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Preparation and characterization of plastic wood from cellulosic residues

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Abstract
In this study, crop residues from rice husks were used to enhance the properties of the prepared wood-plastic composites (W.P.C) are made from epoxy (EP) and unsaturated polyester (UPE) at a ratio of (50:50) and reinforced with scales in different proportions, both types are fine (300µm≤) and coarse (300µm>). These blends were undergoing (wear, impact, hardness, differential scanning calorimetry (DSC), and thermal conductivity) tests and the results showed the best weight fraction. is the fine particle weight fraction at 25% and coarse at 15%, depending on the studied tribological characteristics. The results showed by thermal properties of glass transition temperatures (Tg). For each of the (EP,UP, and50:50 blend), and it notices that the thermal conductivity (K) of Ep recorded high values of up to (0.198) W/m̊.k, while it recorded the lowest thermal conductivity of UP before the blend is (0.17) W/m̊.k, as for the blend (50-50) the thermal conductivity is (0.19) W/m̊.k, The thermal conductivity of the blend is slightly lower than that of EP alone.

Keywords: plastic wood, Epoxy/Polyester blend, Rice Husks, Hardness.

1.Introduction.

Agriculture has a high economic value, especially in countries that have few forests, where Iraq annually produces millions of tons of agricultural crops, including grains, vegetables, and others, wood has become the most widely used in strengthening polymers as natural reinforcement composites in many applications. This is due to its relatively low cost, improved mechanical properties, and lightweight, recyclable, and environmentally friendly advantages [1]. Environmentally friendly polymeric composites supported by sustainable natural materials have received great attention during the recent period due to the appropriate costs and increasing environmental awareness. As wood has become the most widely used in strengthening polymers as natural reinforcement composites in many applications in the construction, transportation, and packaging sectors [2-3]. As a result of the increase in costly manufacturing processes for wood composites, much lower cost and sustainable alternatives such as agricultural waste have been attracted [2, 4].

In (2014) Nasser studied a composite material reinforced with nacre husk and rice straw for polypropylene, and showed results of the wear test using (pin on disc) with different operating conditions of lubricating or wetting the sample with water are presented. It was found that the best performance is for the shell-reinforced composite, followed by the rice straw-reinforced composite, while pure polypropylene has the highest wear rate, that is, adding cementing powders reduces the wear rate and the coefficient of friction [5].

In (2015) Qasem et al studied prepared polypropylene composites reinforced with agricultural residues (rice husks) by weight (56%), in addition to other additives that did not exceed 7%. The mechanical properties were studied, which included (surface hardness, compressive strength, impact resistance, tensile and flexural stress). The results showed that there was an improvement in the mechanical properties of the samples prepared with a particle size [>300μm] [6].

In (2018) Rola et al studied the characterization of the topological behavior of some agricultural waste after conversion to plastic flooring in dry and wet operating conditions in a way that leads to a change in its topological properties, which are wear resistance and hardness [7].

In (2020) Raya et al studied the influence of wood minutes reed on some physical characteristics of (EP+W) composites It is prepared by the casting method. Some mechanical properties were investigated and included (tensile strength, curvature and creep) and the largest number of results Increase bending resistance and flexibility Reinforcement of epoxy with wood particles [1].

In (2020) Raya et al studied some of the mechanical Properties of wood-Plastic Composites and all mechanical properties have been improved [8].

The aim of this research is an attempt to benefit from cellulosic residues by recycling and making plastic wood that is environmentally friendly and useful in our daily lives. There is an urgent need in society to reduce the effects of wood waste and sustainable cellulosic agricultural waste and protect the environment from it.

2. Materials and Methods

Steps for preparing the research samples:

1. In the study, agricultural residues were used as cellulose reinforcement materials represented by rice husks, whose scientific name is (Oryza Sativum), and these materials consist mainly of cellulose and lignin and contain hydroxyl groups. At first, the rice husks were treated with asodium chloride solution for 2 hours . Then the fibrous material is immersed in the permanganate solution for 5 minutes, then washed with water and air-dried. The goal here is to create radical sites in the cellulose that increase its effectiveness with the polymeric substrate, as the high activity of the permanganate ions facilitates the process of grafting the polymeric substrate with the reinforced cellulose. The process of carrying out this chemical treatment of cellulose is in order to increase the surface roughness of the cellulose surface and thus increase the adhesion strength of the polymer. Then it is washed with water, dried and ground using an electric grinder, and sieved with a 300 μm sieve.

