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Environmentally Friendly Wood Adhesives Based on Dextrin/Arabic Gum Blends

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Abstract

Wood adhesives are widely used consisting of urea-formaldehyde resins. Most of the studies aim to find alternative natural materials to replace the carcinogenic chemical adhesives. A mixture of natural materials that are available in abundance, cheap in price and are resistant to water and heat, the failure of the interface between two solid dielectrics is a major source of insulation system failure, hence it is crucial to understand the principles regulating this breakdown occurrence. It is generally agreed that the tangential AC breakdown strength of solid-solid surfaces is primarily determined by the elastic modulus (elasticity), radial/tangential pressure, surface smoothness/roughness, and dielectric strength of the ambient environment. For this purpose, we made use of dextrin and Arabic gum. Physical parameters (Lap shear strength, pull off strength, hardness, roughness, electrical and thermal insulations) of the combination formed with varying amounts of each ingredient were investigated. The adhesive characteristics of D were enhanced by the incorporation of AG, with improved pull off adhesion and lap shear strength at increasing AG levels at 80%. D /AG 20/80 compositions had pull off adhesion values 189 times greater than pure D, and lap shear strength values 820 times higher. It is evident because of the dispersion of AG molecules in decreasing the surface roughness of D/AG films and increasing their hardness on the shore scale. There is a positive correlation between the amount of AG added and the blending matrix of D, therefore boosting A with AG increases A. The dielectric strength, and thermal insulation increases with the increase in the weight ratio of Arabic gum. The blend prepared as an adhesive for wood is a good electrical and thermal insulator at 8% AG/20% D.

1. Introduction

Wood is a material with several innate anatomical traits, including its anisotropy and porosity. For example, softwoods have longitudinal tracheid's, whereas hardwoods have vessel components and longitudinal fibers. Its cells have sufficiently big apertures to facilitate the smooth transport of fluid resin [1]. Pits that are connected to one another usually suffice to allow resin to flow. Nevertheless, flow might be impeded by the presence of highmolecular-weight resins or occlusions in the pits or lumens. The term "interphase region" is used to describe the fusion of resin and wood material. The "bond line" consists of the interface between two substrates, each of which has its own interphase. Wood anatomy, permeability, porosity, resin viscosity, surface energy, consolidation pressure, and other variables all affect the interphase region's shape in unique ways [2]. The use of biodegradable polymers and resins in commercial and academic settings is growing rapidly. These polymers provide a number of advantages over their petroleum-based counterparts. They may be generated from renewable resources for less money and decompose easily [3]. The features of polymer blends include mechanical strength and stability [4], as well as reduced weight, mechanical flexibility, ease of manufacturing, biocompatibility, and chemical stability. There are three hypothesized processes for moisture dispersion in composites. In the first, water molecules go through the tiny crevices in between polymer strands. Whereas the latter is characterized by capillary transport into the cracks and crevices at the particle-matrix contact [5]. Thermosetting Epoxy polymers are widely used as adhesives because they are amorphous, strongly cross-linked, and provide fascinating features for engineering applications such as low creep, high failure strength, and peculiar adhesive properties [6]. Natural gums are favoured over conventional techniques (e.g., chemical, enzymatic) of starch modification [7] because to their lower cost, greater accessibility, and lower risk. Costly adhesives are a significant factor in the overall price of producing anything made with wood. Wood businesses sometimes resort to using affordable adhesives that are cheaper to produce, despite the fact that this may negatively impact product quality [8]. Substrate physical and chemical variables are considered in determining surface roughness. Because of its unique anatomy and morphology, characterizing wood's geometric structure may be a challenging task. It calls for thinking critically about a wide range of variables. Roughness is affected by both wood type (soft vs. hard) and the consequent density and porosity (lower porosity and greater density result in a smoother surface) [9]. Authors Ravindra V. Gadhave et al. The purpose of this study is to examine the effects of incorporating kraft lignin into polyurethane (PU) based wood adhesives during the curing process. Researchers looked at the adhesive's chemical composition, thermal stability, and mechanical qualities. As a means of evaluating adhesives, lap shear strength was measured by adhering canarium wood samples together. The findings showed that raising the lignin weight percent in such lignin-PU adhesives decreased the free isocyanate content, which resulted in a slower setting time and greater shear strength values [10]. As stated by Reza Hosseinpourpia et al. The effectiveness of polyurethane adhesives made using isophorone diisocyanate (MS)-modified wheat starch was studied. MS also greatly improved the tensile shear strength of wood veneers when tested in dry and wet circumstances [11]. The aim of the work prepares an environmentally friendly wood adhesive that is good mechanical properties, resistant to heat, and electricity insulators.

