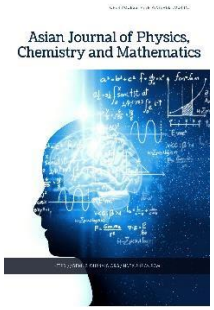

Study of the Mechanical Properties of Polypropylene Composites Reinforced with Alumina Microfibers

Mohammed Jawad H. Kadhim Polymer Eng. and Petrochemical Industries Dep. , Factuality of Mat. Eng., University of Babylon, Babylon, Iraq. alshimaryhana@gmail.com

Balqees M. Al-dabbagh Appl. Sci. Dep., University of Technology, Baghdad, Iraq. 100007@uotechnology.edu.iq

Hanaa J. Kadhim Polymer Eng. and Petrochemical Industries Dep. , Factuality of Mat. Eng., University of Babylon, Babylon, Iraq.. Mat.hanua.jawad@uobabylon.edu.iq

ABSTRACT

The purpose of this research is to create a polypropylene composite reinforced with various weight ratios of alumina filaments, as well as to study the mechanical properties of the resulting composite utilizing and without dispersion. Alumina filaments with weight ratios ranging from 2 % to 10 % were used, with a weight increase of 0.2 weight percentage. The influence of the alumina filament weight ratio on the mechanical properties of the resultant composite, such as Shore D hardness , density, modulus of elasticity, Impact strength, and tensile strength was investigated. All mechanical characteristics improved when the weight ratio of alumina filaments was raised, according to the findings. The modulus of elasticity increased from 25.5 GPa with a reinforcement ratio of 2% to 75 GPa with an 8 percent reinforcement ratio, then decreased to 70 GPa with a 10% wt. of fibers, while the density increased from 0.9 to 1.7 g/cm3 with a weight ratio of the filaments increased from 2% to 10% by weight. The impact strength increased from 1.3 kJ/cm2 to 3. 5 kJ/cm2 when the proportion of fiber by weight was increased from 2% to 8%, but the impact strength decreased to 3 kJ/cm2 when the content of alumina microfibers was 10%.. Furthermore, the Shore hardness enhanced from 20 to 45 by increasing the weight fraction of alumina fibers from 2% to 10% by weight. Tensile strength was also improved, going from 32 MPa with 2% wt. alumina microfibers to 36.5 MPa with an 8% reinforcement phase, however it dropped to 33 MPa with a 10% reinforcement phase. For all weight ratios of alumina filaments, the dispersion approach resulted in better mechanical properties such as higher tensile strength, impact strength, Shore D hardness Young's modulus, and decreased composite density.

Keywords: PP , composites , Alumina , filaments , strength, Young's modulus, Impact strength

1- Introduction

Composite materials have found their way into practically every aspect of life, including civic and military applications. The advancement of science and technology has had a big effect on the improvement of this science, and they are now considered main alternatives to many materials used in similar industries due to the advantages that these materials offer, such as light weight, convenience, and ease of use [1-5] . Two materials must be available in order to produce a composite material. The first is known as the base material, which has various advantages over the reinforcing material, including a lower density, elastic modulus, and stiffness [6-7] . The second substance is reinforcing material, which can come in a variety of shapes and sizes, including fibers, particles, and sheets. The reinforcing material must have better mechanical qualities than the matrix material, such as ductility, elasticity modulus, and stiffness [8-10] . Polymer, ceramic, or metal can be used as the matrix material [11-15] . Polymer is one of the most straightforward engineering materials to employ as a matrix for composites [16-20]. The polymer is a poor engineering material due to the existence of Van der Waals linkages, which cause the polymer to have poor qualities, but it is a highly flexible material, so it can be combined with another strong material, such as ceramic or metal, to produce a high-strength material. There have been numerous earlier publications that looked into the impact of strengthening on polymer mechanical characteristics. Sahib et al. (2010) investigated the dry wear, compression resistance, and hardness of an Epoxy reinforced with a (25 percent) glass fiber ratio. To determine the influence of reinforcement on the composite, the characteristics of the composite at temperature (20 o C) are compared to those of unreinforced Epoxy. The reinforcement material was continuous fiber oriented in weaved pattern, and the volume fraction for the specimen was (25 percent). When the wear rate is measured, it indicates a decrease with reinforcement. With strengthening, compression resistance and hardness increase. Compaction data clearly show that wear rate and wear rate volume increase with typical applied load, sliding distance, sliding time, and disc hardness [21] . Al-dabbagh and Aiob published a study in 2013 regarding ternary polymer blends made from Epoxy and Novolac resins blended with either polyurethane (PUR) or polysulphide (PSR) rubbers. Samples are prepared in two groups : Blend A (70 percent Epoxy + 15% Novolac + 15% PUR and Blend B (60 percent Epoxy + 20% Novolac + 20% PSR. These blends were examined using a wear instrument on samples under normal conditions (room temperature) and after immersion of mix samples in chemical solutions (H2O, H2SO4, and KOH) for (15, 30, and 45 days). These chemical solutions' (Normality) is (0.2N). The wear resistance of the blend samples deteriorated after they were immersed in a chemical solution. The characteristics of polyurthane rubber-containing blends were more influenced. They came to the conclusion that all chemical solutions alter test outcomes, but the alkaline solution KOH is the most effective. The wear rate increases with increasing applied force and increases or lowers with sliding velocity, according to the findings of the wear test (depending on if it is high or low respectively) [22]. Al dabbagh and Bader 2019 investigated the use of industrial fiber and polymer matrix composites in high-speed impact (ballistic) applications. The composite samples in this investigation were made with epoxy + unsaturated polyester, synthetic rubber (polyurethane), Kevlar fiber, polyethylene fiber (ultra High molecular weight), and carbon fiber. Four sample systems were constructed in succession. The first system component was manufactured of (epoxy and 2% graphene and 20 layers of fiber), and then a ballistic test was conducted, with the sample passing the test from a distance of 7 meters or more, using a Glock handgun with a caliber of 9 * 19

