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Original Paper

Investigation of effect of chestnut sawdust on mechanical properties of epoxy matrix composites

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ABSTRACT

Composites have many important properties such as high specific hardness and strength, dimensional stability, adequate electrical properties and excellent corrosion resistance. The composite industry is mostly dominated by thermosetting resins such as epoxy, vinyl ester, unsaturated polyester, phenolic, polyimides. These resins have many advantages such as their relative ease of processing, lower equipment cost for processing and lower material costs. In this study, the effect of chestnut sawdust on the mechanical properties of epoxy matrix composites was investigated. As the resin, thermosetting epoxy resin was preferred as the matrix. As a filler, chestnut wood sawdust, which is produced as a natural waste by local furniture manufacturers, was used. The sawdust was prepared up to 400 micron size and was added to the resin at rates of 5-10-15-20% by weight. Sample preparation was terminated as the resin reached saturation with the addition of 20% sawdust. PTFE material was preferred as the mould because of the very weak adhesion property of epoxy. The prepared mixture was kept in the oven at 180oC for 3 hours to completely harden. Mechanical properties of the samples such as tensile, hardness and impact were investigated. Examination of the broken surfaces was made with SEM images. At the end of the study, it was determined that the addition of 10% by weight chestnut sawdust increased the mechanical properties of epoxy composites. It was also understood from the SEM images that there was a homogeneous mixture in the sample structure.

I. INTRODUCTION

Composites are defined as a combination of two or more materials with a distinguishable interface. Composite materials are widely used in many areas such as automotive, maritime, aviation, textile, defence industry. Composite-based materials contain additives and fillers together with a polymer matrix. The most important advantage of filling materials is that they reduce the cost significantly. However, it is known that it provides many advantages with its contributions to mechanical properties [1-2].

Ceramic-based fillers are mostly used in composites. However, in recent years, the use of natural fillers and fibres has been intensely preferred [3-8]. Natural fibres have attracted the attention of many researchers because they are low cost, highly available, biodegradable and environmentally friendly materials [9]. However, the main disadvantages of wood particles are their relatively low degradation temperatures, which weaken their adhesion with hydrophobic polymers. However, wood fibres show very good mechanical properties [10]. At the same time, the use of natural fibres and polymers from renewable resources has attracted increasing attention recently, mainly due to environmental concerns and depletion of petroleum resources [11-12]. Natural fillers have relatively high strength and hardness, as well as low cost, low density and low CO_2 emissions, and are biodegradable and renewable. One of the natural fillers is wood sawdust. Wood sawdust are suitable for use in polymeric composites due to its lightness, micro grain size, easy availability from local sources and natural waste [13-14].

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In this study, epoxy resin was preferred due to its widespread use as a matrix material. Epoxies have a wide range of applications, from dental fillings to rocket shells [15-16]. The properties that allow such a wide variety of applications are explained by the chemistry of the epoxy functional group as well as the curing reaction [17]. Functionally, this resin exhibits excellent properties due to its high crosslinking properties, adequate strength, low curing shrinkage, increased fatigue and impact resistance, excellent thermal properties, chemical resistance and dimensional stability. Epoxy/hardener ratios and ideal curing conditions are important to obtain the desired properties of composite materials [18].

These new generation environmentally friendly materials with natural fillings are used in many areas as an alternative to synthetic plastics. Products made of these materials, also called green composites, are used extensively in the automotive, furniture, construction and packaging industries. As fibres and filling materials, materials such as cellulose, nutshell, bamboo fibres, wheat stalk, chestnut are preferred intensely [4-5, 7]. In this study, together with epoxy, waste chestnut sawdust will be used as filler. With the use of waste sawdust in composite applications, it will be ensured that the environmental effects are reduced, the cost of composite production is reduced, the amount of waste storage and gas emissions are reduced, and natural resources are protected.