2. Experimental Procedure

2.1. Materials

1. Gum Arabic (GA): GA has high water solubility and a relatively low viscosity compared with other Gums. Manufactured by Shanghai Clinical Research Center (SCRC) in China.
2. Dextrin (D): density 1.8g/cm 3, and boiling point 865.2 °C, Manufactured by Shanghai Clinical Research Center (SCRC) in China.

2.2. Preparation of Polymers Blends Samples

After dissolving (D, and AG) in water at (60 °C) for 1 hour under magnetic stirring continuously until the solution was cleared, adhesives of blend polymer (D/AG) were prepared with weights of 100/0, 80/20, 50/50, 20/80, and 0/100 (w/w). The samples were then cast into a mold with a diameter of 5 cm and allowed to dry at room temperature for 24 hours as shown in Figure (1).

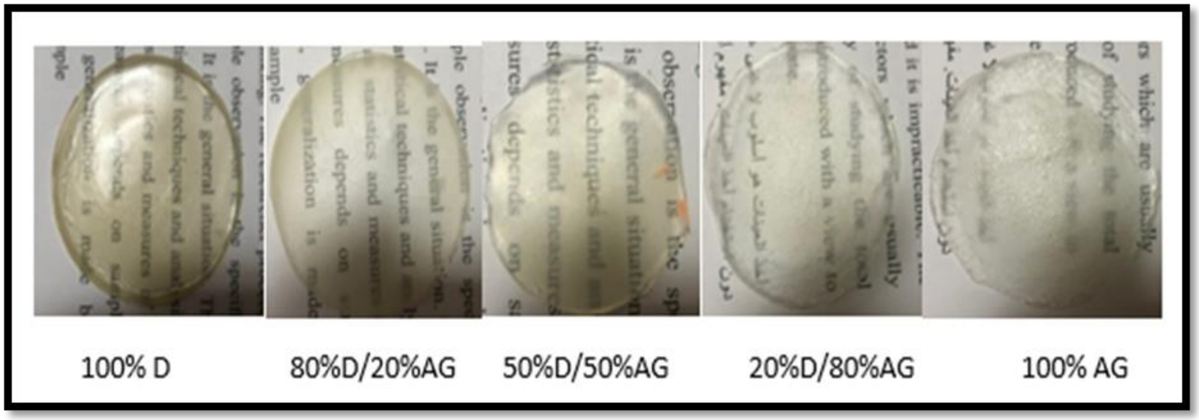

Figure (1). Samples of blends D/AG.

2.3. Fourier Transform Infrared Spectroscopy
By Fourier transform infrared spectroscopy (FTIR), a solid's absorption and emission in the infrared spectrum may be obtained. The FTIR spectrometer can capture data across a large spectrum all at once. It is common practice to employ FTIR to probe the chemical bonds, particularly in such mixtures. FTIR -8400S shimadzu is the model of FTIR instrument typically used in academic studies.

2.4. Pull-off Adhesion Test
The PosiTest pull-off adhesion tester is a handheld device that calculates the amount of force needed to separate a coating from its substrate under increasing hydraulic pressure. Coating adhesion to substrateASTM D4541, D7234, ISO 4624 is represented by the pressure, which is shown on a digital LCD.

2.5. Lap Shear Adhesive Test
The Intron 4502 electromechanical tensile testing equipment was used to perform quasi-static mechanical testing of single-lap joints. The cross-head speed was set at 1.3 mm/min in accordance with the ASTM D 1002 standard.

