International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Preparation and Study of Mechanical Properties of Polyurethanes with Different Waste Wax Ratios

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Abstract**—***This study investigates how adding an additive with a lower thermal conductivity than polyurethane influences the thermal and mechanical behavior of polyurethane-based composites. The results demonstrated a significantly lowered thermal conductivity, improving this material for potential applications that require an effective thermal insulation material. In terms of mechanical performance, the addition of the filler caused notable enhancements: bending resistance increased linearly with increasing additive content added, and at a 5% filler content, the compressive strength was 4.92 MPa, which was the average max value obtained. Furthermore, at 7% additive, the modulus of elasticity increased substantially versus control indicating greater stiffness. Furthermore, the addition of wax as a modifying agent in situ to five varying concentrations achieved overall improvement in the properties of the original polyurethane matrix at each concentration, improving the structure's performance. Overall, these improvements combined suggest that modified polyurethane composites will function well in a range of novel and functional advanced industrial uses.*

Keywords**—** *Thermal conductivity, polyurethane, mechanical properties, polyester polyol, wax waste, tensile strength, bending.*

I. INTRODUCTION

Polyurethane (PUs) is a versatile polymer that is widely used in various applications due to its favorable mechanical properties, chemical resistance, and flexibility. They are produced by the polymerization of diisocyanates with polyols, resulting in a variety of materials that can be adapted for specific uses. The inclusion of fillers in polyurethane formulations has emerged as an effective strategy for improving mechanical, thermal, and other physical properties, leading to improved performance in practical applications. Fillers are materials added to polymers to improve their properties or reduce costs. When applied to polyurethane, the filler can significantly improve mechanical performance by increasing strength and stiffness: Fillers such as glass fibre, carbon fibre, and mineral fillers can increase the tensile strength and stiffness of polyurethane composites, making them suitable for load-bearing applications. Improving toughness and impact resistance: Some fillers can help improve the impact resistance of polyurethane, which is critical in applications where mechanical shocks are common. Improved thermal stability:

The addition of high thermal resistance fillers helps to increase the thermal stability of polyurethane and is suitable for high-temperature applications. Reduce shrinkage and deformation: The filler helps to reduce the shrinkage and deformation that may occur during the curing process of polyurethane. Cost savings: The inclusion of inexpensive fillers helps to reduce production costs while maintaining acceptable mechanical properties. Depending on the desired qualities of the finished product, the filling selection is crucial. Common types of fillers used in polyurethane formulations include: Mineral fillers: talc, calcium carbonate, and clay are used to increase hardness and reduce production costs. Due to their high aspect ratios, they can have beneficial effects on machine performance.

Fiber filling: Glass fiber and carbon fiber are used to increase strength and hardness. These fibers are aligned in a polymer matrix, which provides excellent mechanical reinforcement. Nanofillers: Nanomaterials such as carbon nanotubes and Nano clays can be incorporated into low loads to achieve a remarkable increase in mechanical strength and thermal properties. Rubber particles: The addition of rubber particles can increase the toughness and elasticity of polyurethane, which is especially useful in applications requiring flexibility and impact resistance. Result

The inclusion of fillers in polyurethane formulations is a well-established technique for improving their mechanical properties and overall performance. 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.

II. INSTRUMENTATION AND METHOD

The polyester polyol and isocyanides used in this study were purchased as a basic material by (Henkel A.S.) company, Turkey, wax waste from the State Petrochemical Company/Barah / Iraq. from the State Petrochemical Company/ Basrah /Iraq, sample dimensions (length 110 mm, width 15 mm, height 4 mm) Elongation was tested at fracture, tensile strength, and bending, and examined using a German-made instrument (tensile) to measure tensile strength, flexibility, and pressure resistance, Figure 1. Showed the tensile strength test sample and mechanical properties measuring device (Tensile).

Figure 1. tensile strength test sample and mechanical properties measuring device (Tensile).

Preparation of samples

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 wax 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 mixture is poured into moulds for measuring mechanical properties.