II. EXPERIMENTAL METHOD

2.1 Materials

In this study, waste chestnut wood chips obtained from local furniture manufacturers were used as natural filling material. The chips were prepared in up to 400 micron sizes by passing through 400 micron sieves. Epoxy resin, Epikot 828 (Shell Chemical, density 1.16 kg/liter), which is heavily preferred in composite applications, was chosen as the matrix material. Epikot 828 is a medium viscosity liquid epoxy resin produced from bisphenol A resin and epichlorohydrin. It is free of diluents, providing good pigment wetting and good resistance to filler precipitation and high mechanical and chemical resistance properties in the cured condition. Epicure (Shell Chemical) was used as epoxy resin hardener and benzyl dimethyl amine (BMDA-Aldrich) was used as accelerator.

2.2 Preparation of Samples

Chestnut wood sawdust in the size up to 400 micron was added to the epoxy resin at the rates of 5-10-15-20% by weight. Since saturation was reached in 20% filled samples, no other samples were prepared.

The ratio of hardener used for epoxy resin is 1:1, that is, the same amount of hardener is used by weight of the epoxy resin. In order to remove the air bubbles formed in the mixture of Epikot 828 and Epicure, it was kept in an oven at 50 ºC for about 20 minutes. In addition, 1% by weight of benzyl dimethyl amine (BDMA) was added as accelerator. The mixture poured into the PTFE mould was cured at 180 ºC for 3 hours to completely harden.

PTFE mould was used as open mold in this study. PTFE mould was preferred in order to easily separate the epoxy from the mould due to its weak adhesion property.

2.3 Mechanical Tests

The tensile test was applied in the Zwick brand Z010 universal type tensile test device according to the ISO 527 standard at a tensile speed of 5 mm per minute. The impact strength of the unnotched test specimens was used with a 5.4 J Izod hammer on the Zwick brand B5113.30 impact tester. The hardness test was carried out on the Zwick brand Shore D tester. For SEM analysis, the samples were coated with a 10 Å thick gold/palladium alloy. The SEM test was performed with the Polaron SC branded device located in the Marmara University, Faculty of Technology Laboratory.

III. RESULTS AND DISCUSSIONS

Tensile test, Izod impact test and hardness measurements were performed on composite samples. Tensile strength values and % strain values are given in Table 1. The tensile strength value of the composite, which has a particle reinforced polymer matrix structure, varies depending on the active load transfer between the matrix structure and the particle reinforcements. Factors such as the particle additive ratio, the bond strength between the particles of the fiber layer and the resin affect the strength at the same rate.

Table 1. Tensile strength and % strain values of samples

Filler Rate, by weight	**Tensile Strength** *(MPa)*	**Strain** %
Pure Epoxy	36,9	2,1
5%	37,7	2,2
10%	40,1	2,2
15%	34	1,9
20%	28	1,8

The variation trends for the tensile strength of the samples were close to each other. It is also possible to see from the graph in figure 1 that a partial increase in the tensile strength of the mixture is achieved with the increase of % sawdust ratio in epoxy-chestnut wood chips mixture samples. The pure epoxy sample exhibited a low tensile strength. However, due to the reinforcing effect of sawdust, the tensile strength values of the composites increased partially. With the addition of 10% sawdust, the tensile strength of the pure epoxy was increased by 8%. With the addition of sawdust after 10%, a decrease in tensile strength was observed in the samples.

This may be because the percentage of epoxy resin that firmly binds the composite is reduced. Another possible reason may be that the weak interfacial bond between the polymer matrix and the filler content reduces the tensile strength of the composite. It has been stated in the studies that the tendency to agglomerate with the increase in the amount of sawdust or the insufficient hydrogen bond between the chip particles and the epoxy resin matrix cause a decrease in the tensile strength [10, 18-20].

Shore D hardness value of the samples is given in figure 2. As in the tensile strength, the hardness values also increased as the chip ratio increased, and decreased after 10% sawdust amount. In Figure 3, the variation of Izod impact strength with increasing sawdust ratio is given. A slight decrease in the impact resistance of the composite was observed with the increase in the sawdust ratio by weight. The impact strength of the epoxy decreased by 20% with the addition of sawdust. The reason for this is thought to be due to the fact that the sawdust filler is available in very different sizes (up to 400 micron size) and structures.

