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Influence of Natural Filler Powder on the Some Physical Properties of Polyurethane Foam Composites

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ABSTRACT: An investigation was conducted to analyze the impact of incorporating perlite stone powder particles at different weight ratios (5, 10, 15, 25, and 35) on the polyurethane polymer's mechanical properties and thermal conductivity coefficient. The thermal conductivity coefficient of the samples was calculated using Holmarc's Lee's Disc apparatus device. The mechanical properties like compressive, tensile, and bending strengths were measured using a universal machine. The results indicated that increasing the perlite stone powder ratio leads to an improvement in the thermal insulation ability due to a decrease in the value of thermal conductivity, the addition of perlite stone powder enhances the ability of thermal conductivity at the ratio 5 wt. %, with a value equal to 0.106 W/m ºC, by increasing the thermal conductivities of the sample, while the result indicated a decrease in the thermal conductivity at the ratio 25 wt. %, with a value equal to 0.075 W/m ºC. Also, adding these percentages led to a rise in the values of the mechanical qualities represented by the flexural resistance, especially at the ratio of 10 wt. %, with a value equal to 33.9 MPa, and tensile strength increases at a ratio of 35 wt—%, with values equal to 2.57 MPa.

KEYWORDS: polyurethane foam, perlite stone powder, mechanical properties, thermal conductivity, polymer.

INTRODUCTION

Polyurethane 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]. 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) [2]. 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[3]. Adding materials (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 [4]. 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 [5-7]. 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) [8-10]. This research aims to make polyurethane composite polymers with the addition of perlite stone powder. This additive is unique in that it is widely available, and has no economic cost.

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MATERIALS AND METHODS

The trimethylamine (TEA) was used as a catalyst in the reaction of 1:1 weight percent isocyanate and (polyester-polyol) provided by Sigma-Aldrich Company. Polyurethane was prepared, also added drops of water to release carbon dioxide, which worked to generate cellular gaps inside the mass of the mixture. As filler, perlite stone was used. Large perlite stone pieces were initially collected and then cut into smaller pieces. Then, using an electric grinder of French origin, the small stone pieces were ground into a powder. The powder was put through a wire sieve (an American company, ATM Corp.'s Allen-Bradley Sonic Sifter Model L3P), producing a fine-grained, ultrafine powder with particle sizes of about (125 µm). The perlite stone is shown in Fig. 1

Figure 1: perlite stone.

The Polyurethane samples were prepared with perlite stone powder at laboratory temperature. Then, we have been added different weight ratios (5, 10, 15, 25, and 35) wt% of perlite stone powder to the polymer mixture. The mixing procedure was continued for the mixture was evenly distributed, then, the final product was poured into a cylinder mold, circular and rectangular. Fig.2 shows the Tensile, thermal conductivity and compressive strength test samples [16].

