

## Study the Effect of Adding Vulcanized Rubber Powder on the Mechanical Properties and Fire Retardant of Polyurethane Polymer

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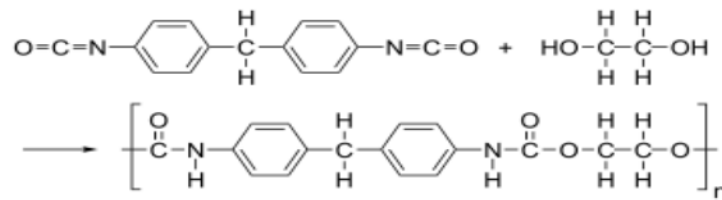
**Abstract:** The aim of the research is to study the mechanical and thermal properties of the blend (Polyurethane (TRITOSIL H10 PU)) and tire rubber powder (waste). The range of added tire rubber powder has the values (5%, 10%, 15%, 20%, and 25%) of Polyurethane (TRITOSIL H10 PU) weight. The practical results showed that adding filler decreases the spaces between the chains of polymer, reflecting the polymer's high ability to withstand the stress imposed on it, that the degree of homogeneity between each of the filler and polymer is high, and that increasing the concentrations of filler gives the prepared models a slight increase in hardness, especially at the ratio (25%). The results of the experiments showed that increasing the amount of used filler has a positive impact on heat diffusion through the polymeric matrix and flame resistance. The use of tire rubber powder as a filler has an impact on the properties of the polyurethane polymer, which has high mechanical properties. This increases tensile strength, which makes it appropriate to cover the flooring of indoor playgrounds, kids' playrooms, and in the manufacture of speed bumps (road bumps). Additionally, tire rubber powder (waste) was found to be appropriate as an additive to reduce elongation in a lot of applications where polyurethane (TRITOSIL H10 PU) is used.

**Keywords:** Polyurethane (TRITOSIL H10 PU), fillers, vulcanized rubber powder (waste), mechanical properties, fire retardant.

### 1. Introduction:

Natural polymers exist in many forms, such as animal horns, turtle shells, pine from pine trees, rubber, asphalt, and so on. Rubber is one of the most useful natural polymers that has been introduced into many human needs in his life, and a wide range of polymers can also be derived from the organic materials found in the raw material (Oil) [1]. The mixing of chemically similar polymers results in a polymer blend. This polymer has good physical properties and an economic cost. However, when mixing different polymers chemically, a new polymer is produced that has poor economic properties and costs. [2-5]. 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 researchers in the field of scientific research, particularly in the industry [6]. Polymers are sometimes filled with fillers to improve their physical, mechanical, and thermal properties, and the fillers are chemically inert materials that are used with a polymer to improve one or more of its qualities or to lower the cost of manufacture. The resulting mixture is known as composite polymers [7]. Antioxidants, fillers, anti-stable agents, coloring agents, plasticizing agents, stabilizers, and other additives are added to polymers to improve or introduce some desirable features. 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 reduce ductility and elongation rate while increasing tensile strength and young modulus. They are either 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, 9]. 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. Figure 1 shows the chemical composition of polyurethane. According to the literature [10], the reaction mechanism of polyurethane is the interaction between the isocyanate and alcoholic groups in the polycondensation of polyester polyol and diphenylmethane diisocyanate, resulting in the formation of urethane linkages along chains of polymer. When TEA is present, an intermediate complex will arise as a result of the nucleophilic assault of the hydroxylic groups on the copolymerized polyester on the isocyanate carbonyl during this process. A few water drops cause foam to form. Water and some isocyanate groups react to begin the formation process. A critical group of carbonic acid was produced as a result, and it swiftly broke down to liberate CO<sub>2</sub> gas. The alkaline treatment was studied by Bachtiar et al. [11] to enhance the tensile properties of thermoplastic polyurethane (TPU) reinforced with sugar palm fiber. According to the study, composites with a 30% weight fraction of alkali-treated fiber had lower tensile strength than composites that weren't treated. Comparatively to the 6% alkali-treated fiber, the composites with the 2 wt.% treated fiber showed a higher tensile modulus of 440 MPa. The mechanical and thermal properties of polymers with fillers (sugar palm fibers) were studied by Atiqah et al. [12]. From the experimental results, the highest tensile strength was obtained at ratio 40%, which is (17.22 MPa), and the bending resistance was 13.96 MPa). Soykan U. [13] studied how natural turkey feather fiber loading affected thermoplastic polyurethane's core properties (water-uptake, mechanical, and micro-structural, thermal). The mechanical test findings showed that for the composite samples containing 3% and 6% of turkey feather fibers, respectively, the tensile strengths were strengthened by 26.8% and 19.7%, and the modulus improved by 6.6% and 45.1%, when compared to neat thermoplastic polyurethane's. The kenaf-reinforced thermoplastic polyurethane (TPU) has varying properties depending on the fiber loading used (20, 30, 40, and 50 wt%). The results showed that the tensile strength of 89 N/mm<sup>2</sup> and the flexural strength of 148 N/mm<sup>2</sup> were both maximum in the (30 wt%) kenaf and thermoplastic polyurethane composite [14]. In Iraq (Basra), the rubber of damaged tires (waste vulcanized rubber) is the most available type of rubber and covers large areas and has no economic cost. Recycling Vulcanized rubber (tire rubber waste) into powder and using it as an environmentally friendly additive to improve the mechanical and thermal characteristics of commercial polyurethane polymers is the subject of the current article. This can contribute to the removal or reduction of vulcanized rubber waste and achieve many important economic benefits. In addition, as a result of the good mechanical properties of the blend polymer, it is suitable for covering the floors of indoor playgrounds, children's playrooms, and in the manufacture of speed bumps (road bumps).