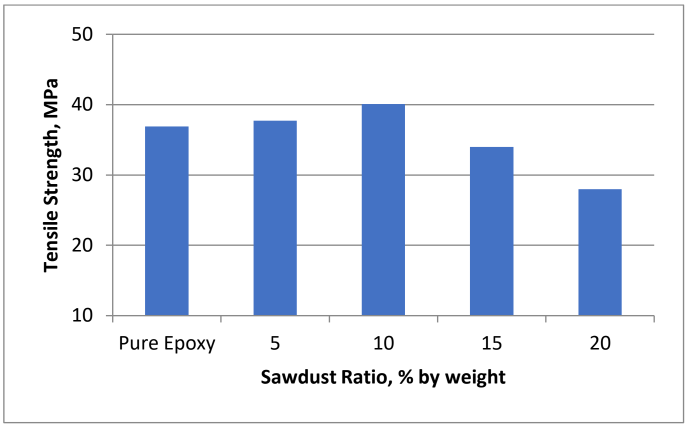


Figure 1. Variation of the tensile strength of the samples depending on sawdust ratio

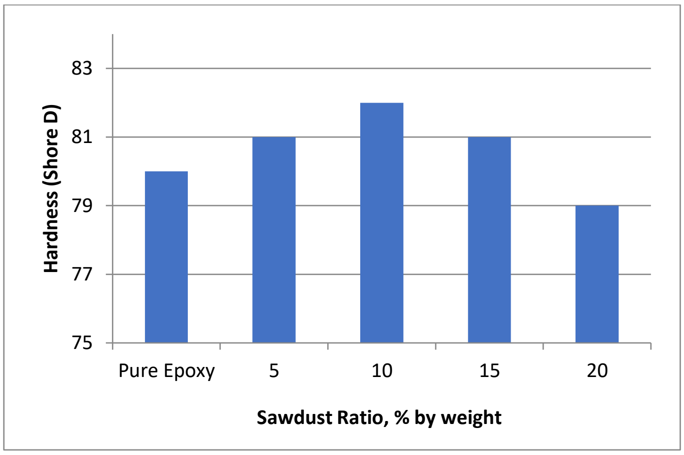


Figure 2. Variation of Shore D hardness value in samples depending on sawdust ratio

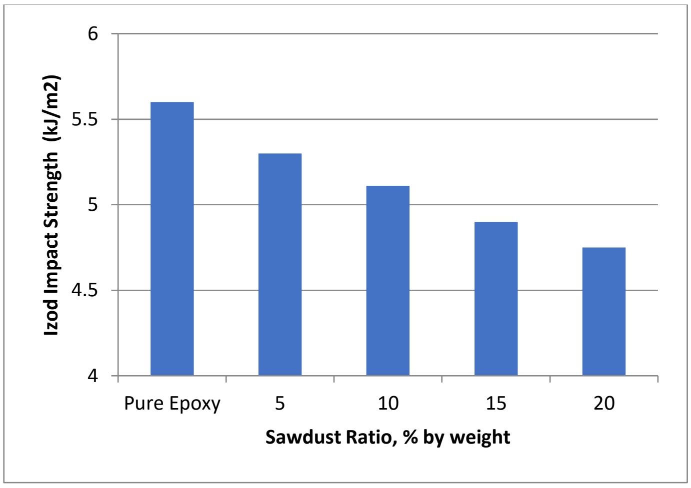
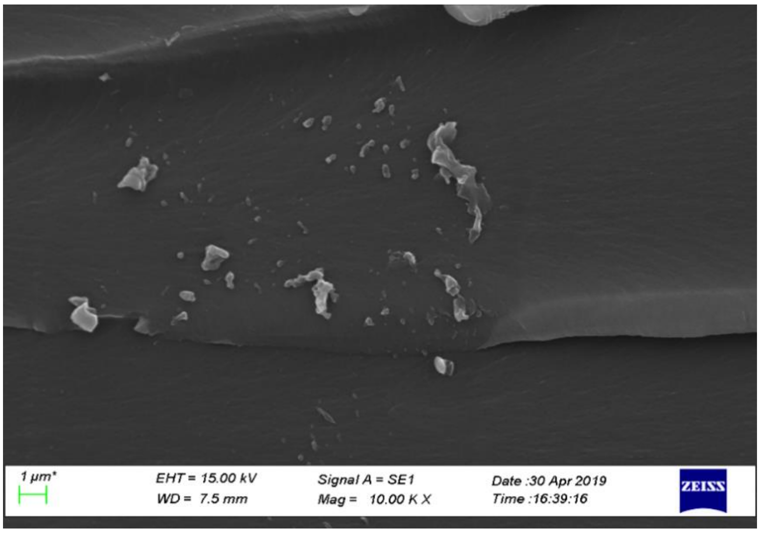