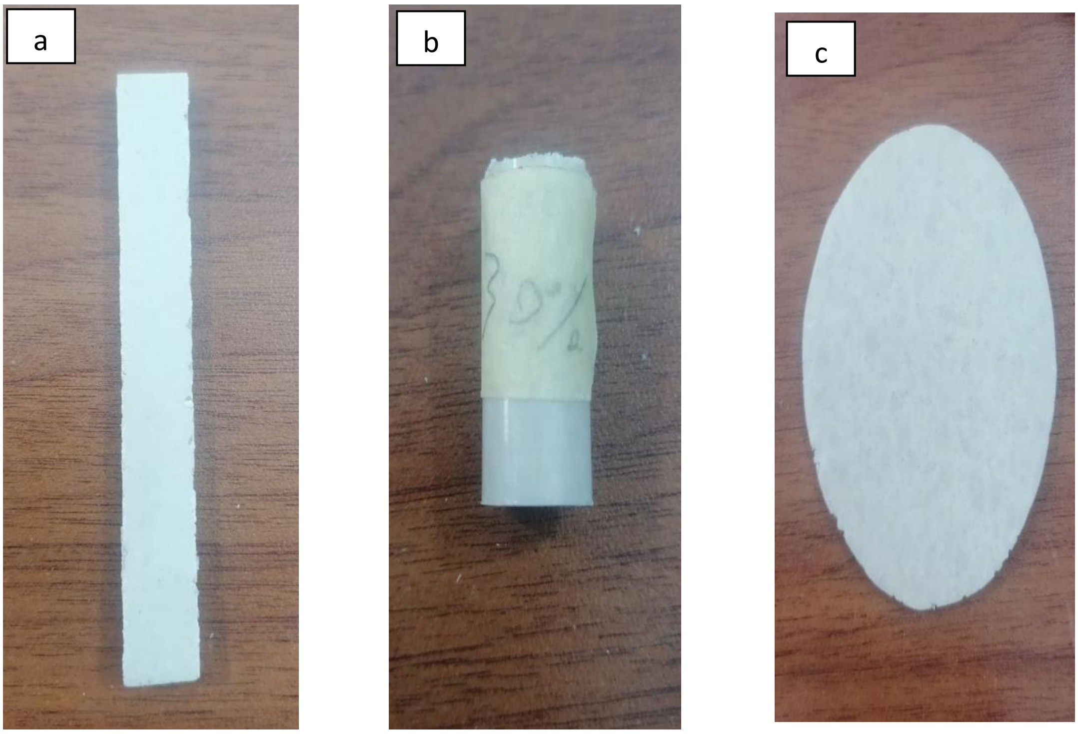

Figure 3: Tensile, thermal conductivity and compressive strength test samples: (a) rectangular slab, (b) cylindrical, (c) circular.

Evaluation of mechanical and thermal properties

A German made tensile instrument (Zwick Rell, type (BTI-FR2.5 TN.D. 14), which measures the mechanical properties (tensile strength, compression resistance, bending resistance), was used to test the polymers models show a Fig.3. The mechanical properties measuring device (Tensile). Tensile strength(Q) can be calculated using Eq. (1).

$$Q = F / A \ (N / mm^2) \qquad (1)$$

Where, F is cutting force (Newton), A is cross-sectional area (mm2).

The relationship (Young's modulus) Y = (Max Stress) / (Max Strain) (MPa)

Was used to compute the young modulus.

The thermal conductivity coefficient (K) of the samples was calculated using a done by the Holmarc’s Lee’s Disc apparatus model HO-AE-LD18 (Kochi, India, Holmarc Opto-Mechatronics Ltd manufactures). Fig.3. b shows the Hilmarc’s Lee’s Disc apparatus for thermal conductivity measurement. Eq. (2) was used to calculated thermal conductivity (K) using Fourier's law.

$$K = -\frac{q\,x}{A\,\Delta T} \quad (2)$$

Where: K is thermal conductivity (W/m.K°), q is Heat energy (W), T is temperature (°K), x is thickness of test specimen (m), and A is area of test specimen (m2).

At the steady state, the thermal conductivity K is calculated using Eq.(2).

$$K = \frac{MC\,\frac{dT}{dt}}{\pi\, r^2\,(T_2 - T_3)} \times \frac{(r+2h)x}{2(r+h)} \quad (3)$$

Where, M is mass of the metallic disc, C is specific heat capacity of the metallic disc, h is height of the metallic disc, r is radius of the metallic disc, $\frac{dT}{dt}$ is rate of cooling of the metallic disc at T3, (T2 – T3) is the temperature difference across the sample thickness (x), Diameter = 76.2 mm, Thickness = 4 - 6 mm for Sample dimensions