2. Epoxy resin was mixed with hardener (3:1) ratio for 20 min, it was supplied from the Modern Paints Industries Company.

3. Polyester resin mixed with hardener to it in a weight ratio of (98: 2) for 3 min, it was supplied from Saudi Industrial.
4. Mix the mixture in step (2,3) together for 7min for a ratio of (50Ep/50UPE), preparing the samples using the casting method, and with a different weight fraction for all samples, and then it was exposed to IR occur cross-link, so that they are ready for the tests:

-**Wear** occurs between any two surfaces in contact between which there is relative motion, removal of materials from a component by mechanical attack of solids or liquids [9]. Where the test was carried out by placing the sample holder on a disc with a capacity of 500 gm and the speed of the disc was 375 (rpm). Samples were placed at a distance of (7cm) from the center of the disc, and the time period for testing was (5min). The wear rate was calculated with the relationship (1).

$$wear\ rate=\frac{\Delta w}{SD}\left(\frac{gm}{cm}\right) \qquad (1)$$

$\Delta W= w_1 - w_2$, $S_D= 2\pi r\ n\ t$, W_1: sample weight before test , W_2: sample weight after test , S_D: sliding distance, r: radius of slide , n: disc speed , t: the time of test [10].

-surface hardness was carried out using the (Durometer Hardness TH210) of the (Shore-D) type, which is a small manual device that is used by stitching a needle-shaped tool, as the stitching tool penetrates the surface of the sample as a result of pressure on the device, and contact must occur between the surface of the stitching tool with the surface of the sample completely, then the hardness value that appears on the device screen is recorded [11-12].

Impact is the highest force that the material holds for a sudden impact without breaking. Brittle materials are measured by the amount of work done per unit volume to break the material under applied load. It was used in order to perform the Impact test on the prepared samples and with a hammer its value 2J Impact strength value was calculated using relationship (2).

$$Impact\ strength=\frac{F.E\times 0.05}{W\times T}\times 1000\left(\frac{kJ}{m^2}\right) \qquad (2)$$

F.E: Flexure energy (J), W: sample width, T: sample thickness. [13-14].

-Differential Scanning Calorimetry: (DSC131 EVO), is a technique in which the heat flow rate difference between a substance and a reference is measured as a function of temperature while the substance and reference are subjected to a controlled temperature program. It is usually used to determine the glass transition temperature Tg and other phase transitions in polymers, depending on the changes in the heat capacity of the sample. Also used to measure the residual monomer [15-16].

-Thermal conductivity of Lee's disk method is used to measure thermal conductivity. It is the property of a material that indicates its ability to conduct heat. Conduction will take place only if there is a temperature gradient in the solid medium [17- 19].

3. Results and discussion.

Figuer 1 represents the relationship between wear rate and weight fraction % , we note from the figure of the lowest wear rate was in the reinforced composites (300μm≤) as the best result was($1.3454656* 10^{-8}$ gm/cm) when 25% then it is in the reinforced composites (300μm>) and this is an indication of the distribution of the material with less volume in its composites, better spread, and higher homogeneity this is consistent in terms of behavior with the researcher [20].

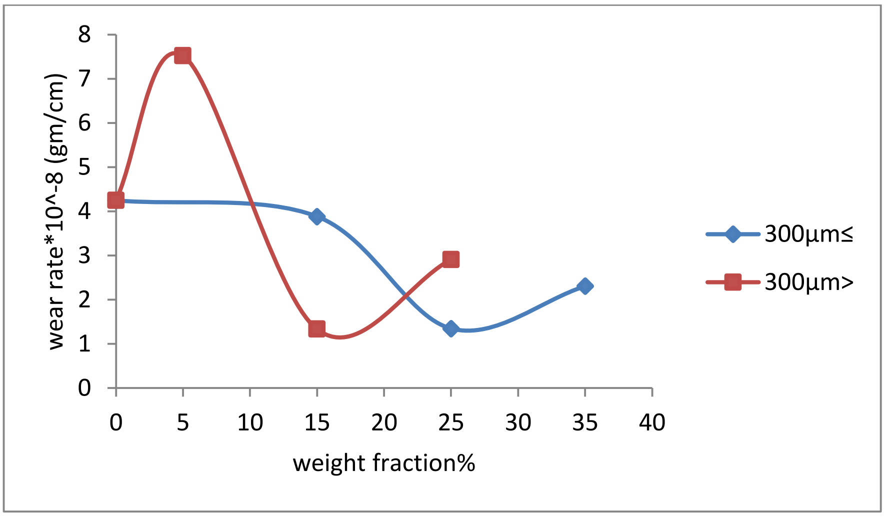


Figure 1 .Wear rate with various weight fractions % of rice husks for the polymeric blend (EP /UPE).

