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Production of Curved Surface Composites Reinforced with Rubber Layer

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ABSTRACT

In this study, laminated composites reinforced with rubber layers were produced under vacuum infusion method for different curved surface geometries. For this purpose, EPDM rubber interlayers, known for their impact-absorbing feature, were laid on curved-surface metal molds processed on computer numerical control (CNC) benches together with woven glass fiber woven fabrics. Thus, sandwich plates with an array of [0 °] 6 glass fiber / EPDM rubber / [0 °] 6 glass fiber were obtained. It has been evaluated how the interface adhesion pr

operties of the structure, which is formed by combining different types of materials under vacuum, depending on the temperature curing. For this reason, composites were produced by curing under high temperature and room temperature. As a result, it was determined that in composites produced by curing at room temperature, separation occurred between layers and the desired interface toughness could not be achieved. However, no delamination defects were observed in the structure of sandwich plates obtained for 100 ° C curing, and it was observed that the adhesion tendency of rubbers with hyper-elastic material structure increased with temperature. A good harmony was achieved between fabrics and rubbers with the effect of temperature together with vacuum and very smooth geometries were obtained

1. INTRODUCTION

With the development of production techniques, a significant part of the elements that make up the machine and building system can be produced from composite materials. Fiber reinforced composites are manufactured in thin section, ie plate form, due to their high mechanical properties. Considering the usage areas and locations of the plates, the most used ones are the plates with curved surfaces. These composite plates can be produced by combining a single type of fiber and matrix, or by combining several fibers with different properties [1]. It is understood from experimental studies in the literature that rubber reinforcement provides improvements in the mechanical, acoustic and ballistic performance of composites [2-14].

As with every element that makes up the machinery and structures, plates are also exposed to impacts and strains depending on where they are used, and as a result, different stresses occur. These stresses can damage the plates and prevent them from fulfilling their essential function. Fiber reinforced composites are mostly orthotropic materials that exhibit elastic behavior. Especially, fiber reinforced composites are materials that exhibit brittle fracture behavior and damage occurs due to fiber breakage as a result of impact. These breaks also cause the onset and spread of the damage on the surfaces outside the impact contact area, and sometimes even invisible delamination (separation between layers) damages. Rubbers are the most effective impact absorbing materials today. Thanks to the rubber layer to be used as an intermediate layer in fiber-reinforced composite materials, large fiber breaks and irreparable structural damage can be prevented. When the studies on this subject are examined; Sabah et al. [5] obtained sandwich samples using rubber and aluminum honeycomb as core material between carbon fiber reinforced plastic shells. Repeated impact tests were carried out on these samples with hemispherical steel strikers at different energy levels. Khodadadi et al. [6] studied the impact absorption energies of composite materials consisting of kevlar fibers and polymer matrix under high speed impact test. Using two different matrix materials, rubber and thermoset (epoxy), they examined the effect of the composite on the impact absorption energy. Therefore, rubber layers have been added between thin composite plates with curved surfaces in order to make the structure more ductile and flexible, to increase the damped impact energy and to distribute the impact load better [5, 6]. Composites with the same alignment and curved surface geometries were produced under room temperature and 100 ° C curing temperature. As a result of the productions made by vacuum infusion method, rubber and fiber interface adhesion properties were examined and compared.

2. MATERIAL AND METHOD

In the study, firstly, molds with flat and curved surface geometries were produced on CNC machines for composite production. For these molds, 600x150 mm cold work tool steel molds are preferred. Metal molds are preferred because curing process will be performed under the effect of temperature in the production to be made by vacuum infusion method. In order to make CNC workmanship less costly, these molds are not emptied. The geometries and dimensions of the curved surface molds to be used for composite production are given in Figures 1 and 4.