**Figure 1:** Chemical composition of polyurethane.

## 2. Materials and Methods:

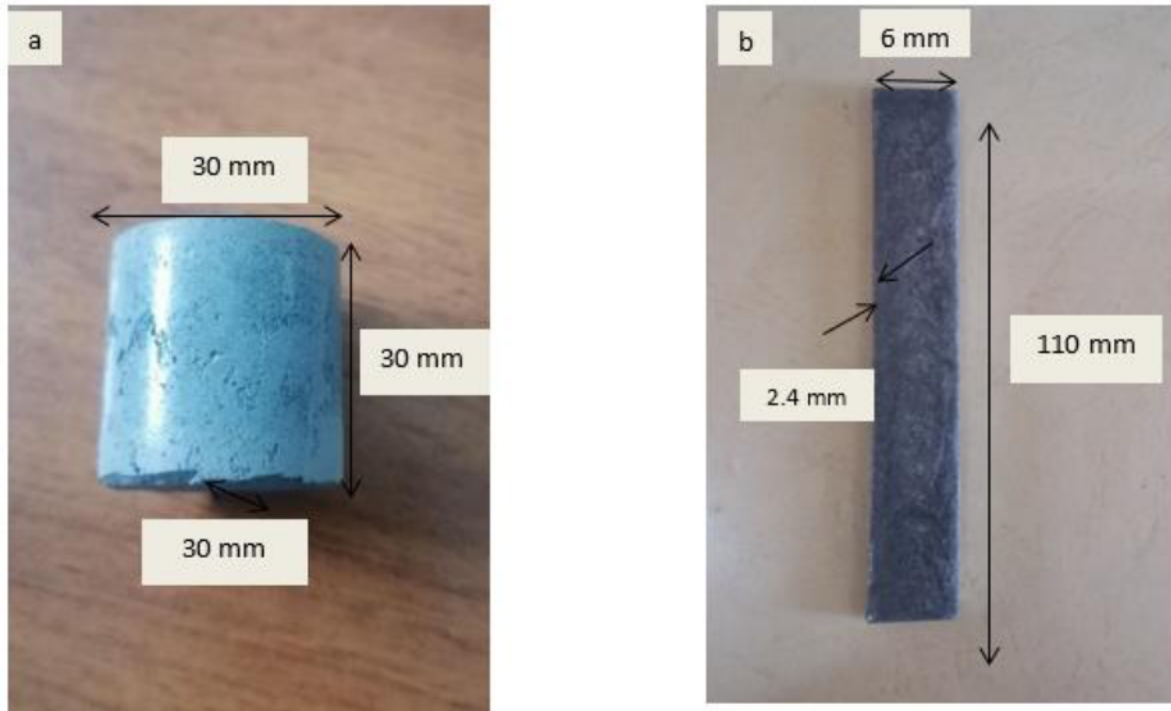
Polyurethane (TRITOSIL H10 PU) as a base material, is a high performance, one-component, isocyanate-free polyurethane sealant. Specially formulated for industrial and construction applications, it adheres to most concrete surfaces and is both ultraviolet (UV)-resistant and always flexible. Tire rubber powder (vulcanized rubber waste) was used as filler. At first, tires (waste) were collected from landfills, and then they were cut into small pieces. Because car tires consist of a group of materials, including rubber, rubber threads, and steel wires, only rubber pieces have been isolated. Then the small pieces of rubber collected by an electric grinding machine of French origin were ground into a powder, and the powder was dealt with by a wire sieve (Allen-Bradley Sonic Sifter Model L3P, provided by ATM Corp., American) to obtain a fine-grained ultrafine powder with particle sizes equal to around (125  $\mu\text{m}$ ), Figure (2) shows the image of the tire rubber powder.