Figuer 2 represents the relationship between hardness and weight fraction %.we note from the figure that the surface hardness values increase with the small size of the particles, and the increase in the surface hardness value is attributed to the primary role of wood particles (rice husks) as they interact with the polymer surface and reinforcing materials that lead to high bonding between them so that the effective mechanical bonding increases, and in this regard, The additives contribute to an increase in the effective area with the matrix as a result of which it increases the cohesion and crowding, which reduces the movement of particles so that it increases the resistance to fracture This is consistent with the behavior of the researcher [7, 21-22].

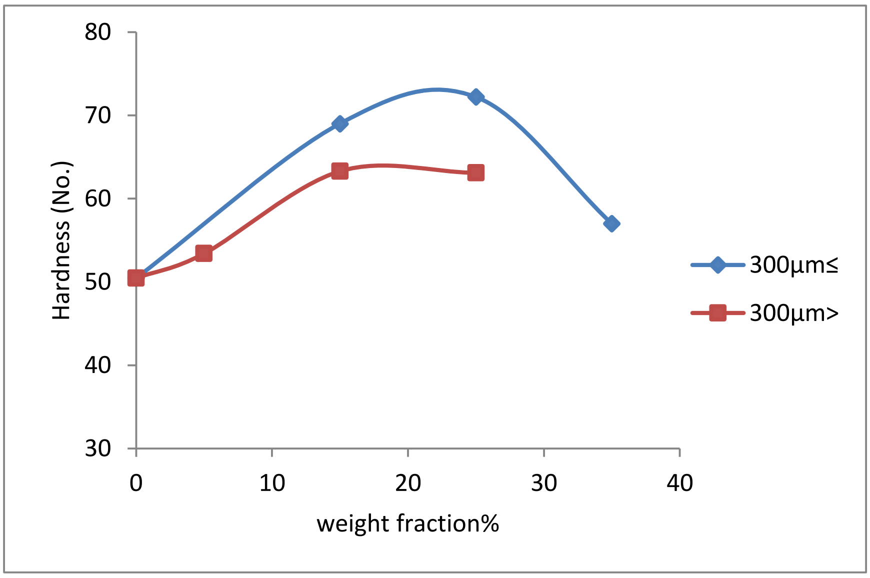


Figure 2. Hardness with various weight fraction %for polymer matrix (EP /UPE).

Figure 3 represents the relationship between impact strength and weight fracture%, We note from the figure that the best impact strength was at the smallest particles (300µm≤) and at the weight fraction 25% and its value was (23.13 kJ/m^2), This is due to the smaller particles of wood particles that enable it to diffuse well within the matrix material and thus be able to resist the impact and increase the impact strength, and this behavior is consistent with the researcher [8, 23]. The increase in the fracture energy of the prepared plastic wood material is due to the added rice husk material bearing part of the impact force in order to increase the bonding between the polymeric base material and the added cellulosic rice husk material, as a result of the penetration of rice husks into the base polymeric material, which led to an increase in the energy required to break the samples. Because the added rice husks acted as obstacles to the crack progression, and the strength of this hindrance depends on the strength of the interface between the rice husks and the polymeric substrate [24-25].