mm. The second system, which consisted of (epoxy, 2% graphene, 36 layers of fiber, and one layer of hard rubber), was successful in testing from a distance of 4 meters or more, using a Glock handgun with a 9*19 mm caliber [23]. Al Zubiedy et al. presented a study in the year 2020 on the fabrication of a composite material using epoxy as a matrix and carbon fiber (20% volume fraction) with nano titanium dioxide (TiO2) particles in various weight fractions (0,2,4, and 10%) as hybrid reinforcement. Mechanical experiments (impact strength and wear resistance), as well as investigations of liquid absorption behavior during immersion in chemical solutions and analysis utilizing scanning electron microscope imaging to reveal minute details, were conducted. The addition of TiO2 to the composites increased mechanical properties, with the specimen reinforced with 4% TiO2 having the maximum impact strength and wear resistance. [24]. Muna et al., prepared in 2021 A polymeric blend nanocomposites with a matrix of (Epoxy + polysulfide rubber) and Zirconia Nano-powder as a reinforcement material, in various particle sizes and the same 2 percent wt addition ratio. The samples were prepared using hand lay-up molding. All samples were tested for impact strength, compression resistance, and thermal conductivity before and after immersion in tap water. The addition of Nano zirconia powder to the polymer blend increased mechanical characteristics, while the polymer blend's thermal conductivity was higher than that of the composites. In addition, water immersion resulted in a corresponding drop in impact strength, compression resistance, modulus of elasticity, and thermal conductivity [25] . Majeed et al. 2022 published a study to see how natural sisal fibers affect the mechanical properties of polymethyl methacrylate (PMMA). Ninety specimens are being prepped for the investigation. The specimens are separated into three main groups: 30 heat cure PMMA specimens without additives (control) and 60 heat cure PMMA specimens with salinized sisal fibers in two different weight percentages (5 and 10%) wt. The flexural strength of the specimens is determined using a three-point bending test, while the impact strength is determined using Charpy's machine and the tensile strength is determined using ASTM D-638. For statistical analysis, the analysis of variance (ANOVA) test is utilized . The results showed that with fiber reinforcement, the tensile strength increased considerably. Flexural strength is not significantly different between the reinforced and control groups. They found that adding natural sisal fibers to a heat-cured acrylic resin considerably increased its impact and tensile strength while having no effect on flexural strength. [26] .Impact strength It is the amount of energy absorbed by the body in a certain block of cross-sectional area, and it can be computed using equation 1. [27]

$$I.S = U/A \quad \ldots(1)$$

I . S = Impact strength (kJ / cm2) , U = Energy of fracture , A = cross-sectional area

Surface hardness is a measurement of a surface's resistance to scratching. [28-29]

2- Experimental : Materials , Methods and Tests

As a matrix phase, atactic polypropylene with a density of 0.9 g/cm3 and a melting point of (170 o C) was utilized. Alumina microfibers with a diameter of 20 μm and a density of 3.9 g/cm3 were employed as a reinforcing material, and these materials were obtained from Sigma Aldrich.