**Figure 2:** Vulcanized rubber (car tire rubber powder waste).

### 2.1. Sample preparation:

Based composites created by blending polyurethane (TRITOSIL H10 PU) with vulcanized rubber powder were prepared at laboratory temperature by adding various percentages (5, 10, 15, 20, and 25 wt.%) of vulcanized rubber powder. The blend process was repeated until the mixture was homogeneous. Then the blend was poured into a rectangular and cylindrical slab mold. Figure.3 shows the dimensions of each sample, where the measurements of the cylindrical-shaped samples are (30 mm) in diameter and (30 mm) in length, while the rectangular slab is (2.4 mm) in thickness, (6 mm) in width, and (110 mm) in length [15].



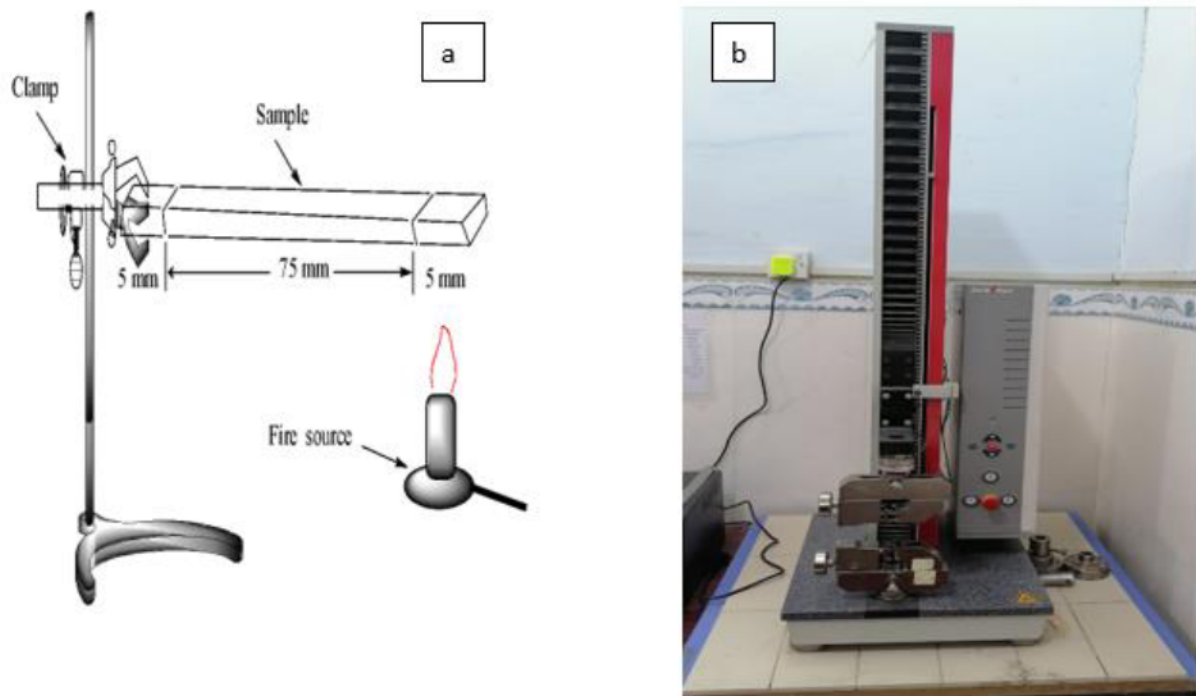
**Figure 3:** Tensile and compressive strength test samples: (a) cylindrical slab, (b) rectangular.