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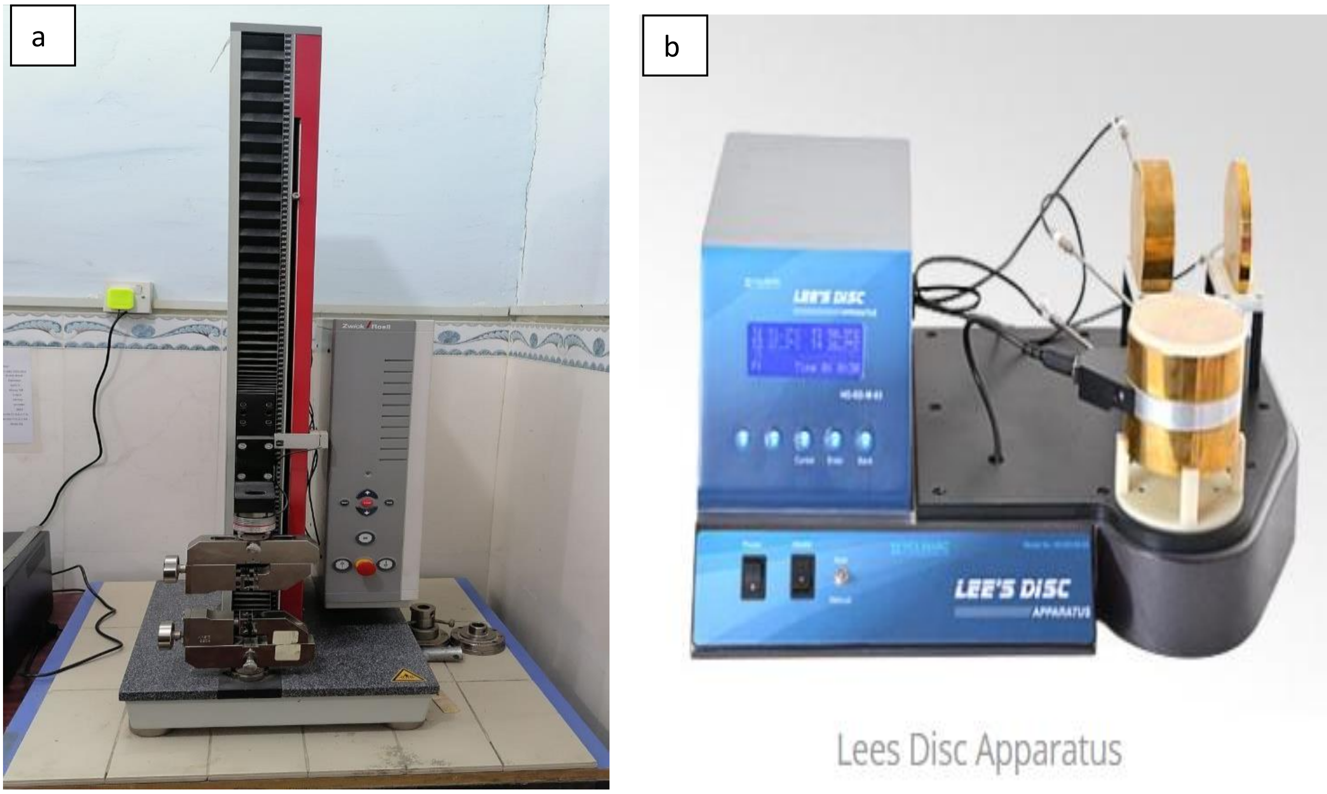

Figure 3: Equipment is used to assess the samples: (a) mechanical properties measuring device (Tensile), (b) The Hilmarc’s Lee’s Disc apparatus for thermal conductivity measurement.

RESULTS AND DISCUSSION

The relationship between the tensile force (stress force) and the proportion of the polymeric additives is depicted in Figure 4. At lower filler content levels as low as ratio (10%), there was a modest reduction in tensile strength, however at higher filler content levels from ratio (20%), the maximum strength is comparable to that of ratio (25%). This is because the additive powder is distributed uniformly throughout the polymeric chains. However, the maximum strength decreases with greater percentages. The ratio (25%) of the powder additive was best for the mixture's hardness, estimated at to (2.64 MPa)