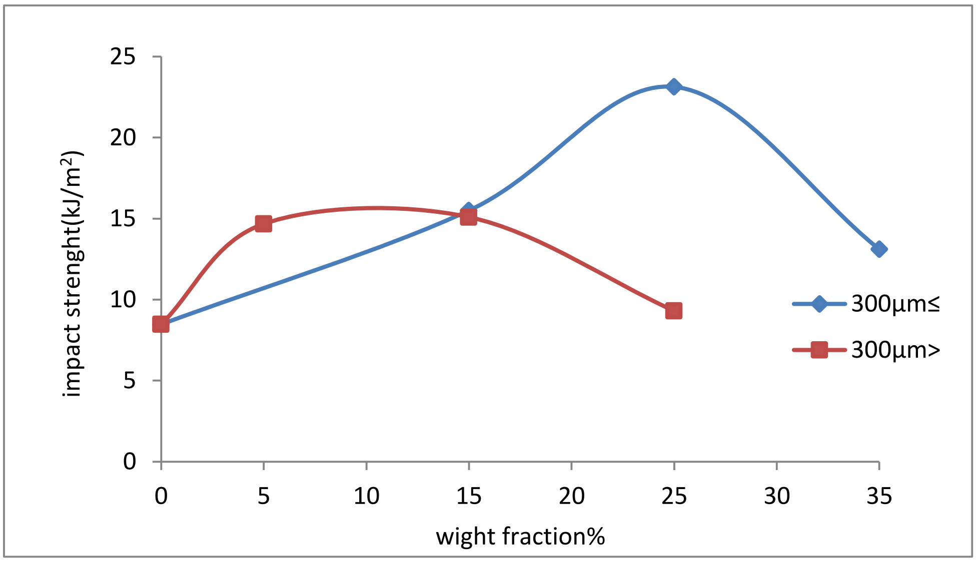


Figure 3 impact strength with various weight fracture% for polymer matrix (EP /UPE).

The **Figure. 1, 2, and 3** have the better tribological properties (wear rate, Impact strength, and hardness) of blends, we observed that 25% fine and 15% coarse weight had the best hardness value, impact strength, and the lowest wear rate. Because epoxy resins are excellent adhesives and have high mechanical properties and low creep, the addition of unsaturated polyester improves hardness, tensile strength, bending strength, and heat distortion temperature. Thus, the results showed that when the hardness increased in the composite material containing powders of different sizes, the increase will be in the smaller powders, which in the fine part of the hardness more than in the coarse composite materials and this applies to the impact. As for wear, in the event that the wear resistance decreases, this means that the rate of wear increases. This will be the cause of sliding friction between the polymer and the reinforcement material, while if the wear resistance increases, then the wear rate will decrease. This indicates an increase in the sliding friction rate between the two phases of polymer and Reinforcement material [7-8],[20-23]. **Figures 4,5, and 6** show heat flow with sample temperature, we note that the Tg values of epoxy are 52°C, polyester is 114.6°C and we notice that the value of the glass transition temperature of the blend 96 °C compared to the pure materials, and this means that the mixture is homogeneous, the values inside the figure represent the specific heat (Δcp) of the material, (t) the time [26].

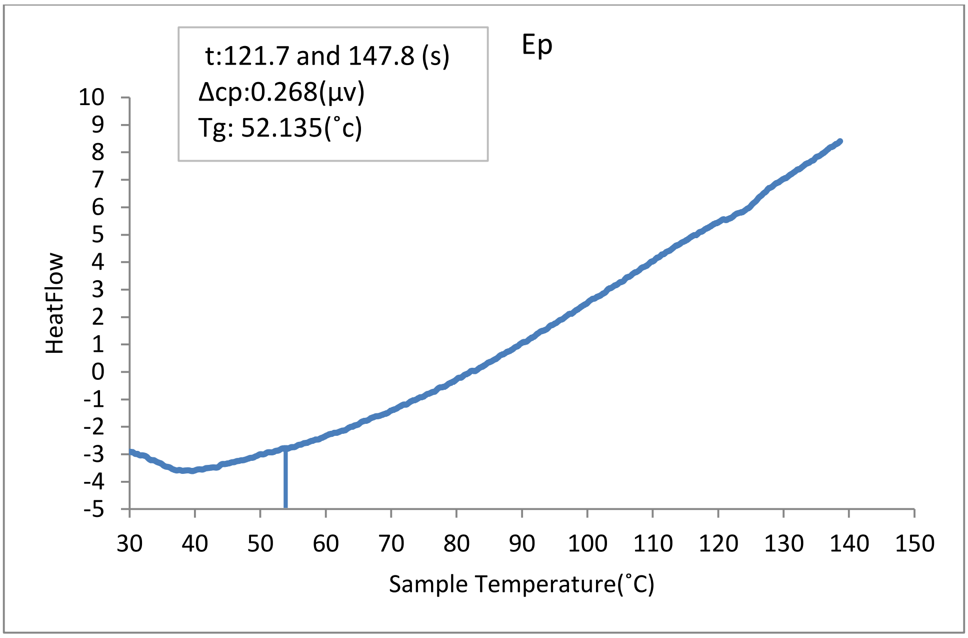


Figure 4. Heat flow with sample temperature for EP.