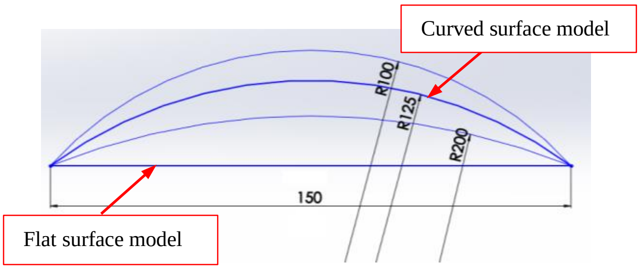

Figure 1. Sandwich plate models with fixed width and different curved surface (3 models)

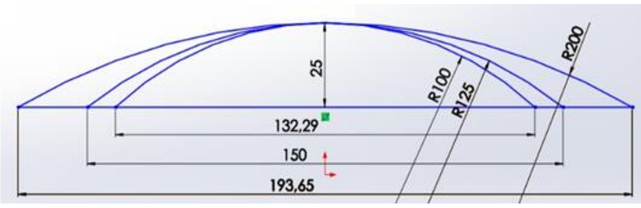

Figure 2. Sandwich plate models with different curved surfaces with fixed height (3 different models)

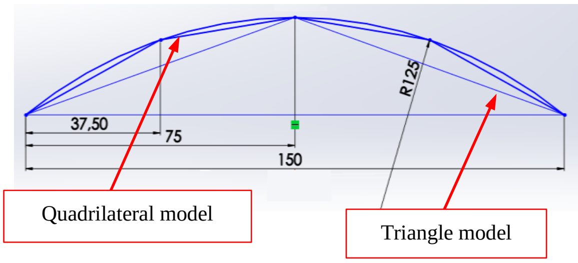

Figure 3. Sandwich plate models with different geometries tangential to the curved surface from inside

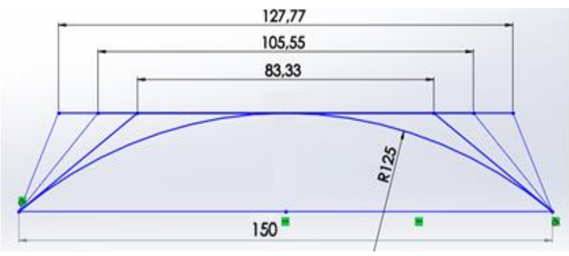

Figure 4. Sandwich plate models tangent to the curved surface from outside (3 different models).

In the production of sandwich plates, woven glass fiber fabrics with a weight of 300 g / m2 are used as fiber material and epoxy resin suitable for 100 ° C curing is used as matrix material. Lineflex EPDM membrane with a thickness of 0.5 mm was preferred as an intermediate layer. In the vacuum infusion method; First, a release film is laid to allow the mold to separate. Then, a flow net was laid on the curved surface where the fabrics will be spread, so that the resin can also wet the lower fabrics. Afterwards, the plate was affixed around the mold surface with double-sided tape that would leave the fabrics within its boundaries and provide sealing. After cutting the appropriate fabric and rubber for the size of the plate to be produced, how many layers and which fiber orientation is desired, the fabric is laid on top of each other and rubber layers are added between them. After the stripping layer is added to the fabrics to scrape the bag and the flow net, the flow net is laid on the peeling layer and closed with vacuum nylon. Finally, resin transfer was achieved by connecting one end of the mold to the resin and the other to the vacuum pump with a hose. After the vacuum process was completed, the fabric and rubber layers were left to dry and removed from the mold as a curved surface plate.