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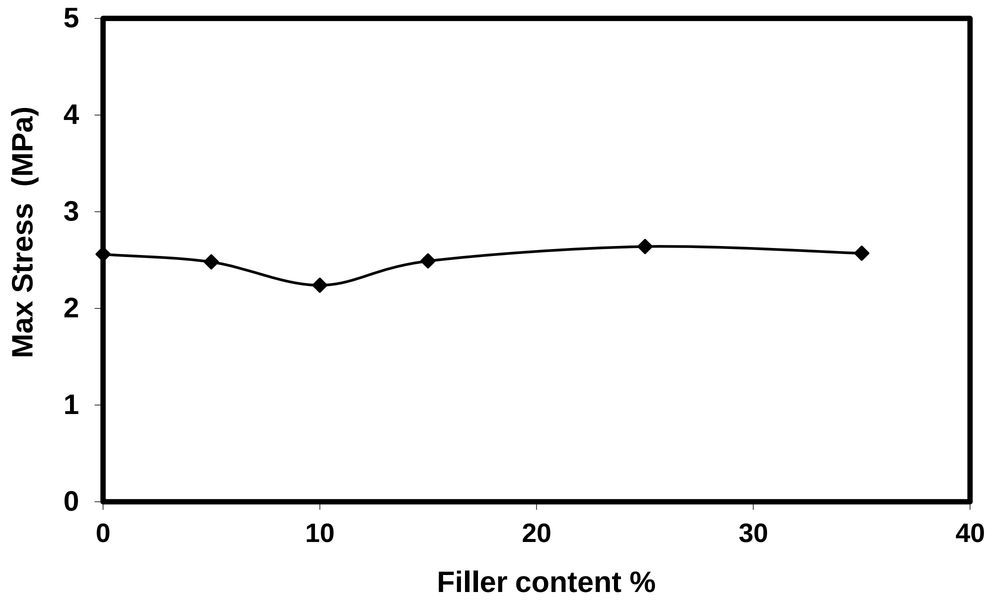

Figure 4: The relation between tensile strength and the filler content.

Figure 5 shows the polymer elongation model with concentration. With rising perlite stone powder percentages, the effect of filler addition on the polymer's elongation % became less pronounced. The elongation reduced as the polymer filler concentration rose because the particles filled the gaps between the polymeric chains, preventing and restricting the mobility of those chains. The ratio (0%) is best for the polymer's elasticity, while the lowest value of elongation is (1.7 MPa) at the ratio (15%).

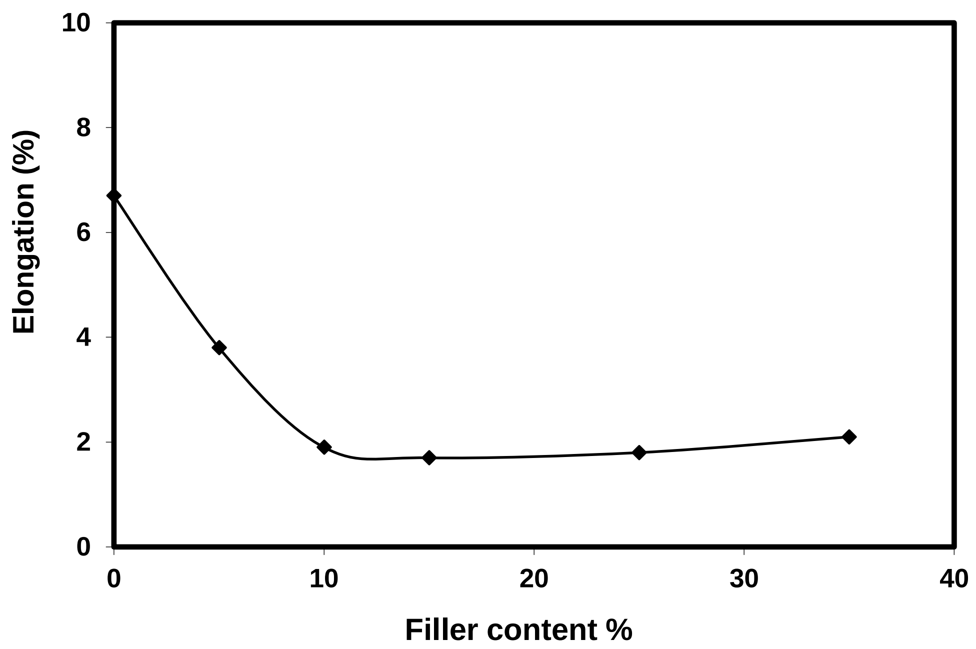

Figure 5: The relation between elongation and the filler content.