## 2.2 Evaluation of mechanical and thermal properties:

Mechanical properties of all samples were measured by A universal testing machine (Zwick Rell) was used, this device origin(Germany), from type (BTI-FR2.5 TN.D 14), power operating card(100–129 V/4, 4–3,7A) at room temperature (RT). Combustion rate measurement apparatus, the average burning duration (average time of burning ATB) and burning rate for each of the samples manufactured were determined using the standard technique 81 ASTM D635 - [15]. The time it took to burn the model to a distance of (75 mm) was computed, and the measurement was repeated three times for each sample, after which the average results were obtained. Using the mathematical equations below was calculated the average time of burning (ATB). Figure. 4 shows the equipment used to measure the samples.

$$ATB = \frac{\Sigma (t - 30 s)}{\text{number of specimens}}$$





**Figure 4:** Equipment is used to assess the samples: (a) schematic diagram of the combustion time rate meter, (b) mechanical properties measuring device (Tensile).

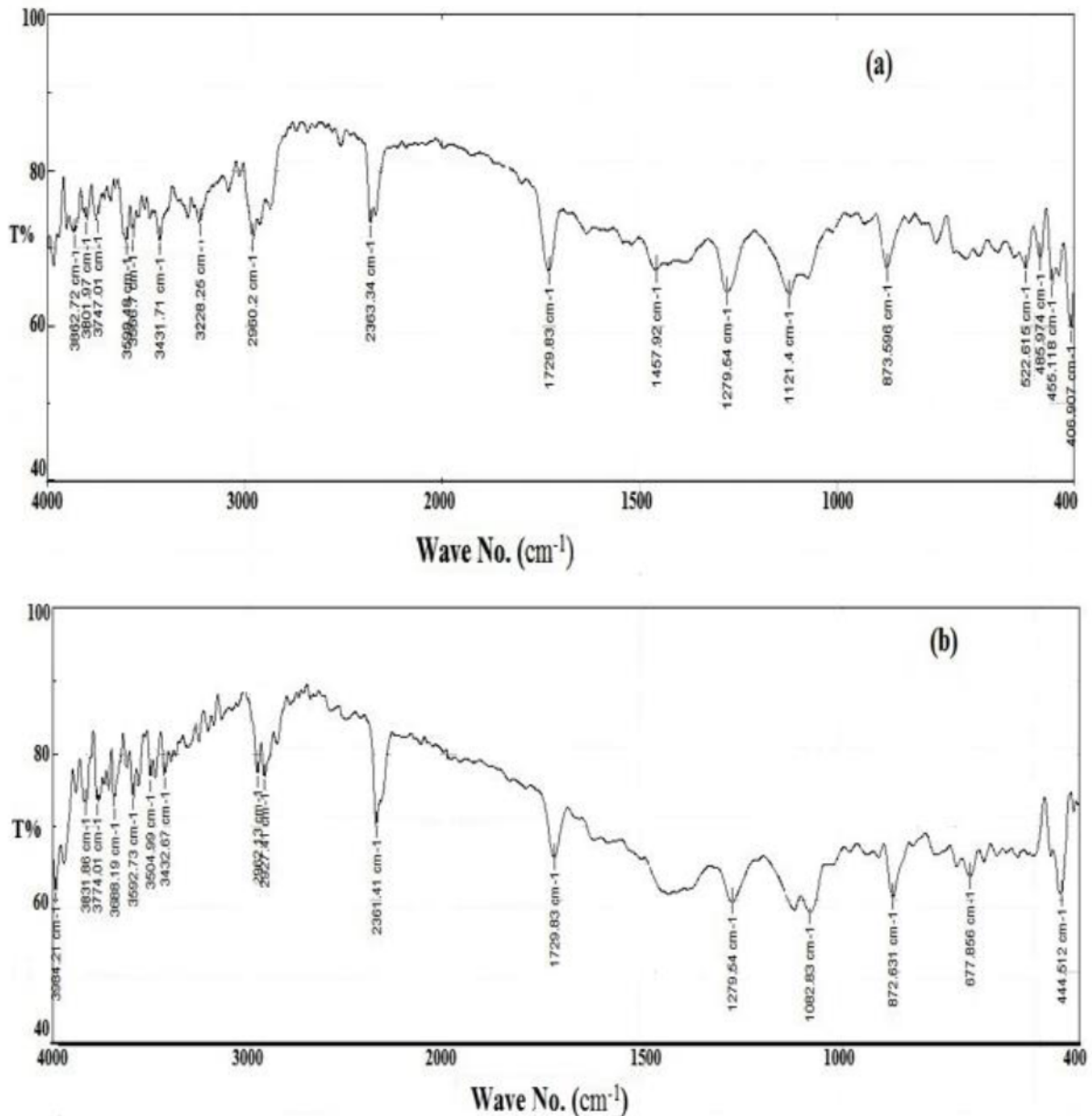
### 2.3 Characterization:

Spectrometric analysis of Polyurethane (TRITOSIL H10 PU) and its composites with vulcanized rubber powder was measured by a testing instrument JASCO FTIR-4200 device, this device origin (Japan). The range  $400\text{-}4000\text{ cm}^{-1}$  is the wave number applied in this analysis, The prepared samples were tested by using KBr disks contain 1:10 well-scattered of polymer composite and KBr. and prepared samples were tested by using potassium bromide (KBr) disks contain 0.1 to 1% of the sample is mixed with (200 -250) mg of potassium bromide (KBr).

## 3. Results and Discussion:

### 3.1 Fourier transform infrared Spectroscopy (FTIR):

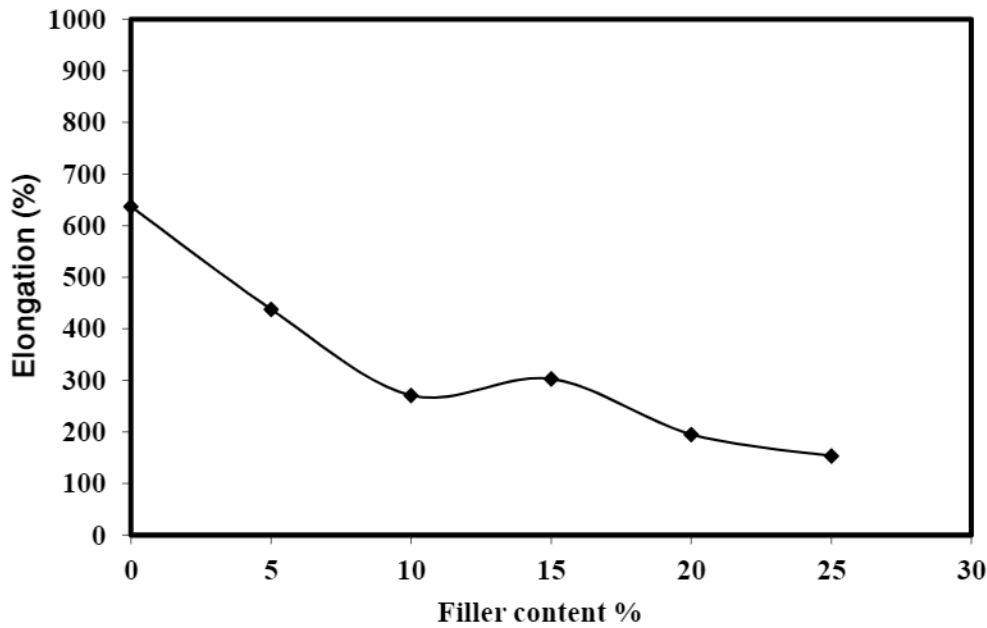
The pure polyurethane, Figure. (5-a), showed adsorption band at  $2960\text{ cm}^{-1}$  and assigned to N-H amino stretching of urethane group [16]. Also, carbonyl of urethane group showed as a strong adsorption band at  $1720\text{ cm}^{-1}$  due to C=O bond stretching. Band at  $3010\text{ cm}^{-1}$  represented to C-H bond stretching of aromatic methylene group [17, 18]. While, bands between  $2960\text{ cm}^{-1}$  and  $2830\text{ cm}^{-1}$  are a result of C-H bond stretching of aliphatic methyl and methylene group, respectively [19]. FTIR also indicated bands represented to the following bonds vibrations; C-H bending at  $1457\text{ cm}^{-1}$ , C-N stretching at  $1279\text{ cm}^{-1}$  and C-O stretching at  $1210\text{ cm}^{-1}$  [17]. Similar FTIR spectrum pattern was recorded with blend of 25% vulcanized rubber, Figure. (5-b). However, adding vulcanized rubber to the urethane polymer means more aliphatic methylene groups in blend and that results in increase the absorption bands at  $2927\text{ cm}^{-1}$  and  $2860\text{ cm}^{-1}$  [16].



