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The Role of Dioctyl Phthalate (DOP) Fillers to Improve The Mechanical Characteristics of Polyurethane Polymer Composite Materials

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ABSTRACT
An investigation was conducted to analyze the impact of incorporating Dioctyl Phthalate (DOP) at different weight ratios (5, 10, 15, 25, and 35) on the mechanical properties of the polyurethane polymer. The mechanical properties of the tensile and bending strengths were measured using a universal machine. The results indicated that increasing the Dioctyl Phthalate (DOP) ratio leads to an increase in tensile strength at a ratio of 7 wt.%, with values equal to 2.81 MPa. The obtained results showed that the addition of Dioctyl Phthalate (DOP) led to a reduction in the spaces between the polymer chains, which reflects the high ability of the polymer against the applied stress. The degree of homogeneity is high between polymer and additives, also the results indicate an increase in bending resistance at a percentage of 7 wt.% DOP, reaching 29 MPa.

Keywords: polyurethane foam; Dioctyl Phthalate (DOP); mechanical properties; polymer.

INTRODUCTION
Polyurethane is one of the important polymers in many applications, and Tritosil Polyurethane is one component with highly resistant to seawater-diluted acids and alkalis, odorless, Non-sag, moisture-cure polyurethane sealant designed to skin and cure rapidly, outstanding UV resistance, and long-term durability. The PU is widely used in several industries, including construction, packaging, and furniture. The remainder of the polyol chain, which is flexible, and hydrogen bonds, which are rigid, make up polyurethane [1-2]. Since the Inflexible PU foam's hardness rises with density, foam with better properties is produced. More specifically, an increase in density of (1000 g/cm^3) suggests an increase in hardness of approximately (100 Pa), adding fillers to polymers is a rapid and inexpensive approach to changing the properties of basic materials; as a result, the mixture (polymers with fillers) was and still is of interest to interest of researchers in the field of scientific research, particularly in the industry [3-4]. Fillers are solid materials added to polymers to improve mechanical properties and reduce cost, and they have the opposite effect of plasticizers in that they minimize ductility and elongation rate while increasing tensile strength and Young modulus, or know that they are organic or inorganic materials added to the polymer. It can either be used to increase the volume of the plastic material, lowering the cost of usage (inert fillers), or it can be used to improve mechanical qualities (effective fillers) [5-7].

When certain fillers are added to polymers or a mixture of similar polymers to form a new polymer, a new system is formed that differs in its attributes and characteristics in terms of performance and has an appropriate and relatively low cost, but when chemically different polymers are mixed, the final product lacks integration and compatibility and does not have good characteristics [8-10]. The choice of filler and compatibility with the polyurethane matrix play an important role in determining the success of the material for a particular application. As research progresses, new fillers and processing methods continue to emerge that increase the potential of polyurethane-based composites in various industries, from automotive to construction.

EXPERIMENTAL
Materials and Methods
The trimethylamine (TEA) was used as a catalyst in the reaction of 1:1 weight percent isocyanate and polyol provided by Sigma-Aldrich Company. The raw materials for preparing polyurethane (isocyanide and commercial polyester polyol) were dissolved in a commercial organic solvent to prevent the materials from hardening and to increase the time required for manufacturing different ratios of Dioctyl Phthalate (DOP) waste from (General Company for Petrochemical Industries) (0,1,3,5,7) were added to the reaction mixture of 1:1 (polyester polyol: isocyanides) and mixed well for 15 minutes until complete homogeneity was achieved, after which the miture is poured into moulds for

measuring mechanical properties[11-12]. Samples of a polyurethane mixture with Dioctyl Phthalate (DOP) were prepared at laboratory temperature. Different weight percentages of powder of coal (1, 3, 5, and 7) wt.%, were added to the polyurethane to form a mixture of polymer and fillers. After that, the final product of the mixture was placed in a rectangular mold, and Figure 1 displays the measurements of the dimensions of the sample.