Figure 6 shows how perlite stone powder affects the Young modulus, which is the ratio of stress to strain for solids only and is defined as the elasticity modulus. In general, adding more filler had a beneficial effect on the elasticity modulus. Elasticity would be decreased while homogeneity would be increased since the powder increases the polymer's hardness. Possibly the decrease in the Young modulus is explained by the ratio (5%) for the additive to the heterogeneity of the mixture although the samples were mixed in the same conditions, the polymer chains are not limited to a certain ratio. The stiffness is low at this ratio, that is, it is free to move, and these results are consistent with many other pieces of research in this field. Figure 7, shows the effect of perlite stone powder on affects compressive coefficient, which is a measure of a material's capacity to withstand compressive pressures acting perpendicularly on solid materials. While the compressive modulus at 5% is at its highest value (4.45 Mpa), the compressive modulus at 0% is noticeably low, close to (1.08 Mpa). It has led to the realization that the additive, through a homogeneous interphase with the polymeric chains, imposes on the polymer's hardness. However, the behavior of the polymer begins to decline at high percentages of the additive, especially at the percentage of 35%, where the compressive strength was recorded by (1.8 Mpa). It may be attributed to excessive bubble formation which makes the walls easier to collapse

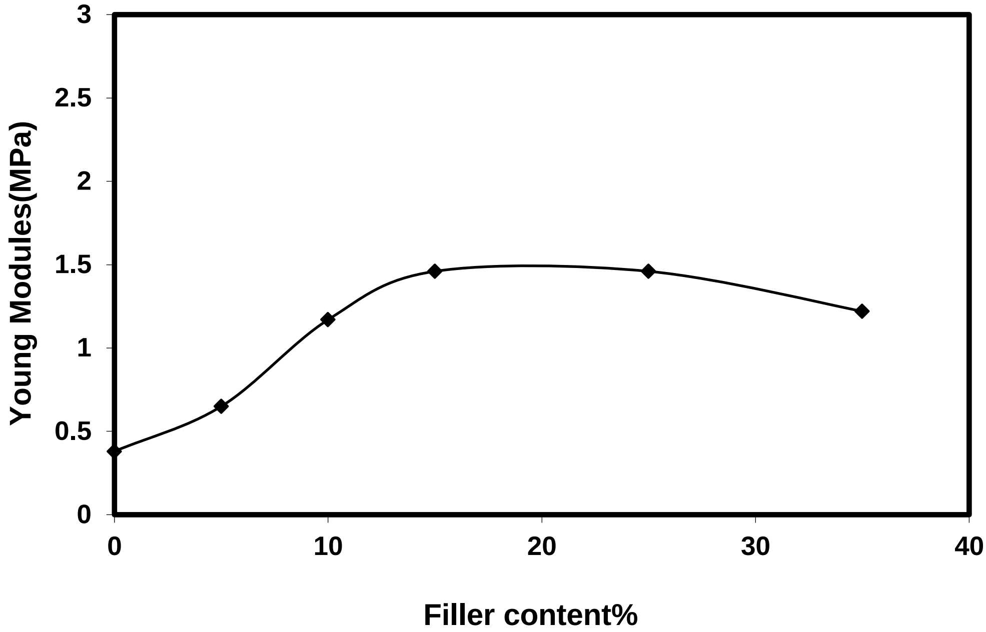

Figure 6: The relation between Young's modulus and the filler content.