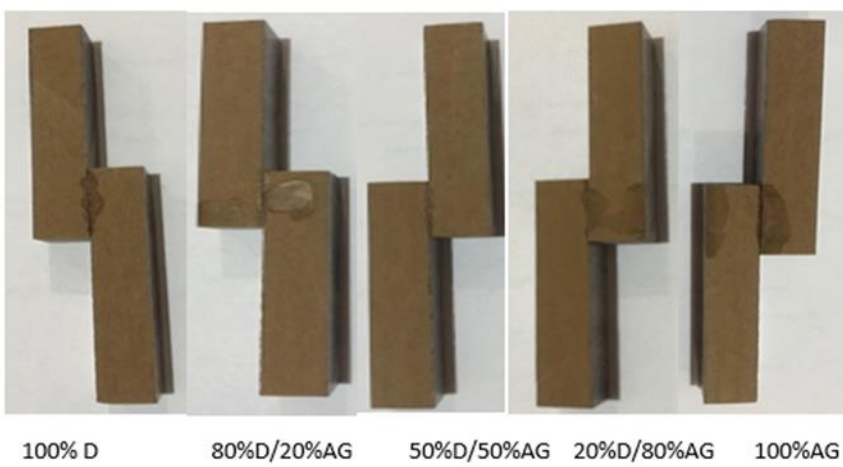

Figure (2). Samples of blends D/AG for shear test.

2.6. Surface Roughness
The roughness of a surface is a quantitative measure of its texture. A vertical deviation from a perfectly smooth surface is the definition used to describe this phenomenon.

2.7. Hardness Shore A

Durometer (shore A) (shore A), Penetration "A" hardness test results for the cured material. The penetrometer is used to measure the softest durometer, penetration. The indenter is continuously pressed into the cloth, producing motion.

2.8. Dielectric Strength

System components equipped with voltage and functioning within range (0-60Kv) and frequency were used to evaluate the longevity of electrical insulation of type (BAUR - PGO - S3), originally from Germany (50Hz).

2.9. Thermal Insulation

Using the measured data from the lee's disk (manufactured by Griffin and George, UK), the thermal conductivity coefficient was determined using the formula [10] below.

$$K\,[TB-TA\,/ds] = e\,[TA+ 2/r\,[dA + dS/4]\,TA+ 1/2r\,(dS\,TB) \quad \text{…………. (1)}$$

$$H=IV=\pi r^2 e\,(TA+TB) + 2\pi re[dATA+(1/2)\,dS(TA+TB) + dBTB+dCTC] \quad \text{………… (2)}$$

K: Thermal conductivity Coefficient, e: Represents the amount of thermal energy passing through unit area per second disk material, H: Represents the thermal energy passing through the heating coil unit of time, d: Thickness of the disk (mm), r: The radius of the disk (mm), dS : Thickness of the sample(mm), T The temperature of the disk (^oC).

3. Results and Discussion

3.1. Fourier Transform Infrared Spectroscopy (FTIR)

Extracts of AG were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) between 4000 and 400 cm1. The obtained spectra showed that there was a lot of crossover between the absorption spectra of the different components, with transmission peaks for functional groups visible in each band. Figure 3, the resulting FTIR spectra of the AG 3642, 3286.4, 2960.3, 2497.6,2341.4,1639.3, 1554.5, 1413.7, 1022.2, 800.4, 642.2, and 522.6 cm−1 the band C-H-O , C-H starch , C=C , C-O-C , C-H aromatic which agree with [12] and FTIR spectra of the D 3467.7, 3425.3, 2925.8, 2362.6, 1639.3, 1554.5, 1413.7, 1022.2, 800.4, 640.3, 524.6 cm−1 the band O-H , C-H stretch ,CH_3 and CH_2 , C-O , C-H which agree with [13].