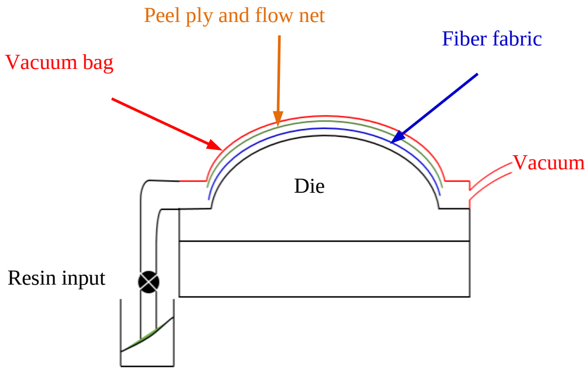

Figure 5. Vacuum infusion method schematic representation

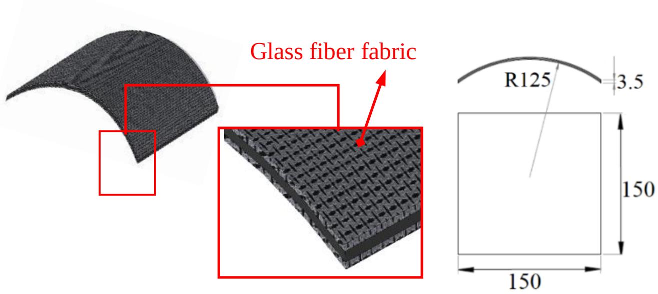

Figure 6. Vacuum infusion method schematic representation

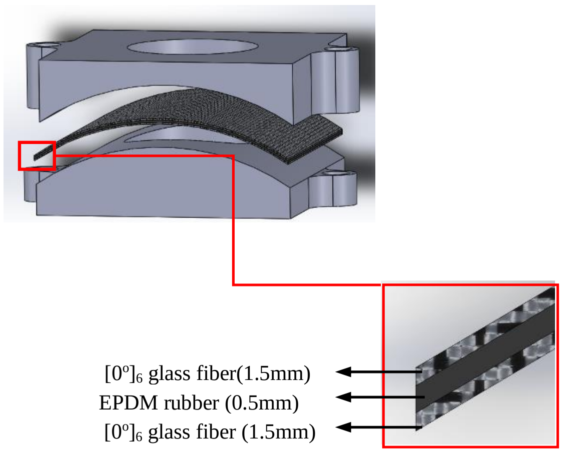

Figure 7. Solid model and alignment of the sandwich plate.

The schematic view of the vacuum infusion method is shown in Figure 5. In addition, the surface geometry and layer (rubber and glass) arrangement for the plate with common geometry in all sandwich groups to be produced are given in Figures 6 and 7. The graph of the curing process over time is presented in Figure 8.

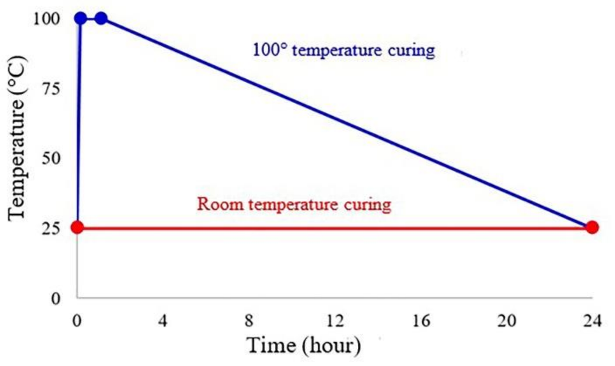

Figure 8. Curing process change over time [15].

Production stages of triangular, rectangular and common model composites from curved surface composites are presented in Figure 9. These samples have an array of $[0°]_6$ glass fiber / EPDM (Ethylene Propylene Diene Monomer) rubber / $[0°]_6$ glass fiber. It is also produced separately at room temperature and under 100 ° C curing. Later, these composite plate samples were prepared by cutting along the mold boundaries. Wet marble cutting machine is used for cutting. It was preferred to use the wet cutting method because the glass dust that will occur during the cutting of the glass composite is harmful to health.

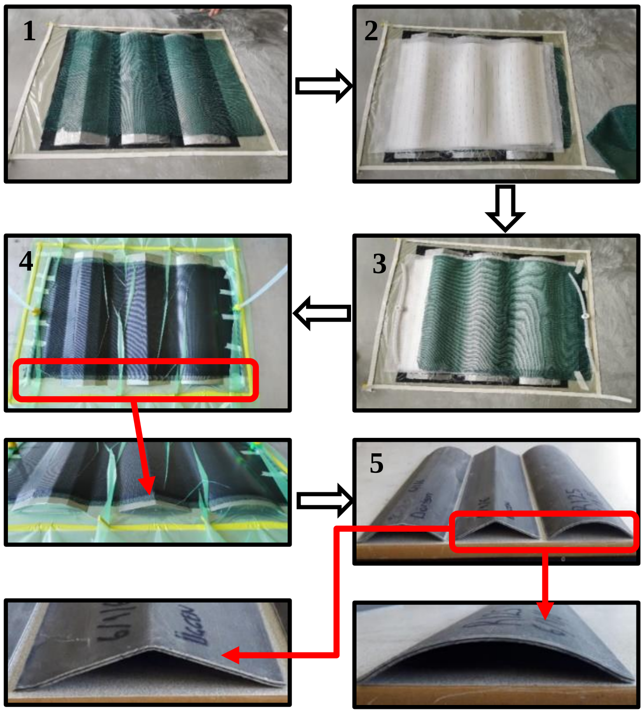

Figure 9. Sandwich composite production stages; 1) laying a flow net on the molds, 2) lining up fabric and rubbers between two peeling layers, 3) adding a flow net to the top for the resin to flow easily, 4) laying vacuum nylon to check its tightness under vacuum, 5) the samples obtained.