**Figure 5:** FTIR spectroscopy of polyurethane with various additive weight percentages: (a) 0% and (b) 25%.

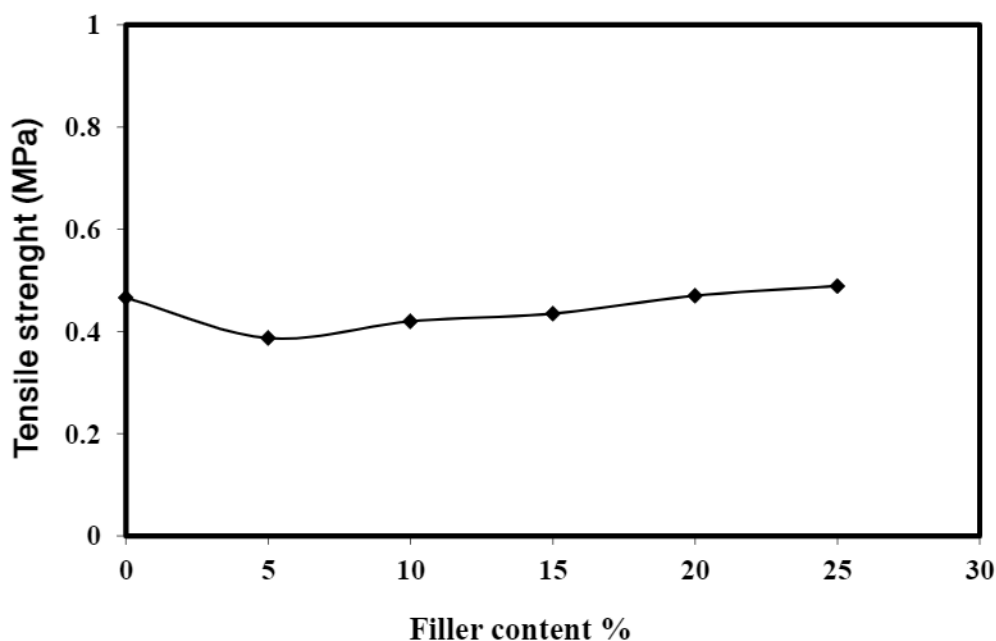
### 3.2 Mechanical properties:

Figure. 6 indicates the relationship between the elongation and the additive filler concentrations. Elongation behavior of the blend begins at the highest value of the pure polymer, which is 637.2%, and then declines in value at the percentage 5%, which is 438.2%, because the polymer is less flexible at this ratio, and the filler powder fills the polymers main chains, obstructing and limiting blend chain movement, leading to a decrease in elongation. The practical study indicated that a decrease in elongation behavior at a ratio of 25%, which is 153.6%, shows that the polymer has low flexibility and high hardness, implying that the polymeric chains are restricted and not free. The additive strengthens the polymers by forming a strong bond with the polymer chains, which leads to a decrease in the flexibility of the polymer and limits its movement. [20].