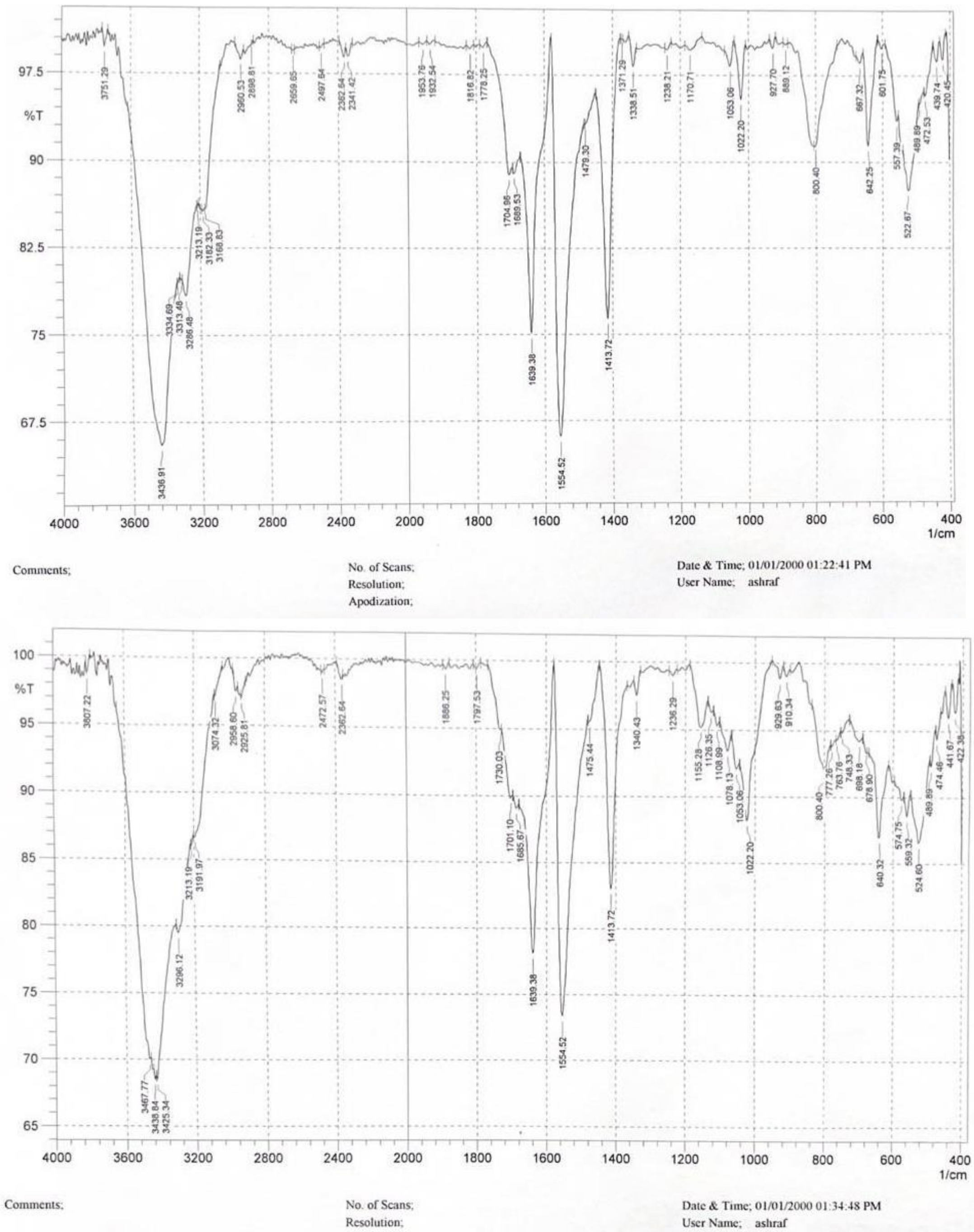

Figure (3). FTIR of a. Arabic gum b. Dextrin.