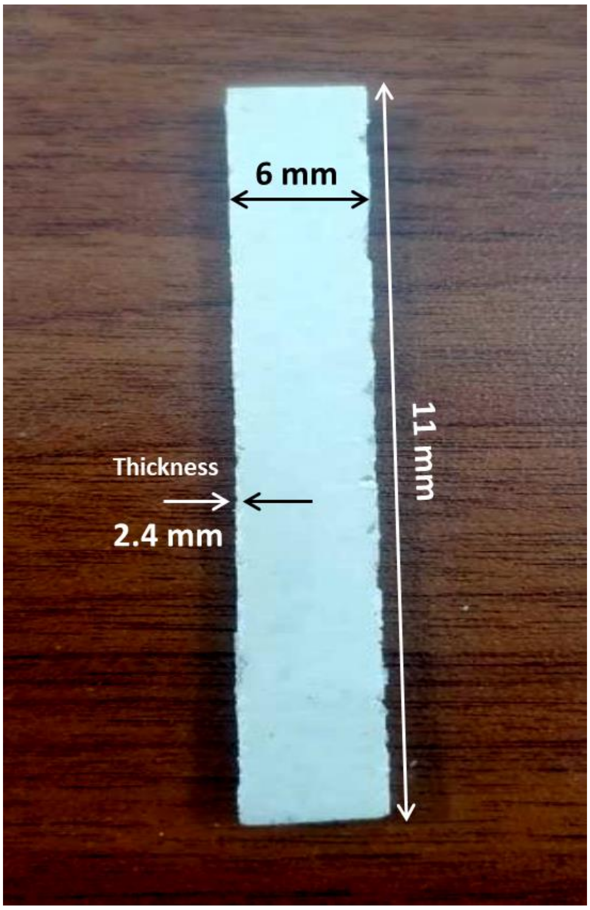

FIGURE 1: The rectangular sample for the compressive strength, tensile strength test.

Mechanical and thermal properties measuring devices

A tensile instrument (Zwick Rell) manufactured in Germany, which measures the mechanical properties (tensile strength, compression resistance, and bending resistance), was used to test the polymer models shown a Figure 2. The mechanical properties measuring device (Tensile). Using the equation below, the tensile strength (Q) of the materials can be calculated:

$$Q = \frac{F\,(N)}{A\,(mm^2)}$$

Where, F – cutting strength (Newton), A – sample area (mm^2).

The relationship (elasticity modulus) Y=Stress/ Strain (MPa) was used to compute the Young modulus.

FIGURE 2: Mechanical properties measuring device (Tensile).

RESULTS AND DISCUSSION

The empirical results indicate a decrease in the tensile strength behavior at the 0 % percentage, with a value of 2.56 MPa [13], which indicates that the polymer mixture at this percentage has high elasticity. While the polymer at a percentage of 1 %, the tensile strength is high, reaching 2.77 MPa, as shown in Figure 3. Whilst the practical results indicate that the maximum tensile strength was at 7 %, with a value of 2.81 MPa. This showed that DOP at this percentage improves the rigidity through homogeneous distribution between the polymer chains in this mixture, thus enhancing strength. The tensile strength has a direct relationship with the percentage of fillings, especially at weight percentages of 1 % and 7 %. Experimental results indicate a direct relationship between the weight percentages of DOP and tensile strength behavior, indicating that increasing the weight percentages of fillers enhances the hardness of the mixture [14-16].

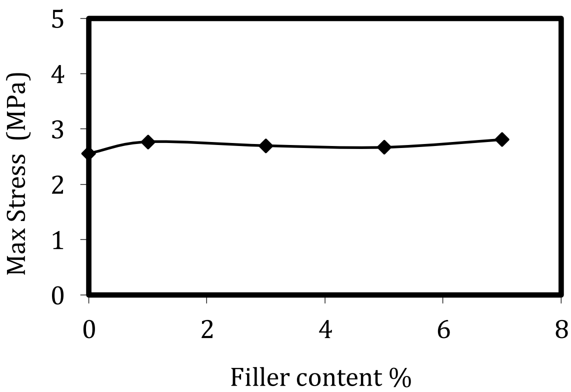

FIGURE 3: The relationship between tensile strength and weight ratios DOP additive to the polyurethane polymer.

Figure 4 presents the relationship between elongation (%) and filler content (%) for polyurethane polymer incorporating various weight ratios of the plasticizer dioctyl phthalate (DOP). The results indicate a gradual increase in elongation from 0% to 4% filler content, followed by a sharp rise between 6% and 8%, where elongation reaches approximately 30%. This behavior can be attributed to the action of DOP as a plasticizer, which reduces intermolecular attractions between polyurethane chains, increases free volume, and enhances chain mobility, thereby improving flexibility and ductility. At low filler contents (≤4%), the plasticizer amount is insufficient to produce substantial structural changes, leading to only minor improvements in elongation. In contrast, higher filler contents (6–8%) provide enough DOP to significantly separate polymer chains and reduce secondary bonding forces, resulting in a marked increase in elongation. It should be noted that in typical polymer–plasticizer systems, excessive plasticizer may lead to a decline in tensile strength due to overly weakened intermolecular interactions [17]. However, in the present study, such deterioration is not observed up to 8% filler content, indicating that the investigated range remains within the optimal enhancement zone for flexibility.

