Effect of Magnesium Hydroxide on Flame Retardant Properties for Adhesive Materials by Solution Mixing Process

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Abstract. The objective of this research was to investigate the effect of magnesium hydroxide on the flame retardant properties of adhesive materials. The amount of magnesium hydroxide was varied from 2.5 to 10 phr. The adhesive preparation was performed by means of an aqueous filler dispersion technique. The dispersion of magnesium hydroxide in adhesive was observed by SEM images. The mechanical property of the adhesive joint was conducted by shear stress according to the ASTM D1002 standard. The flame retardant property of adhesives was measured in the horizontal burning testing method. The results revealed that the magnesium hydroxide formed agglomeration. For mechanical test, incorporation of magnesium hydroxide caused a cohesive failure in the substrate. The amount of magnesium hydroxide at 7.5 phr. possessed a maximum adhesive shear stress of 1,140 N. This was due to the magnesium hydroxide acting as reinforcing filler. The flame retardant properties of magnesium hydroxide increased with increasing magnesium hydroxide content. However, only adhesive with 10 phr was lower than 75 mm/min. The results can finally be concluded that the incorporated of magnesium hydroxide at 10.0 phr. remarkable improved the flame retardant properties of adhesive materials.

1. Introduction
Glue, often known as adhesive, is a fundamental component of furniture. It's a mix of liquids or semi-liquid ingredients that can be used to glue or join wood pieces together. The majority of furniture adhesives are constructed of synthetic compounds, which are less difficult to work with than natural rubber.
Thermoplastics and thermosettings are two types of synthetic adhesives used in chemicals. Both are utilized in various ways. Thermoplastic adhesives, such as Polyvinyl acetate and Ethylene Vinyl Acetate, may deteriorate when heated. When heated, thermosetting means it will harden. Polyvinyl acetate, urea formaldehyde, melamine formaldehyde, and phenol formaldehyde isocyanate are other examples. Each type of adhesive is appropriate for usage in a variety of situations. In addition to mechanical features, safety after incineration is particularly crucial since, while wood is a suitable fuel; it can generate insecurity among people in the event of a fire.
Several studies have looked at and improved the adhesive's qualities in order to decrease fire damage. Add a flammable filler such as Aluminium Oxide (Al₂O₃) [1-3] or Magnesium Hydroxide (Mg(OH)₂) [1,4] to one of the simple patterns not wasted. In order for the adhesive to have flame retardant qualities, these particles must typically be introduced in considerable numbers. Large
amounts, on the other hand, may have a direct impact on the adhesive's mechanical qualities, reducing its flexibility.

The goal of this study is to use the property of releasing little water molecules from the structure to inhibit the spread of fire by adding a flame retardant filler in small quantities (less than 10 phr). It also improves the adhesive's reinforcing qualities, making it stronger and giving value to the furniture sector.

2. Methodology

The adhesive materials used in this work were Polyvinyl acetate (PVAc) which are in water-based. The adhesive was available in market. The Mg(OH)₂ was supplied from Himedia laboratories Pvt. Ltd. The amount and proportion of the Mg(OH)₂ were designed by requiring the amount of adhesive to remain constant and increase the amount of Mg(OH)₂. The Mg(OH)₂ was varied of 2.5, 5.0, 7.5 and 10.0 phr, which were designed to less than 10 phr. There are the following steps of preparation. Firstly, the dispersion of Mg(OH)₂ was prepared by mixing the adhesive with Mg(OH)₂ with the proportional RO water in Table 1. Then, the Mg(OH)₂ dispersion was stirred on the magnetic stirrer at 375 rpm for 10 minutes. The adhesive was gradually poured in dispersion Mg(OH)₂ and continued stirring for 10 minutes. Finally, the obtained mixture was poured onto plastic for easy removal. The sample was allowed to dry completely at room temperature for 24 hours.

| Mg(OH)₂ (phr) | Amount (g) | Adhesive | Mg(OH)₂ | Water |
|---------------|------------|----------|---------|-------|
| 0             | 50         | 0        | 12.5    |
| 2.5           | 50         | 1.25     | 12.5    |
| 5.0           | 50         | 2.50     | 12.5    |
| 7.5           | 50         | 3.75     | 12.5    |
| 10.0          | 50         | 5.00     | 12.5    |

*phr = parts per hundred of rubber

The morphology and dispersion of Mg(OH)₂ adhesive was observed by SEM images. The average sizes of particles were measured by image processing program called Image J.

The mechanical property of adhesive joint was conducted by shear stress according to ASTM D1002 standard.

The flame retardant property of adhesives was measured in horizontal burning testing method.

3. Results and Discussion

Figure 1. shows the SEM image (a-e) of adhesive added Mg(OH)₂. The average particle size is also included in figure 1. It reveals that the morphology of Mg(OH)₂ particles form agglomeration as an increase of Mg(OH)₂. The agglomeration sizes were 15, 19, 26 and 30 mm for 2.5, 5.0, 7.5 and 10.0 phr, respectively.

Figure 2 (a) shows the shear stress of an adhesive with a dosage of 0-10 phr Mg(OH)₂. The maximum tensile strength increased from 1.02 N to 1.05 N when Mg(OH)₂ equal to 2.5 phr or roughly 3% was added, according to the data. When the quantity was increased to 5.0, 7.5, and 10 phr, however, the maximum shear stress increased before the decrease, reaching a high of 1.14 N for 7.5 phr. This value, however, is still higher than that of neat adhesive compounds. Considering the type of adhesive failure in figure 2 (b), the addition of Mg(OH)₂ changes the failure type from cohesive failure of adhesive to adherend failure in substrate.
The change in shear stress for the addition of Mg(OH)$_2$ may be due to the losing filler reinforcement factor, which is the interaction factor on the surface between filler and polymer[5-7]. If this interaction is of great value, the material will withstand the force that would destroy the sample. This is the reason that the shear stress of the Mg(OH)$_2$ adhesives increased with the higher adding content (2.5-10.0 phr). The agglomeration size increased with increase of Mg(OH)$_2$ which can lose the filler-polymer interaction or dilution effect.

The flame retardant properties were tested. The flame rate at constant distance was measured and shown in figure 3. It found that the addition of Mg(OH)$_2$ reduced the flame rate or prolonged the time of burning. The flame rate was reduced with an increase of Mg(OH)$_2$. In addition, according to standard, only adhesive with 10.0 phr passed. There are two reasons behind this result. First, the reduction of flame retardant may be caused by the highly endothermic reaction of Mg(OH)$_2$ [8-10]. The second reason is that the water vapor converted in reaction in bonding between the hydroxyl group to the magnesium [4].

Figure 1. SEM images and particles size of adhesive added Mg(OH)$_2$. 

Figure 2. Mechanical test in shear stress.
In this study, the fire resistance of adhesive was clearly improved by Mg(OH)$_2$ via solution mixing method. The Mg(OH)$_2$ forms agglomeration with an increase of Mg(OH)$_2$. The reinforcing properties increased as Mg(OH)$_2$ is contained. However, the amount of Mg(OH)$_2$ over than 10 phr, the dilution effect occurred which decreased the mechanical properties. The flame retardant was also improved when the Mg(OH)$_2$ was increased. In summary, according to the results, the proper amount used for improving the thermal resistance was 10.0 phr.

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