3.2. Pull-off Adhesion Test and Lap Shear Strength

The impact of adding Arabic gum to dextrin polymer on the adhesive qualities was evaluated utilizing pull off and shear strength tests. Figure 4 and 5 illustrates the pull off adhesion and shear strength of all the compositions investigated. The adhesive characteristics of D were enhanced by the incorporation of AG, with improved pull off adhesion and lap shear strength at increasing AG levels at 80%. To put it another way, the D /AG 20/80 compositions had pull off adhesion values 189 times greater than pure D and lap shear strength values 820 times higher than pure D. The addition of thermoplastics, thermosetting, and rubber to standard blends has enhanced their adhesive characteristics, which in turn has led to increased toughness. Both dextrin and the novel bio-based hydrophobic gum Arabic-based copolymer are effective adhesives; dextrin is particularly well-suited for use with soft substrates like paper, while the characteristics of the latter are significantly enhanced by the addition of Arabic gum in appropriate proportions [14].

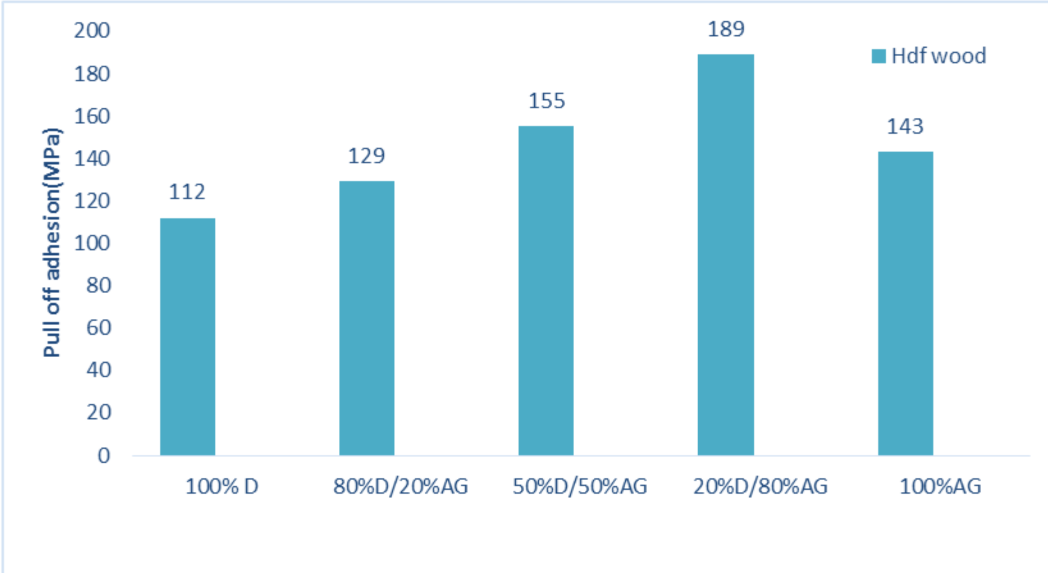

Figure (4). Pull off adhesion strength of blend.