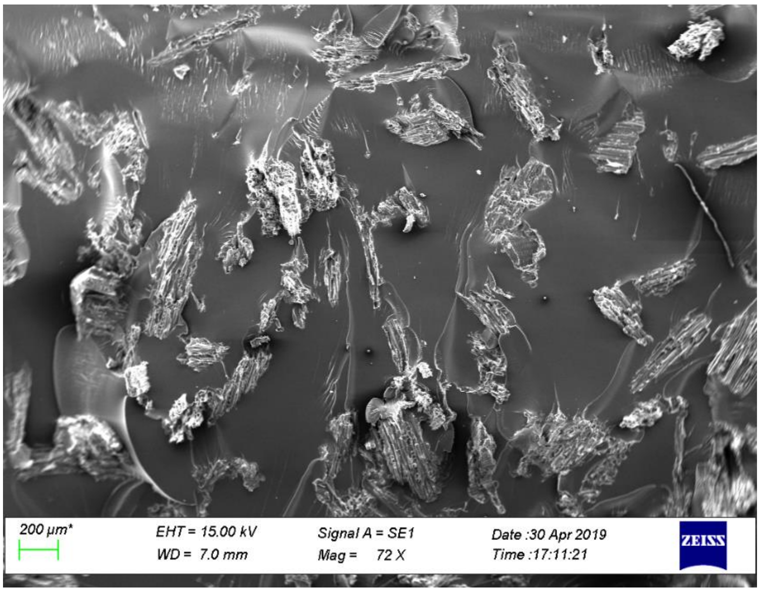
Figure 3. Variation of Izod impact strength of samples depending on sawdust ratio

SEM images of the samples are given in Figure 4. In Figure 4a, it is seen that there is a brittle fracture on the fracture surface of the pure epoxy. The other SEM image figure 4b contains 10% chestnut sawdust. It is clear that the sawdust adheres well to the epoxy resin. There are chestnut sawdust in many different sizes and shapes in the sample. As it can be seen from the images, it is seen that there are sawdust in the size of 10 microns, as well as in the size of 400 microns. However, as the weight ratio of sawdust particles in the resin increased, agglomeration was observed. This is thought to cause the formation of bubbles and pores that may interfere with the mechanical properties of the composites.

It can be thought that 10% by weight of sawdust filled epoxy has good adhesion, and with the increase in the amount of sawdust by weight, there may not have been enough epoxy resin to completely cover all cellulosic surfaces. Thus, from these images, it can be understood why composites containing 10% by weight sawdust show better mechanical properties than composites containing 20% by weight of sawdust. Similar observations in this study were also observed in other studies [19, 21].



a.



b.

Figure 4. SEM images of the fracture surfaces of pure epoxy (a) and 10% chestnut sawdust filled (b) samples

IV. CONCLUSIONS

In this study, the use of chestnut sawdust as a filler in thermosetting epoxy-based composite material was investigated. A slight improvement in tensile, hardness properties was observed as the chestnut sawdust filler silently increased in the epoxy. According to the tensile test data, it was observed that 10% sawdust filler showed a better strength than all other samples. There was also a partial increase in the hardness value. Impact test values showed a partial decrease due to the different sizes of sawdust filling in the structure. When the data of all samples were examined, it was understood from the SEM images that the sawdust ratio was ideal in the samples with 10% sawdust filling and that the sawdust was homogeneously mixed in the structure.

At the end of the study, it has been determined that the addition of chestnut sawdust filler will reduce the amount of heat-cured epoxy usage, which will reduce the cost to some extent and contribute positively to the mechanical properties. However, it is clear that the use of natural fillings instead of synthetic fillings will contribute to the solution of environmental problems. Therefore, it has been concluded that the use of chestnut sawdust as a filler in thermosetting epoxy matrix composite material applications may be an appropriate decision.

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