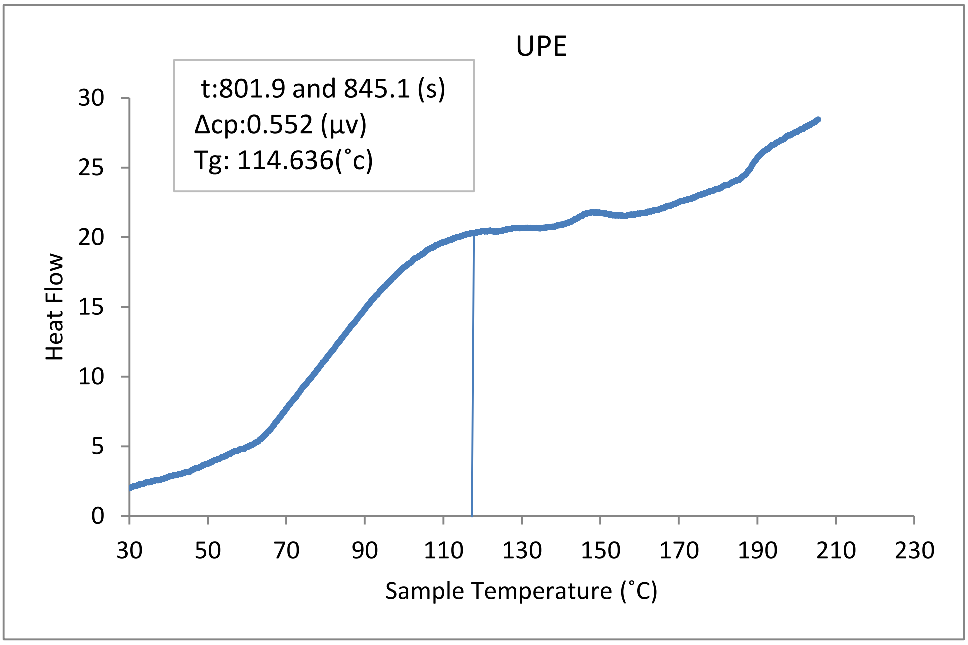


Figure 5.Heat flow with sample temperature for UpE.

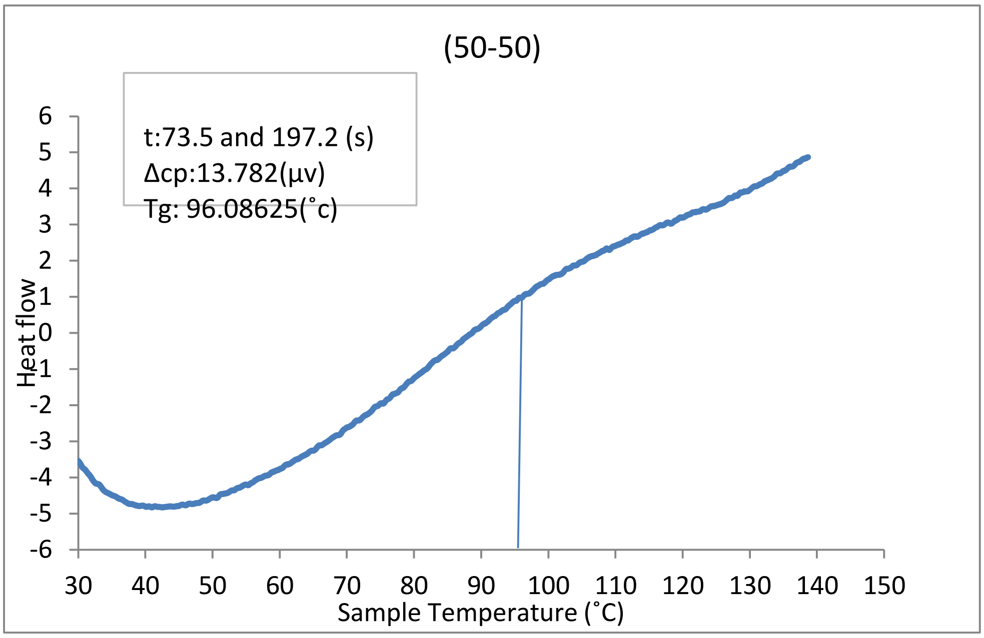


Figure 6. Heat flow with sample temperature for blend (EP/UPE).

Figure 7 Show The relationship between thermal conductivity and materials, from the figure obtained, it notices that the thermal conductivity of Ep recorded high values of up to (0.198)W/m.k, while it recorded the lowest thermal conductivity of UP before the blend is (0.17)W/m.k, as for the blend (50-50) the thermal conductivity is (0.19) W/ m.k. [17, 27-29] The polymer contains localized electrons so that Heat in them only by vibrating the reticle.