Mechanical properties

- Tensile strength

Tensile strength is defined as the stress applied to the model and stress is defined as the force that causes deformation in the unit area of the model under examination, that is, it is the force applied to the unit area of the cross-section of the model.

In the current study, the tensile strength of the polyurethane mixture was evaluated for the percentages of wax waste, where we notice from Figure (2) that the tensile strength at the percentage (0%) of the polymer, which is (Mpa 2.74), i.e. we notice from the figure below the behavior of the tensile strength is of a high effect at the ratio (0%) for the polymer and then begins to decrease at the ratio (1-5%) for fillings (wax) that (wax) works to decrease the hardness at the mixture, so the polymeric chains are unrestricted, so its flexibility increases, but The tensile strength behavior of the compound increases when the percentages of the fillers are increased to reach their greatest value at the percentage (7%), which is (Mpa 3.37), i.e. the filler at this ratio improves the hardness property by the effect of the homogeneous distribution of the material of a solid nature, as it works as fillers by affecting the polymer[1,3].

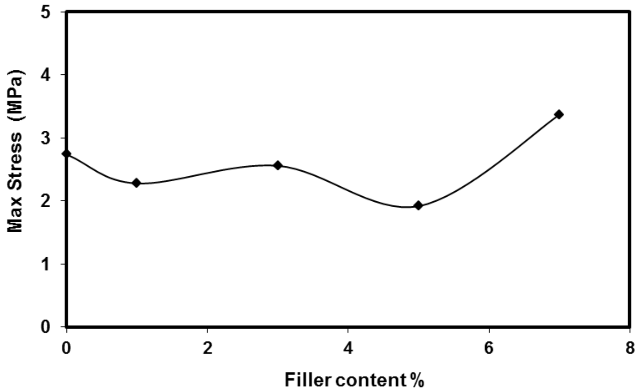

Figure 2. The relationship between the tensile strength and the concentration of the wax additive of the polyurethane polymer.

-Elongation

Figure (2) shows the relationship between the percentage of elongation in the model with the concentration of the additive, that the elongation of the polymer begins at the percentage (0%) of the pure polymer, which is (3.6%) and then decreases at the percentage (1%), which is (2.6%) The polymer is slightly flexible at this ratio, so the fillings fill the spaces between the main chains of the polymer, which hinders and limits the movement of the chains, thus reducing the elongation and then increasing when the percentage of the concentration of the additive E increases at the ratio (7%) and the polymer at this ratio is high Flexibility Because at this ratio of fillers, the polymeric chains are unrestricted, i.e. they are free to move as a result of the homogeneous distribution of the material of a solid nature, as they act as fillers by acting on the polymer and thus increase the elasticity of the polymer [2,4].

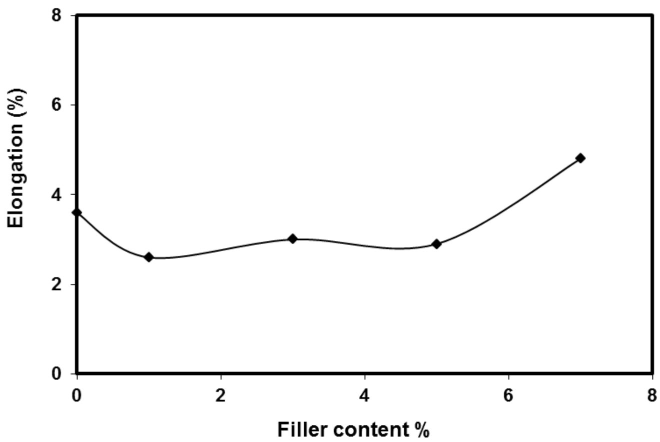

Figure 3. The relationship between elongation and wax additive concentration of polyurethane polymer.