At a temperature of 170 degrees Celsius, the PP and alumina microfibers were extruded. The samples were prepared for tensile testing according to the (ASTM D638-87 protocol) and evaluated on a (computerized universal testing machine model) (WDW-50E, Jinan Shijin Group Company). At room temperature, tensile tests were applied at a constant strain rate of 10 mm/min. As a sample lay until it failed, tensile stress was identified and a stress-strain curve was constructed. Each sample was checked three times and the results were averaged. To limit the samples' Young's modulus, a tensile test was done. Archimedes' law was used to determine

the composites' density. A Durometer was used to determine Shore D hardness.

3. Result and Discussions

3.1 Shore D hardness

In a variety of applications, hardness is a crucial property of polymers and composites. It can be increased by uniformly spreading suitable microfibers in a polymer. Figure 1. depicts the influence of alumina microfibre content on composite Shore D hardness. The hardness of composites increases as the quantity of alumina fibers increases. Because alumina fibers are stiffer than PP, increasing the amount of alumina microfibers in a composite raises the Shore D hardness of the composite. Hardness is formed as a result of crystalline microstructure structures enhancing hardness. This is due to microfibers' capacity to interact with polymer matrix and improve interfaces between PP and alumina microfibers, resulting in greater linking and improved strength. As we can see, the dispersion procedure increases hardness because the result composites are more homogeneous, resulting in more compact surface contents.

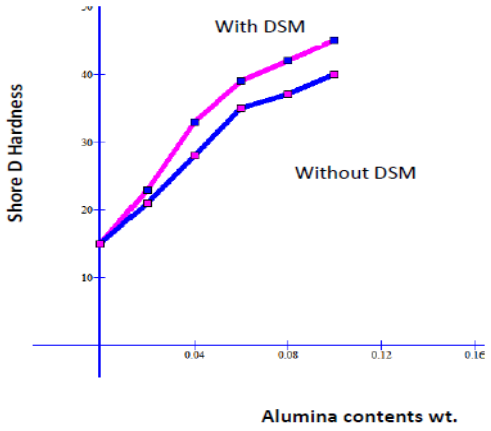

Figure 1 Relationship between Shore D Hardness and Alumina Microfibers contents

3.2 Density

Figure 2 illustrates the density of composite samples; as the amount of alumina microfibers in the composite increases, the density of the composite increases. The composite sample follows the rule of mixture since crystalline fibers have a higher density than PP. Furthermore, the addition of alumina microfibers causes additional packing between matrix chains, resulting in an increase in crystallinity degrees. The dispersion method (DSM), on the other hand, results in lower density due to the excellent homogeneity of the composites and less agglomeration of reinforcement phase. [30]

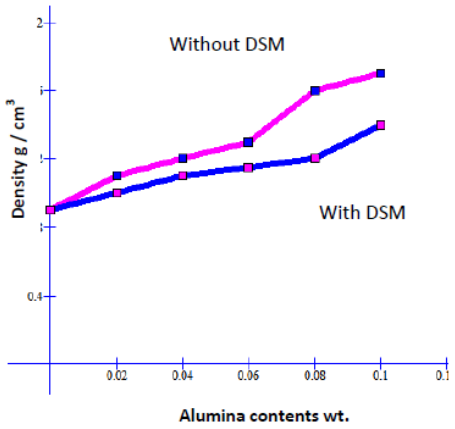

Figure 2 Relationship between the density ad Alumina Microfibers contents

3.3 Tensile strength and Modulus of Elasticity

Figure 3 shows the tensile strengths, maximum fracture forces, and maximum extensions for pp specimens and (PP/Al2O3) microfibre composites. Tensile strength of PP/ alumina composites increased marginally to (33 MPa) before the dispersion process when the alumina percent increased by 2%. This is due to alumina dispersion in composites and better interfacial adhesion between the fiber and matrix. The tensile strength declines to (32.5 MPa) when the alumina percentage is increased by another 4%, yet it is still higher than the tensile strength of neat PP samples. The tensile strength lowers to (31.5 MPa) when the alumina percent is increased by another 6%, and it continues to diminish when

the weight ratio of alumina fibers is increased until it reaches 10%. Because the composites contain alumina agglomeration fillers, this is the case. Tensile strength of PP/ alumina composites improved from 30 MPa with 2 percent wt. of alumina fibers to 40 MPa with an increase in the weight ratio of alumina The tensile strength reduction caused by the addition of alumina fibers without the use of a dispersion process could be due to the weak chemical bond between the matrix and the fibers, which makes it difficult to convey randomly oriented fibers with sharp corners, or the tensile load resulting in matrix stress concentration regions in the body during tensile loading, or the increase in vacuum percent in composites along filler content altitude. Figure 4 indicates that increasing the weight ratio of alumina microfibers from 2% to 8% wt increases Young's modulus. The higher Young modulus values are due to the effective dispersion of Al2O3 micro fibers into the polypropylene matrix to fill the gaps left by the composites sample preparation process. Due to aggregation of alumina microfibers at high ratios of content, the young's modulus decreases as the content of alumina microfibers increases to 10% wt.