3. RESULTS

The interface adhesion properties of the samples obtained under different curing temperatures were checked and evaluated. In the examinations, it has been observed that especially rubber materials with hyperplastic material properties have a good compatibility with the fabrics under temperature and their adhesion properties increase. In addition, it has been determined that temperature is a highly influential parameter on glass fiber / rubber interface adhesion properties. Pictures of the products obtained at two different temperatures are shown in Figure 10.

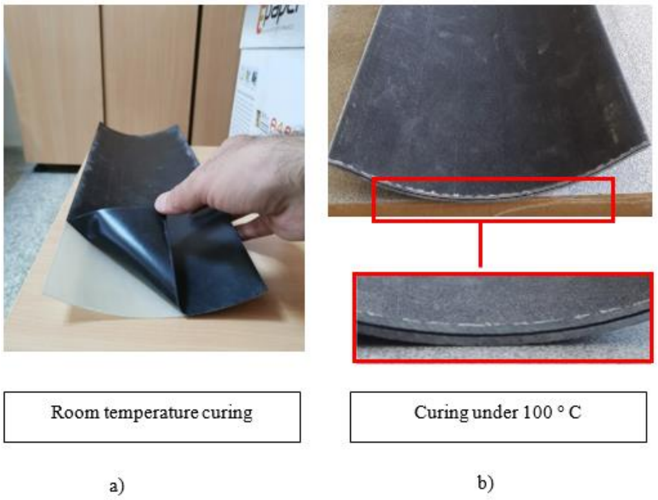

Figure 10. Interface properties of the samples produced; a) Sample obtained by curing at room temperature b) Sample obtained by curing at 100 ° C.

As can be seen in Figure 6, it has been observed that as a result of curing at room temperature, a sufficient adhesion surface has not been formed between EPDM rubber and glass fiber layer and it can be easily peeled off the glass fiber surface by hand. Sivaraman et al. [10] performed the curing of carbon fiber / rubber composites at room temperature and observed delamination damage at the fiber / rubber interface in the bending test. In addition, in the curved surface samples obtained by curing under high temperature, the interface strength between the fabric and the rubber was clearly seen and smooth geometries were obtained with vacuum. As a result of the study, it has been revealed that ductile materials such as rubber, which have the feature of hyper elastic material, must be cured under high temperatures in order to be used with fiber fabrics. It has been determined that only this way the desired adhesion surfaces can be obtained. Stelldinger et al. [16] produced sandwiches with a rubber interface layer of Krabion® EPDM using carbon fiber / epoxy prepreg layers at 135 degrees Celsius, and they did not find any delamination damage in impact tests. Similar situation Taherzadeh-Farda et al. It is also valid in the study by [17].

4. CONCLUSION

In this study, sandwich plates with rubber interlayer with different curved surface geometries were produced under different curing temperatures. The results obtained can be briefly summarized as follows;

- With the increase of temperature, the melting rubber layer surface adhered to the glass fiber surface and created a high bond strength. However, it should not be forgotten that the melting event is at a partial level at this point.
- Since rubber does not melt in production at room temperature, the internal force that holds the rubber and fiber interface together is only the strength of the epoxy. This force

is insufficient to hold the rubber and glass fiber interface together.

- The next step is to examine the impact behavior of sandwiches produced by curing at 100 ° C. In addition, in order to understand the damage mechanisms as a result of the impact, numerical analysis based on the appropriate damage model should be done. For this, the fracture toughness of the rubber / glass fiber interface Mod-I and Mode-II should be determined.

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BIOGRAPHIES

Mustafa ALBAYRAK obtained his BSc degree in mechanical engineering from Firat University in 2010. He received MSc. in Mechanical Engineering from the Firat University in 2013. He is still PhD student in Mechanical Engineering department of the same university. His research interests are composite materials, finite elements methots, impact and failure analysis. In 2013 he joined the Department of Machine and Metallurgy Technologies, Cumhuriyet University as a teaching assistant, but he is working now in Machine and Metallurgy Technologies Department, Malatya Organized Industrial Vocational School . He is active in teaching and research in the finite element modeling, analysis.

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