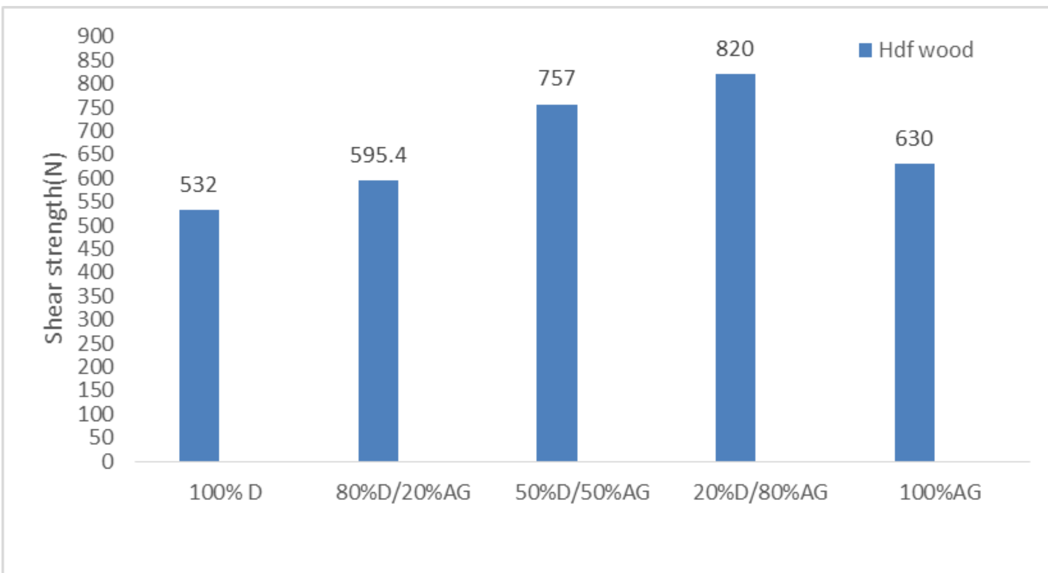

Figure (5). Lap Shear strength of blends.

3.3. Surface Roughness and Hardness Shore A

It was hypothesized that the addition of hydrophilic AG during the mixing process would promote miscibility between the two polymers, so flattening the ridge-valley structure of the surface of the formed D/AG films and thereby lowering their surface roughness. Similar results were reported in a publication by Yehia Manawi et al. [15], who found that including hydrophilic AG into the IP process enhanced miscibility between the aqueous and organic phases, leading to an improvement in membrane shape and a reduction in surface roughness. Overall, D/AG-containing films had smoother surfaces (lower average surface roughness) than the pure D film (fig.6), which is an evident result of the AG molecules being evenly distributed over the film's surface. As compared to the D film's roughness of roughly 3.78 8 nm, the D/AG films with 20%, 50%, and 80% of AG showed smoother surfaces (3.52 and 2.87 m, respectively). Hardness Shore values are shown in Fig. 6. Since AG and D interact well with one another in a matrix mix, raising A results in a higher overall A value. Several parameters, such as mix miscibility, loading, and surface adhesion between two polymers, might affect the mechanical characteristics of a polymer blend.

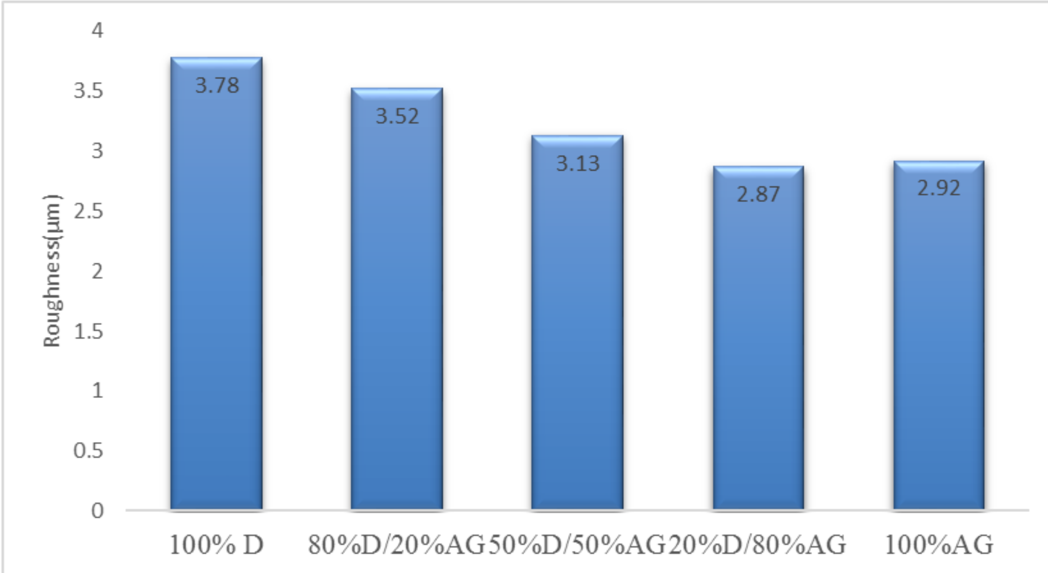

Figure (6). Roughness surface of blends.

