig. 3. Tensile strength comparison of various weight percentages of Cu-slag

Figure 3 shows the tensile strength comparison of various weight percentages of Cu-slag. The flexural study of the varying percentage of copper slag composites shows the workability of copper slag in the matrices is good. The powder (Cu-slag) dispersion is very excellent, which is responsible for the improved results of the flexural test. The higher weight percentage of copper slag shows a reduction in the flexural strength is noted, this represents the poor build quality of copper slag in less curing time. In the particle dispersion method, the build quality behaviour of the particle decides the strength of the composite [17]. Figure 4 represents the specimens before and after examination of the flexural test.

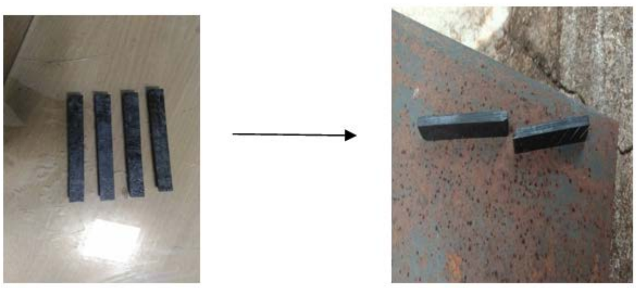

Fig. 4. Before and after flexural tested specimen

Impact Strength. The geo-polymers (Cu-slag) have excellent capability of the material to withstand a suddenly applied load with higher energy absorption [18]. The impact specimen is prepared with respect to ASTM D256 and the dimension of (60×13×3mm). The Izod impact tester is used to study the impact responses of the chosen composite. Figure 5 represents the impact strength comparison of copper slag polyester composites.

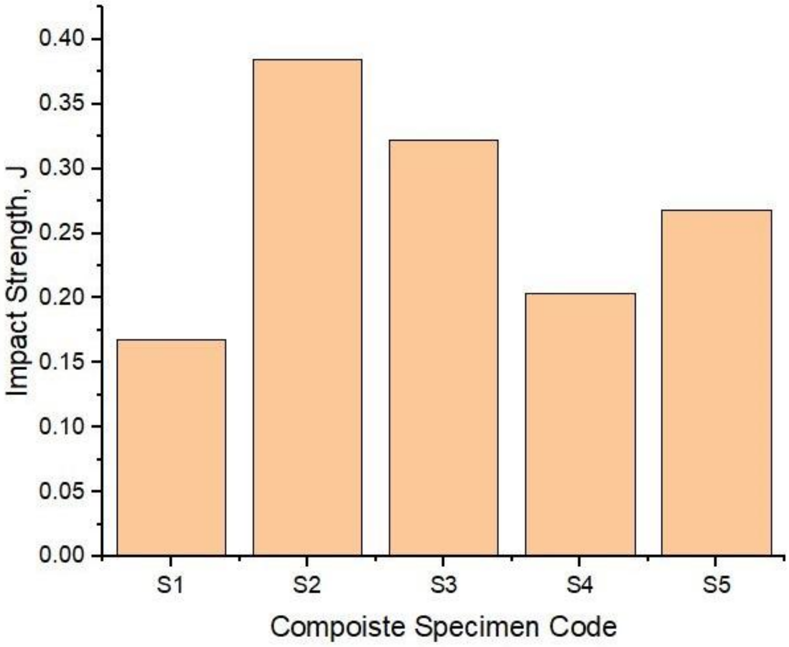

Fig. 5. Impact strength comparison of various weight percentages of Cu-slag

The Collected specimens are tested for impact test and the specimens load condition values are taken for the discussion. The 20 wt. % of Cu-Slag breaks at 0.268J of load but 15 wt. % of Cu-Slag breaks at 0.204 after it the values of 10 wt. % and 5 wt. % are slight increases but for 0 wt. % the load will be stable for only 0.168J the 0 wt. % Ccu-slag is 0.200J differ than 5 wt. % Cu-Slag. But the difference between the next two specimens is 0.60J the peak of the load is acting on 5% Cu-Slag sample and the difference between 10 wt. % and 15 wt. % samples are 0.120J. The final two specimen readings are differing by 0.60J the maximum impact load act on 5 wt. % of copper slag content. The effect of the impact study shows the pro-active function of the powder material in the time of applying sudden loading conditions. The aggregation of copper slag in the polyester resin improves the energy absorbing capability of the composite [19]. This may happen at any time after the happening of the impact event. This type of observation is fully depending on the quality of dispersion ratio and ambient temperature at the time of composite preparation. Figure 6 represents the before and after happening of the impact test.

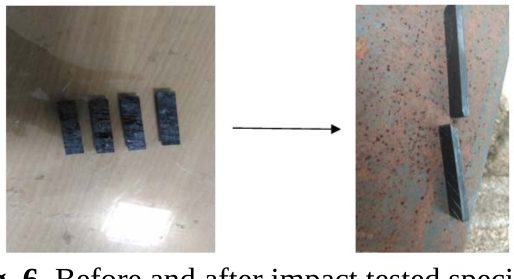

Fig. 6. Before and after impact tested specimen

SEM Morphology of Mechanical Properties. Scanning electron microscope images of (20 wt. %, 15 wt. %, 0.5 wt. % Cu-slag) of tensile, flexural and impact tested specimen shown in Fig. 7(a),(b), and (c). The better binding of copper slag with polyester matrices shows better mechanical results [20]. The SEM image on Fig. 7(a) shows the tensile specimen of 20 wt. % of copper slag polyester composite.