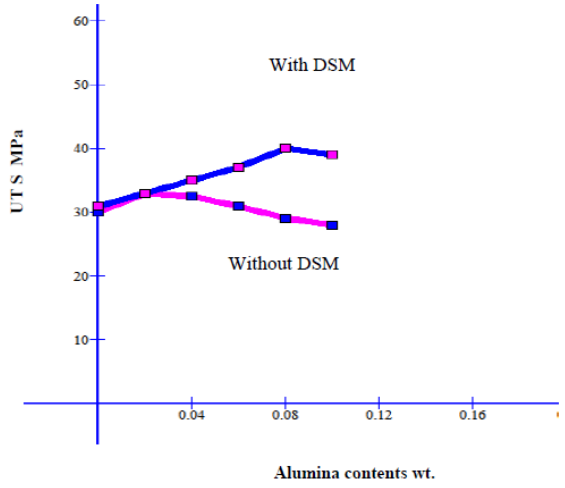

Figure 3 Relationship between the tensile strength and Alumina Microfibers contents

3.4 Impact Strength

Figure 5 shows how raising the weight ratio of alumina microfibers from 2% to 8% wt increases impact strength. The fracture will change its direction and shape as a result of the fibers restricting the expansion of the crack by the materials composite and the dislocation; thus, cracks will become micro cracks. Toughness is increased as crack behavior changes and crack energy is lost. On the other hand, raising the quantity of alumina microfibers to 10% reduces the sample's impact strength due to brittle fracture mechanisms caused by agglomeration of the reinforcing phase. On the other hand, the dispersion process leads to a greater improvement in impact strength because it effectively inhibits crack propagation by spreading homogeneously in all directions of the composite sample and preventing reinforcement material aggregates, which in turn prevents brittle fracture. [31]

4. Conclusions

We concluded from this study that adding alumina microfibers in appropriate ratios improves the mechanical properties of PP composites, while increasing the ratios decreases the mechanical properties of these composites. We also concluded that using the dispersion process for alumina microfibers through PP matrix improves the mechanical properties of PP composites.

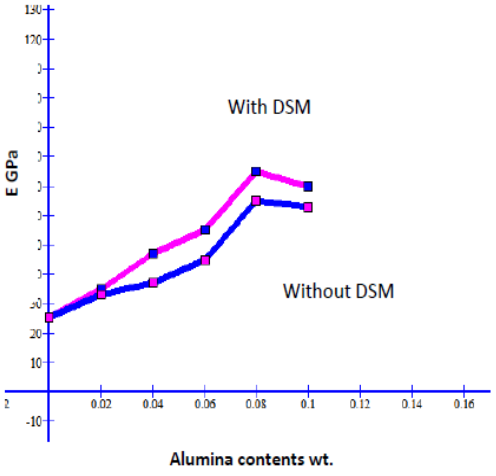

Figure 4 Relationship between the Young's modulus and Alumina Microfibers contents

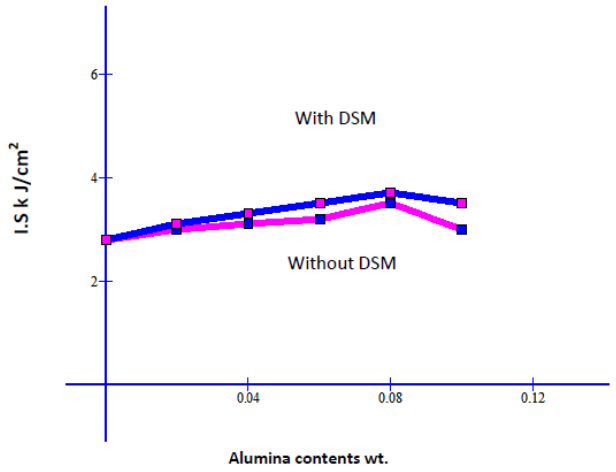

Figure 5 Relationship between the Impact strength and Alumina Microfibers contents

Acknowledgments

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