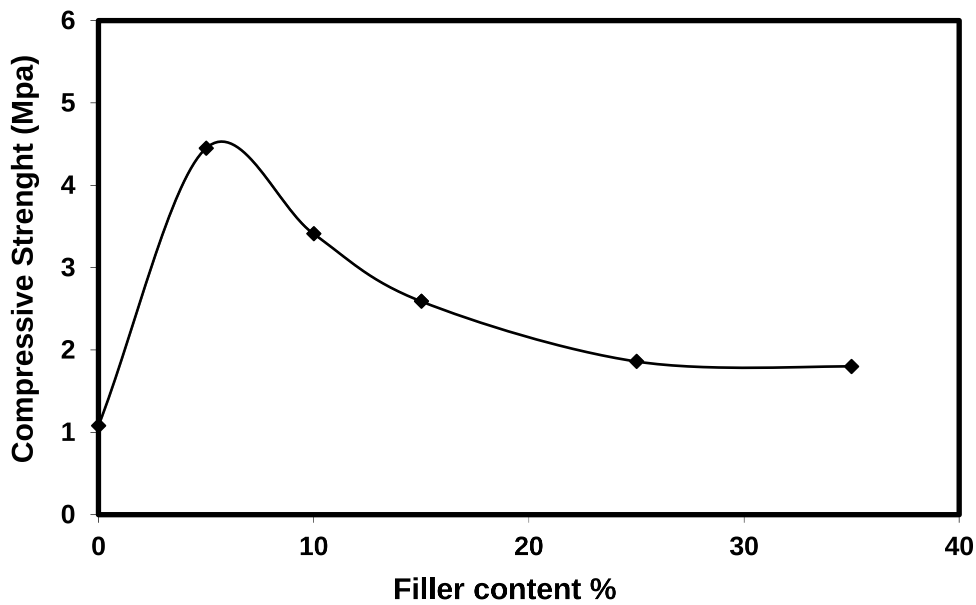

Figure 7: The relation between the compressive strength and the filler content.

Figure 8, depicts the relationship between bending resistance and additive percentage. The pure polymer exhibits a bending resistance of (12.6 Mpa), meaning that it is more elastic than the other samples but less rigid. Lower flexibility and higher hardness are caused by the rigid filler, which restricts the mobility of the polymer chains [14]. This discovery is readily apparent at a ratio of 10% when there is high compatibility between the chains of the filler and the polymer. Nonetheless, the additive particles dispersed uniformly as the percentage of additives increased

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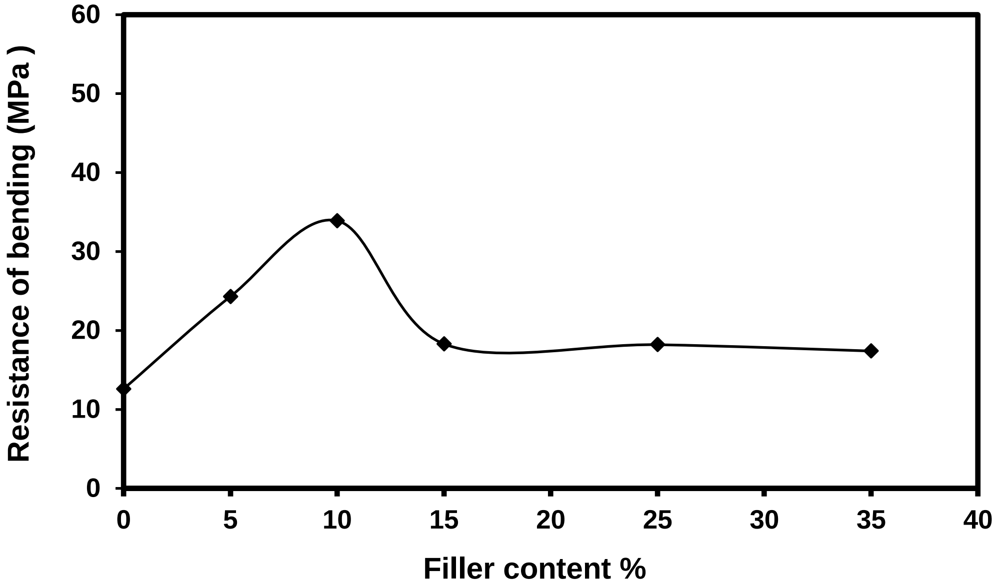

Figure 8: The relation between the bending resistance and the filler content.