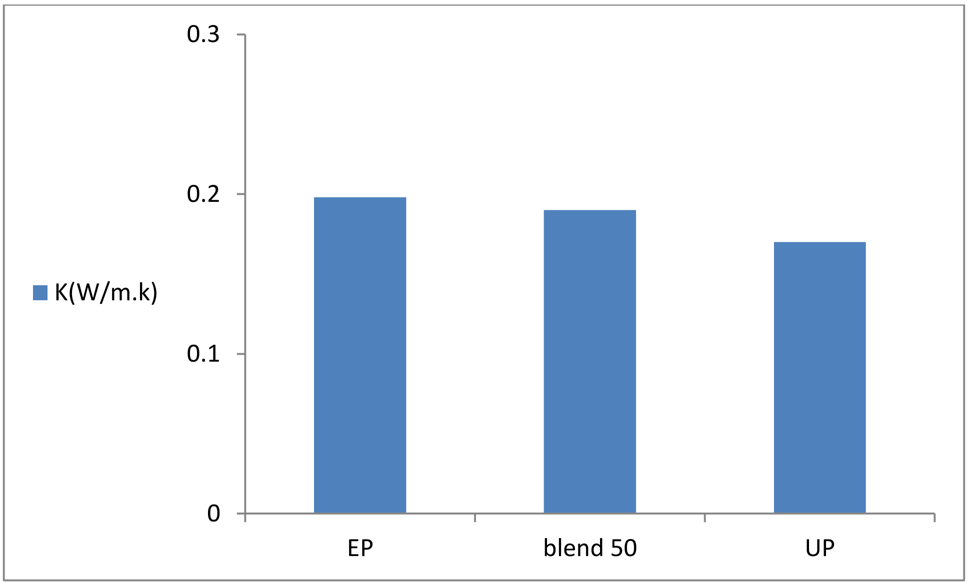
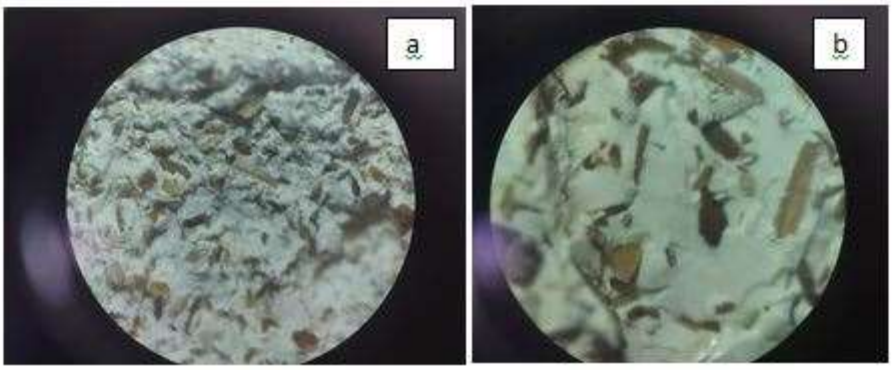


Figure 7 .Thermal conductivity for Materials.

Figure 8 shows Pictures of samples from the fracture side using an optical microscope represent it was noted that the preparation conditions had the greatest effect on the formation of the features of the surface structure of the prepared samples. The distribution of the micro-material within the substrate, where the micro-material was distributed by the mixing method (distraction)[30].



Figuer 8 a-25% of 300μm≤ rice husks. b- 15% of 300μm> rice husks.

4. Conclusion

1.It is possible to obtain an Ep/UPE polymeric blend when polyester is added to epoxy with a balanced reaction and mechanical properties, between toughness and softness, and has one glass transition temperature, and has a thermal conductivity slightly lower than the thermal conductivity of EP alone.

2.It is possible to use agricultural rice husk residues to reinforce the Ep/UPE blend to obtain wood-plastic composites, with good mechanical and physical properties.

3.The tribological, mechanical, and thermal conductivity of Ep/UPE polymeric blend composites reinforced with rice husk residues with smaller particle size is better than the reinforcement with rice husk with larger particle size.

4.The best values of the morphological and mechanical properties are shown by the plastic wood composites reinforced with fine rice husks with a weight fraction of 25% and the plastic wood composites reinforced with coarse rice husks with a weight fraction of 15%.

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