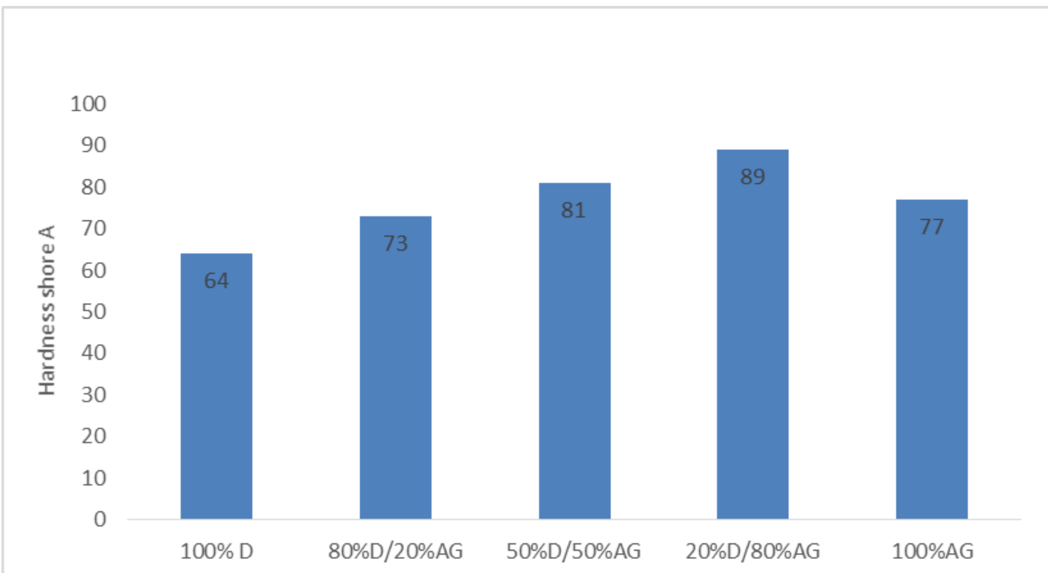

Figure (7). Hardness shore A of blends.

3.4. Dielectric Strength and Thermal Insulation

Figures (8) and (9) demonstrate that an increase in the weight ratio of Arabic gum improves dielectric strength and thermal insulation. Hence, the 8% AG/20% D mixture used to make adhesives for wood is also an effective thermal and electrical insulator. The interfacial breakdown strength is significantly affected by the surface roughness. The interfacial breakdown strength is shown to correlate highly with the roughness of the surface. From the roughest to the smoothest surface, the breakdown strength might increase by a factor of two. It is consistent with the claim in [16]. From 2007 to 2011, Hasheminezhad [17] worked on his Ph.D. on the interfacial breakdown strength of solid-solid surfaces. Via adjusting the surface roughness, he studied the BDS and PD inception field strength of XLPE-XLPE contacts in a homogenous AC field. These concur with the findings that will be presented in the next paper. Since the voltage increasing average (0.5kV/sec) causes more heat to be generated by leakage currents, and as applying voltage for longer periods of time raises the risk of electro thermal breakdown, it is noted that dielectric strength rises with the increase in voltage. The dielectric strength will drop as the average voltage rises because insulating materials have lower electrical resistance as their temperature rises. Although polymers as a whole have a low thermal conductivity (TC of 0.1-0.5 W•m•K-1), their individual chains have a much greater TC. Less crystalline (amorphous) polymers are also less thermally conductive [18].

It is known that in single polymer chains the stronger covalent bonds in the backbones can transfer phonons more efficiently. Additionally, in bulk polymers the interactions between the chains should be considered for bulk thermal conductivity values. These interactions can be either covalent (in crosslinked polymers) or non-covalent bonding [19].