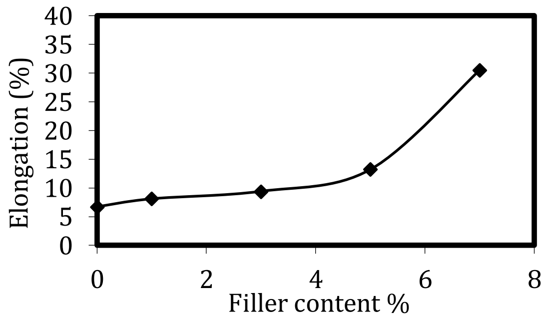

FIGURE 4: The relationship between elongation and weight ratios DOP additive to the polyurethane polymer.

Figure 5 depicts the effect of DOP on the Young modulus (elastic modulus). The modulus of elasticity is the maximum stress to maximum elongation. The experimental results showed the largest value of the Young modulus at the percentage (0 %), which is (0.38) MPa, while the lowest value of the Young modulus at the ratio (7 %) is (0.09) MPa. There is a negative effect on the modulus of elasticity when the filler (DOP) content is increased, because the filler decreases the hardness of the polymer, and therefore its elasticity increases [18].

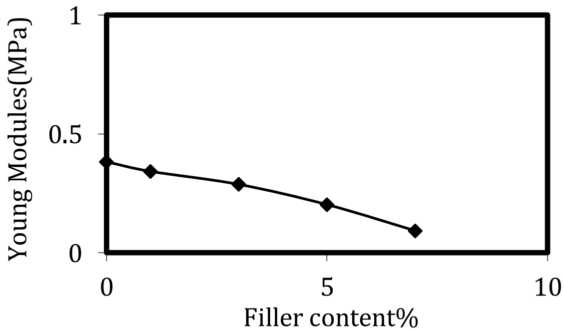

FIGURE 5: The relationship between Young modules and weight ratios DOP additive to the polymer.

Figure 6 illustrates the relationship between bending resistance (MPa) and the filler content of Dop incorporated into polyurethane polymer. The results indicate that adding a small amount of filler (up to approximately 1%) leads to a noticeable increase in bending resistance, which can be attributed to the improved stress transfer within the polymer matrix due to the uniform dispersion of fine DOP particles acting as micro-reinforcements. When the filler content increases to around 2–3%, the bending resistance decreases significantly. This drop may be caused by particle agglomeration and poor interfacial adhesion between the filler and polymer matrix, leading to stress concentration points and premature mechanical failure. However, at higher filler loadings (>3%), the resistance increases again, reaching its peak at around 7%. This enhancement could be attributed to the formation of a continuous supporting network of rigid filler particles within the matrix, which improves stiffness and bending resistance[15,19].

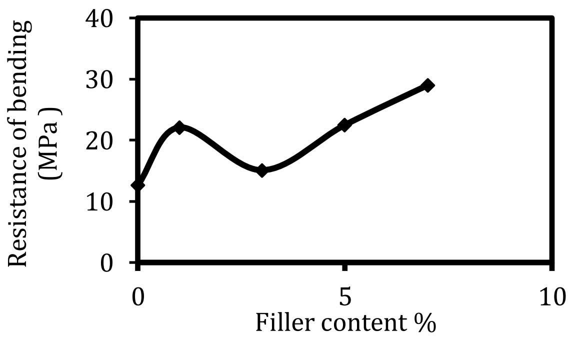

FIGURE 6: The relationship between bending resistance and weight ratios of DOP added to polyurethane polymer.

CONCLUSION

The values of the mechanical properties of the tensile and bending strengths increase with the increase in the weight percentage of the materials added to the polymer, special at the ratios (3,7) wt.%. The results indicated that increasing the Dioctyl Phthalate (DOP) ratio leads to an improvement in tensile strength increase at a ratio of 7 wt.%, with values equal to 2.81 MPa. The obtained results showed that the addition of Dioctyl Phthalate (DOP) led to a reduction in the spaces between the polymer chains, which reflects the high ability of the polymer against the applied stress. The degree of homogeneity is high between polymer and additives, also the results indicate an increase in bending resistance at a percentage of 7 wt.%, reaching 29 MPa.

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