Flammability Behavior of Hemp Fibre Reinforced Epoxy Composites

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Abstract

In this study, the behavior of hemp fiber/epoxy composites subjected to flammability properties. for the production of composite samples, hemp reinforcements were used: unidirectional two balanced laminates (00/900) different in thickness were studied: 2 plies, 4 plies. The composites were fabricated by hand lay-up process the flammability properties of composites are analyzed by using UL-94. The effects of two different fire retardant compounds (Magnesium hydroxide and Aluminum hydroxide) filling on the Underwriters Laboratories (UL)-94 horizontal and vertical tests were carried out for evaluating the effectiveness of these FR treatments. The effects of 2 - 4% Mg (OH)2 and Al (OH)3 loading on the composites' burning rate was studied. It was seen that the composite results of vertical burning tests classified these composites under No Classification. The rate of burning of the composites decreased with the inclusion of fire retardants and the rate of burning of 11,60 and 11,22 and 12,20, and 10,60 mm/min was found with 4% wt of Mg(OH)2 and Al(OH)3 in composites respectively.

Keywords: flammability, hemp fibre, epoxy, composites

Introduction

In recent years most researchers and industries are focusing their interest to develop natural fibers such as hemp, kenaf, coir, cotton, jute, and sisal-based composites for several applications to reduce unpleasant environmental conditions. Natural fibers are used as predominant fibers in fabricating composites with polymeric or bio-based resin by many researchers. This is used rapidly to improve the mechanical and thermal properties to satisfy the needs of the automotive, textile, and packing industries [1,2].

Natural fiber-reinforced composites require low energy and have significantly less environmental impact than synthetic fiber formed by melting at high temperatures. Due to the high volume ratio of its fibers, less resin is used when becoming composite. However, the disadvantages of natural fibers are low stiffness, low strength and rapid degradation, and non-consistent material properties[3]. During the last decade, since the importance of the environmental aspect, there has been a renewed interest in natural fiber taking into account the ecological advantages of using renewable resources[4]. Moreover, they are producible with low investment at low cost, they are friendly processing, and present good thermal and acoustic insulating properties [4]. Hemp fiber-reinforced composites have found applications in diverse fields ranging from home appliances to aviation industries.

In this study, it was aimed to improve the flame-retardant properties of composites by adding Mg(OH)2 and Al(OH)3 microparticles at different weight percentages (2 and 4%) to the hemp fiber under the form of unidirectional fabric /epoxy composite.

Experimental

Hemp reinforcements, Figure 1, were used to fabricate a natural composite unidirectional, and, with a weight of 340 g/m^2 .Purpox® epoxy resin EFLR-0190 provided by Polikor Inc (Turkey). was used as matrix material, which is a solvent free resin with a transparent coating. The density of this resin was 1.00 – 1.10 g/cm^3, the while viscosity was 300,500 mPa. s. The epoxy resin and EFLR-0190 hardener were mixed at a weight ratio of 100:50 to produce the composite materials.

Fig. 1. Unidirectional hemp reinforcements

Manufacturing composites

The composite samples were manufactured using the hand lay-up technique. A metal mold (per ASTM D3039 (2017) and UL 94 (2001) was used for composite fabrication. The inner surface of the metal mold was treated with a stripping agent (Polivaks SV-6, İzmir, Turkey) to facilitate easy removal of the samples after fabrication. Then the two different (2 and 4 plies %) hemp fabrics were placed over the base plate. The contents of the mold were cured at room temperature for 48 h and then removed from the mold for the tests. (Table 1)

Tab. 1. Composition based on weight (%)

Sample Code	Reinforced	$Mg(OH)_2$	$Al(OH)_3$
Control (1)	2plies hemp fabric	-	-
Control (2)	4 plies hemp fabric	-	-
3	2plies hemp fabric	30	-
3^1	2plies hemp fabric	40	-
4	2plies hemp fabric	-	30
4^1	2 plies hemp fabric	-	40
5	4 plies hemp fabric	30	-
5^1	4 plies hemp fabric	40	-
6	4 plies hemp fabric	-	30
6^1	4 plies hemp fabric	-	40

The flammability test

The flammability test based on UL-94 is usually applied to evaluate and classify a fire performance of a material. Therefore, a horizontal burning test and vertical burning test were conducted to investigate the effect of fire retardants on the flammability of hemp/epoxy composites. In the vertical burning test, the sample was held vertically and a flame was applied to light one end of the sample for 10 sec. Samples (125mmx15mmx3mm) were prepared by ASTM D 3801 standards. The height and angle of a flame against vertical direction were 20 mm and 45˚C, Based on the outcome, the samples were categorized as V-0/V-1/V-2 or No Rating (NR)/NC (No Classification). In the horizontal burning test, Test specimens are 125 mm long and sliced 13 mm. Each specimen was marked with two lines expanding 25 ± 1 mm and 100 ± 1 mm from the tip to be ignited and fixed in a horizontal position with a grip. A 20 mm long flame was applied to one end of the sample at a 45° angle (30 seconds) After the flame was extinguished, the length of the burner was measured. The burning rate was calculated according to the formula; (Eq) [5].

$$V = \frac{60 \times L}{t} \qquad (1)$$

where V is the burning rate (in mm/min); L is the burning length (mm); and t is the time (s) for the flame to travel L (mm). The tests were conducted at least three times for each sample.

Results and Discussion

The flammability test

In the vertical test study, when the samples were ignited, they started burning slowly and continuously till the holding clamp with no flaming drips. As it did not extinguish, it was not ignited the second time and hence they were classified under No Classification. The Horizontal burning test results of composite specimens are summarized in Table 2. hemp/epoxy composite without neat was used as a control sample. According to the test results, it was observed that the burning rate decreased with the increase in the amount of $Mg(OH)_2$ and $Al(OH)_3$ in the loading composite. Similar studies have also been reported in the literature [5-8].

Tab. 2. Flammability(Horizontal Burning) test results of composite samples

Samples	Samples Horizontal Burning Rate (mm/min)	Flaming Drops
Control (1)	25,20	No
Control (2)	30,70	No
3	15,20	No
3^1	11,60	No
4	15,50	No
4^1	11,22	No
5	13,50	No
5^1	12,20	No
6	13,12	No
6^1	10,60	No

Conclusion

When the flammability test results of the composites were examined, similar results were seen in all of the composites, and Vertical test results of composites were No classification. However, As the amount of increased $Mg(OH)_2$, and $Al(OH)_3$ the horizontal burning rate of composites decreased. The samples (3, 3^1 4, 4^1, 5, 5^1 6 and 6^1) showed 60,31%, 46,03%, 61,50%, 44,52%, 43,97%, 39,73%,42,73%, and 34,52% less burning rates than the control composite respectively.

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