Polymeric chains that have a randomly arranged structure and are linked with each other in a regular manner, in addition to the presence of what is called free volume within the polymer structure, Irregularity in the structure and the presence of voids between the strings, all this leads to making the process The transfer of thermal energy from one end to the other through the polymer is difficult, taking into account the existence of Interfaces between the two phases of the polymeric mixture, heat is transmitted in the form of elastic waves within the structure And the presence of interfaces will obstruct the movement and passage of these waves, so the wave will lose Part of its energy is at the inter-mixture interface

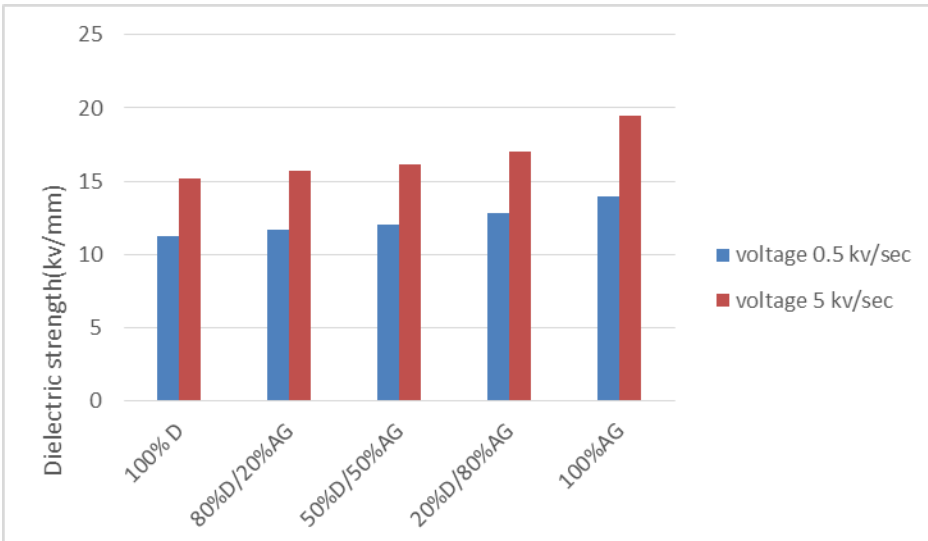

Figure (8). Dielectric strength of blends.

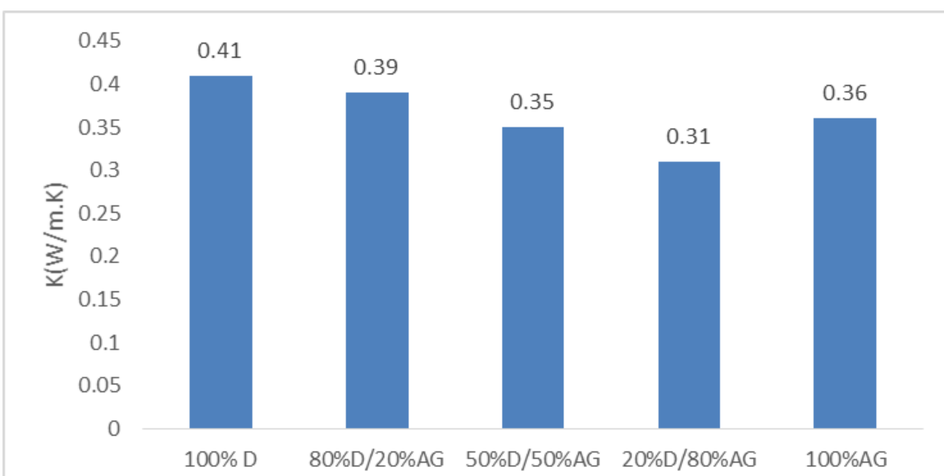

Figure (9). Thermal insulator of blends.

4. Conclusions

The adhesive characteristics of D were enhanced by the incorporation of AG, with improved pull off adhesion and lap shear strength at increasing AG levels at 80%. It is evident because of the dispersion of AG molecules in decreasing the surface roughness of D/AG films and increasing their hardness on the shore scale. Since AG and D interact well with one another in a matrix mix, boosting A is accompanied by an equivalent rise in A. Using more Arabic gum by weight improves dielectric strength and thermal insulation.

Conflict of Interest: The authors declare that there are no conflicts of interest associated with this research project. We have no financial or personal relationships that could potentially bias our work or influence the interpretation of the results.

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