Figure 9 shows the relationship between the thermal conductivity coefficient and the weight ratios of perlite powder and polyurethane. Practical results show that the values of the thermal conductivity coefficient decrease with increasing weight percentages of the polymer mixture, where the value of the thermal conductivity coefficient for the pure polymer has the lowest value, which is 0.018 W/m.kw, and after that, the behavior of the conduction coefficient begins to increase with increasing The concentration of the polymer additive, especially at the weight percentage (5%), is 0.106 W/m.ºK. The increase in the thermal conductivity coefficient of the polymer mixture is due to two main reasons: increasing the concentration of additives, which work to reduce the gaps and pores of the sample. Because these materials do have a small thermal conductivity coefficient, they increase the values of the thermal conductivity coefficient for the resulting samples of the polymer mixture

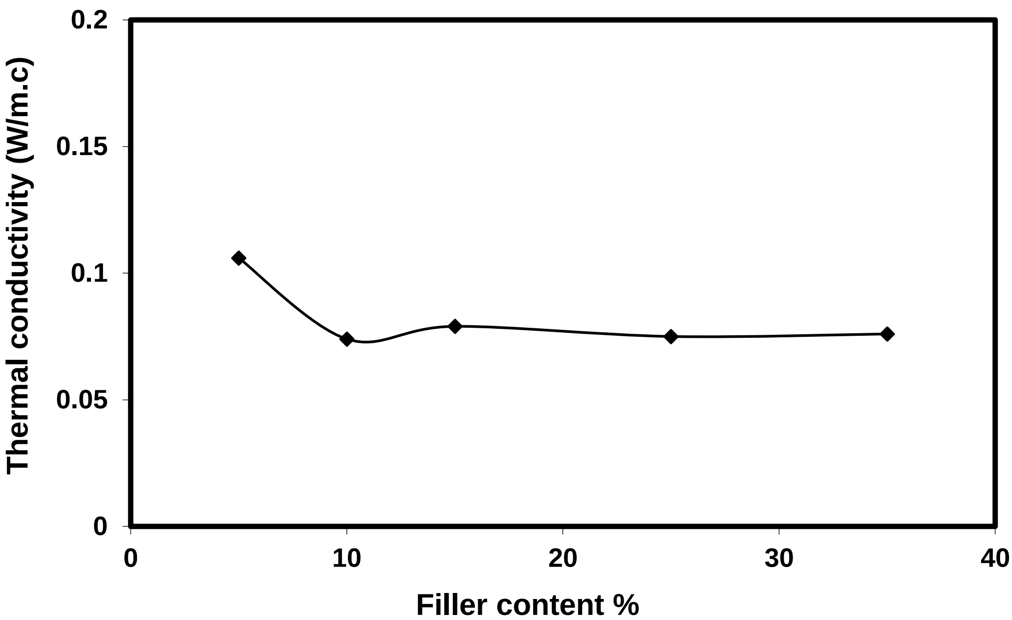

Figure 9 shows the relationship between the thermal conductivity and the filler content.

CONCLUSION

We conclude that adding perlite stone powder to polyurethane has a significant impact on the mechanical properties and thermal conductivity coefficient. The results indicated that increasing the perlite stone powder ratio leads to an improvement in the thermal insulation ability due to a decrease in the value of thermal conductivity, the addition of perlite stone powder enhances the ability of thermal conductivity at the ratio 5 wt. %, with a value equal to 0.106 W/m ºC, by increasing the thermal conductivities of the sample, while the result indicated a decrease in the thermal conductivity at the ratio 25 wt. %, with a value equal to 0.075 W/m ºC. Also, adding these percentages led to a rise in the values of the mechanical qualities represented by the flexural resistance, especially at the ratio of 10 wt. %, with a value equal to 33.9 MPa, and tensile strength increases at a ratio of 35 wt. %, with values equal to 2.57 MPa.

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