-Young modulus

Figure (3) shows the effect of alum powder on the elastic modulus (Young's modulus), which is defined as the ratio of stress to elongation of solids only, and it is clear from the figure that the Young coefficient decreases at the weight ratios of wax fillings confined between (0%-1%), and this leads us to that wax fillings increase the elasticity of the polymer, then the Young coefficient increases to reach the maximum value (MPa 0.87) at the ratio (2%), and may explain the decline in the Young coefficient at the ratio (5%) for the added to the heterogeneity of the model despite This indicates that the polymer has a high elasticity and a lack of hardness at this ratio, and these results are consistent with much other research in this field[5-8].

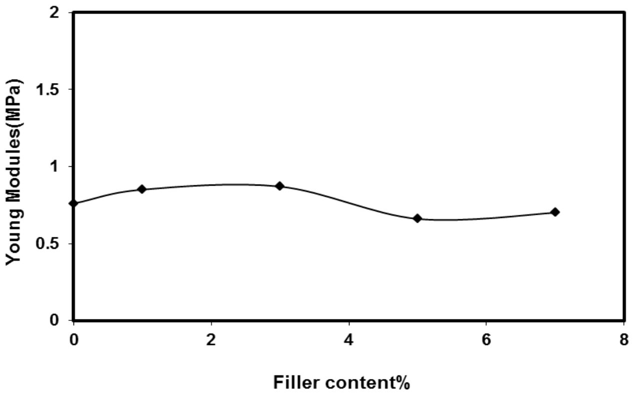

Figure 4. The relationship between the young modulus and the concentration of the wax additive of the polyurethane polymer.

Figure 4 shows the effect of the concentration of wax fillings on the compression coefficient, which is a measure of a material's ability to withstand compressive forces acting perpendicular to solids. Where the value of the pressure coefficient at the percentage (0) % is significantly low, with a value of (1.18 Mpa). But the compressive resistance behavior increases when the percentage of fillers increases until it reaches the highest value, which is (4.92 Mpa) at the percentage (5) %, and this has led to the realization that the wax additive and through the homogeneous interphase with the polymer chains, it affects the hardness of the polymer, i.e. increases the ability of compressive resistance. However, the behavior of the polymer begins to decrease at the high percentages of the additive, especially at 7%, where the compressive strength of (3.09Mpa) was recorded. This may be due to the formation of excessive bubbles, which makes the molecular structure of the compound easier to collapse and thus the ability of the compound to withstand the forces exerted on it is more quickly lost, thus reducing the compressive strength [2].

-Bending resistance

Figure (5) shows the relationship between the bending resistance and the added ratio of wax fillings. The pure polymer exhibits a bending resistance of 14.6Mpa, which means that it is more flexible than other samples but less rigid. Low elasticity and high rigidity result from added filler, limiting the movement of polymer chains [14]. This is shown at the high percentage of fillers, especially 7%, where the bending resistance value is (49.8Mpa) when there is high compatibility between the filler and polymer chains. However, polymer molecules bind well with high percentages of additives and thus increase the bending resistance value at high compound ratios. [1]

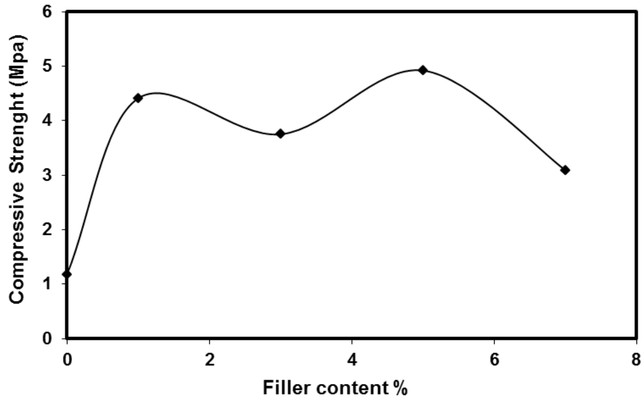

Figure 5. The relationship between the young modulus and the concentration of wax additive of polyurethane polymer.