Form that, SEM image of Fig. 7 the poor bonding is noted. This poor bonding in the particulate composite represents the lack of mixing, during the preparation of the composite. Micropores are one of the weaker symptoms which represents the lack of interconnection between the reinforcement Cu-slag and polyester matrices [21], this was observed for 15 wt. % of the flexural tested specimen from Fig. 7(b).

Occupancy of copper slag in the surface area of the composite is very less, the increased surface area reduces the inclusion of the copper slag in the composite [22]. For achieving better bonding strength, the role of copper inclusion is very essential. Figure 7(c) shows the lack of copper inclusion in the 0.5 wt. % of copper slag in the impact tested specimen.

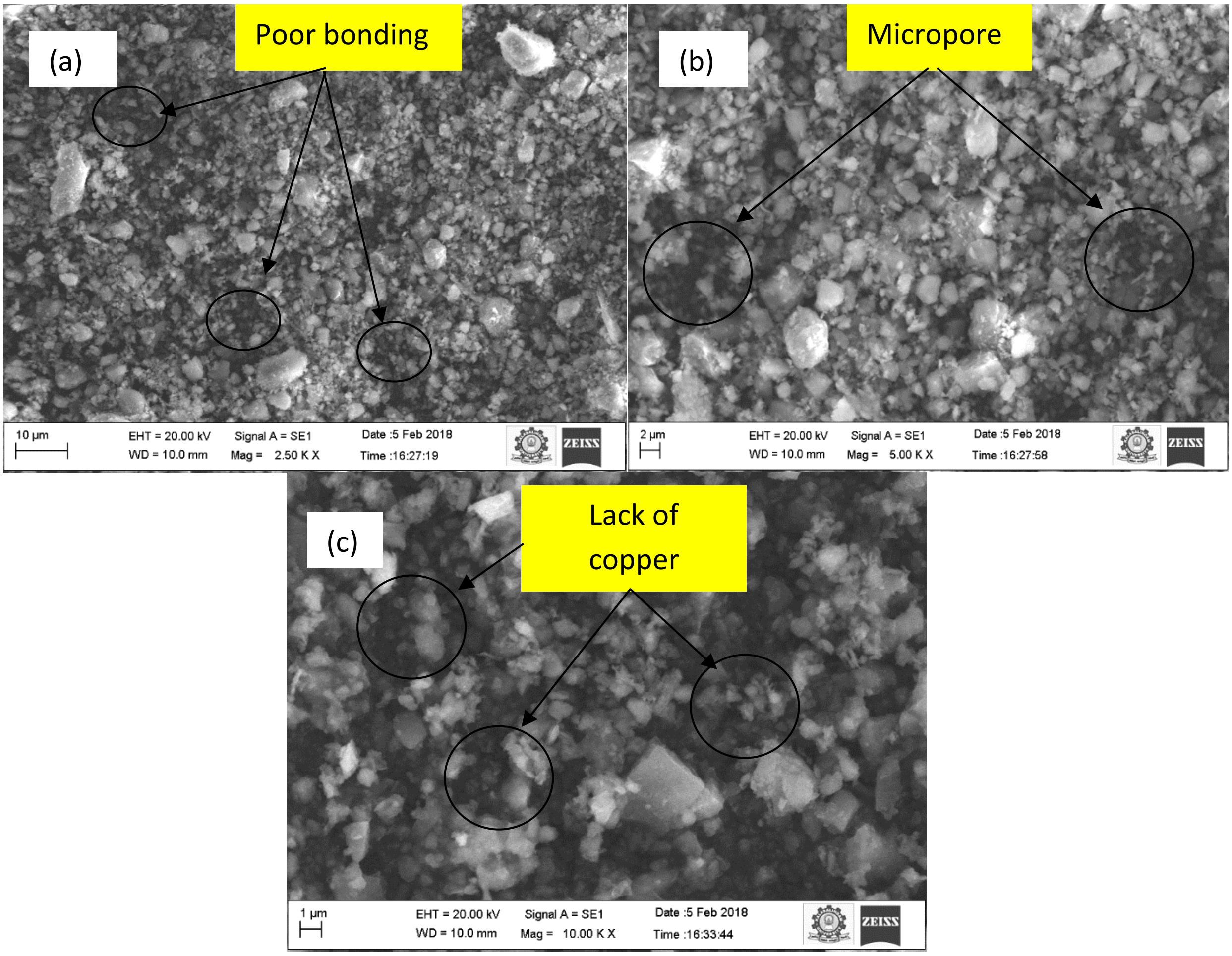

Fig. 7. (a) Tensile specimens of 20 wt. % of copper slag, 7 (b) Flexural specimens of 15 wt. % of copper slag, 7 (c) Impact specimens of 0.5 wt. % of copper slag

4. Conclusion

From the literature studies and the experimental analysis of mechanical properties of Cu-slag with various weight percentages were studied and the results are shown below,

1) The Tensile strength of 20 wt. % of Cu-slag content shows better results about 32.98MPa, compared to other combinations of copper slag with varying weight percentages.

2) The flexural strength of 15 wt. % of copper slag content shows better results and withstand the maximum bending of about 268MPa.
3) In the impact strength the better result is seen for 0. 5 wt. % of Cu-slag about 0.384J which shows the very good aggregation of copper slag in the matrices is the reason for this kind of observation.
4) SEM analysis of (20 wt. % of copper slag of tensile strength, 15 wt. % of copper slag of flexural strength, and 0. 5 wt. % of Cu-slag of impact strength) results reported with poor bonding, micropores, and lack of copper inclusion.

An overall observation of this study, represents the utilization of copper slag an industrial waste for useful mechanical applications. This research work act as a bridge to enhance the work in the area of waste to energy or to make any useful products to this environment to create a sustainable development of products from waste materials.

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