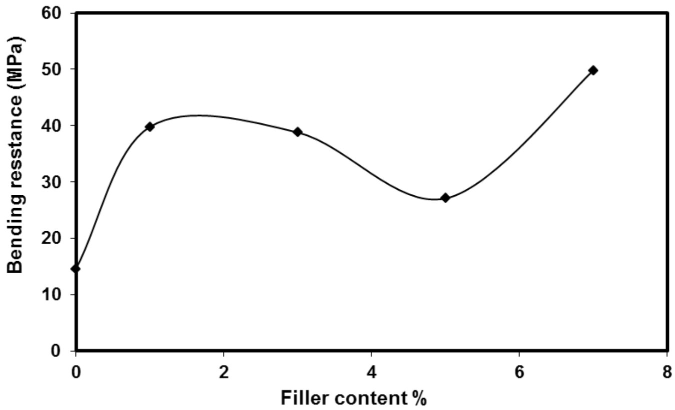

Figure 6. Relationship between bending resistance and wax additive concentration of polyurethane polymer.

-Thermal conductivity

Figure (6) shows the relationship of thermal conductivity with the weight ratios of polyurethane wax fillers. The variation in the results is sometimes attributed to the heterogeneous distribution of the fillings with the polymer, which leads to asymmetry in the number of gaps per unit volume and, consequently, the difference in the results, resulting in different thermal conductivity coefficient values for some unit series samples. The figure also shows that the coefficient of thermal conductivity decreases with increasing the weight ratio of additives and that the coefficient of thermal conductivity of pure polymer (without any addition) has the lowest value, which is (W/mºC 0.105), then it begins and decreases with increasing the concentration of the additive, especially at (3%), which is (W/mºC 0.077) [9]. The decrease in the coefficient of thermal conductivity of the polymer with increasing filler concentrations is due to two main reasons: the first is that increasing the concentration of wax fillings with the polymer increases the gaps and pores within the sample. Secondly, additives have a lower coefficient of thermal conductivity than polyurethane, so they reduce the coefficient of thermal conductivity of the resulting samples [11-10]. This leads us to the fact that the models have the characteristic of thermal insulation and this is useful in many applications that require high thermal insulation.

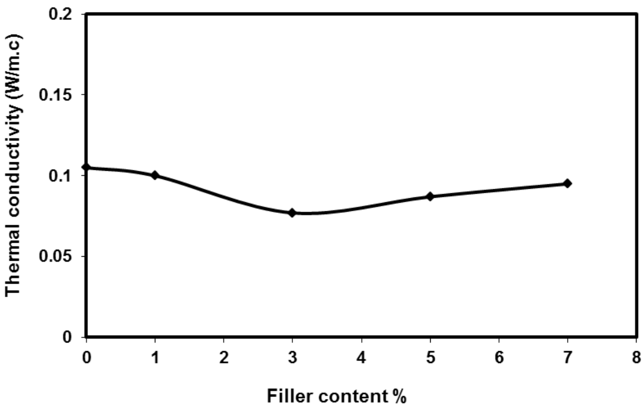

Figure 7. The relationship between thermal conductivity and wax additive concentration of polyurethane polymer.

III. CONCLUSION

The effect of additives with a thermal conductivity lower than polyurethane reduces the thermal conductivity of the prepared samples, making it possible to use the prepared models in many applications that overcome these specifications. The bending resistance increases at high additive ratios, and the compressive resistance behavior increases with the additive ratio until it reaches the highest value of 4.92 MPa at a ratio of 5%. At high ratios of 7% of the filler, the modulus of elasticity of the prepared models increases, and we notice a change in the properties of polyurethane with the addition of the additive (wax) at different ratios, which improved some important mechanical properties, making it possible to use polyurethane in a range of important applications.

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Zainab J. Sweah, Ahmed J. Mohammed, Ziyad T. AL-Malki, Ibrahim Kadim. A., and Sukaina Abod Hameed Al-ali, "Preparation and Study of Mechanical Properties of Polyurethanes with Different Waste Wax Ratios," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 8, Issue 1, pp. 766-769, 2025.