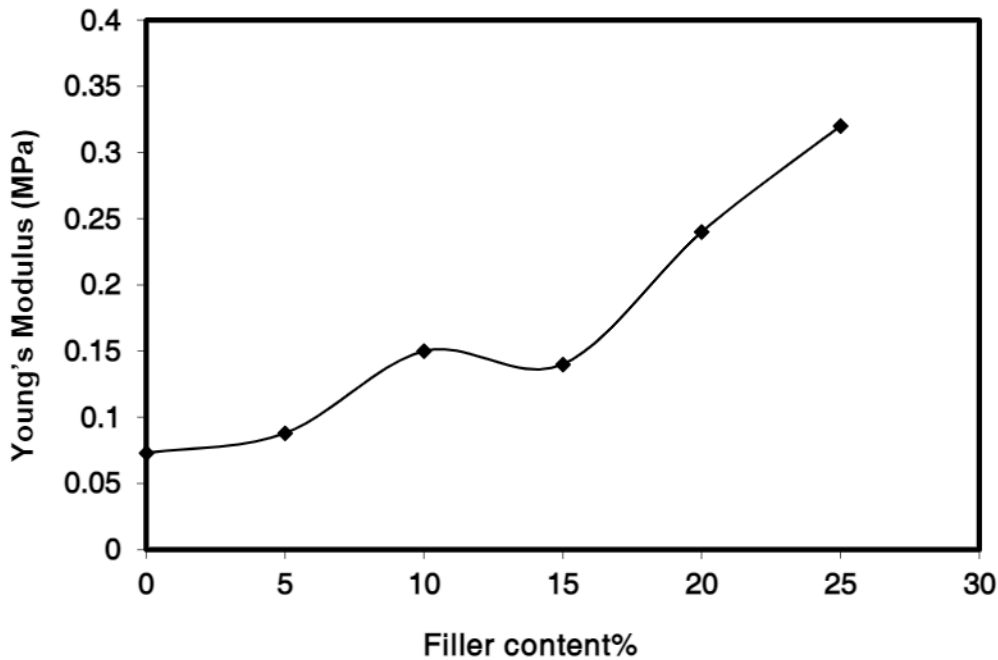
**Figure 6:** *The relation between elongation and the filler content.*

The behavior of the stress has a high influence on the percentage 0%, that is, when the polymer is pure, as shown in Figure. 7, while the experimental results indicated a decrease in tensile force at the ratio 5% value of 0.387 MPa, indicating that the powder works at this ratio to decrease the rigidity of the polymer and increase flexibility. The tensile force increases when the percentages of the additive increase, especially at the ratios 20%–25%, and the practical study showed that the highest tensile force was at the ratio 25%, which is 0.489 MPa. This indicates that the powder improves the hardness through the impact of homogeneous distribution with the chains of polymers in this blend. The experimental results indicated that the tensile force behavior increases through a linear ratio as a result of increasing the weight percentages of the powder, which increases the hardness of the blend [21].



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

Figure. 8 indicates the influence of vulcanized rubber powder on the young's modulus (known as the elasticity modulus), which is defined as stress to strain for solid materials only. In general, there was a positive effect on young's modulus with increasing blend content because the filler powder worked on the polymer hardness while the flexibility would be reduced. Figure. 8 indicates the blend behavior at the ratio 25% to the highest value of young's modulus, which is 0.32 MPa. While at a ratio of 5% to the less value of the elasticity modulus, about 0.088 MPa, the experimental results indicated at a percentage of 15% that the blend behavior of the polymer has high flexibility and low tensile strength because the chains of the polymer are freely moved [22].



**Figure 8:** *The relation between young's modulus and the filler content.*

Figure. 9 indicates the influence of vulcanized rubber powder on the compression modulus, which is defined as the ability of a material to resist compressive force only in solid materials. The practical study showed that the compression modulus increases when the percentages of the additive increase, indicating that the powder works on the hardness of the polymer and its homogeneity with the chains of polymer, increasing its resistance to compression. The compressive coefficient behavior is low at the ratio 0%, which is 0.12 MPa, and then, as the percentages increase for the blend, the compression modulus behavior starts to increase, while the greatest value of the compressive modulus is 0.29 MPa at the ratio 25%. The additive imposes rigidity on the polymer through its interphase homogeneity with the chains of polymer, indicating that the material atoms are in a stable position.



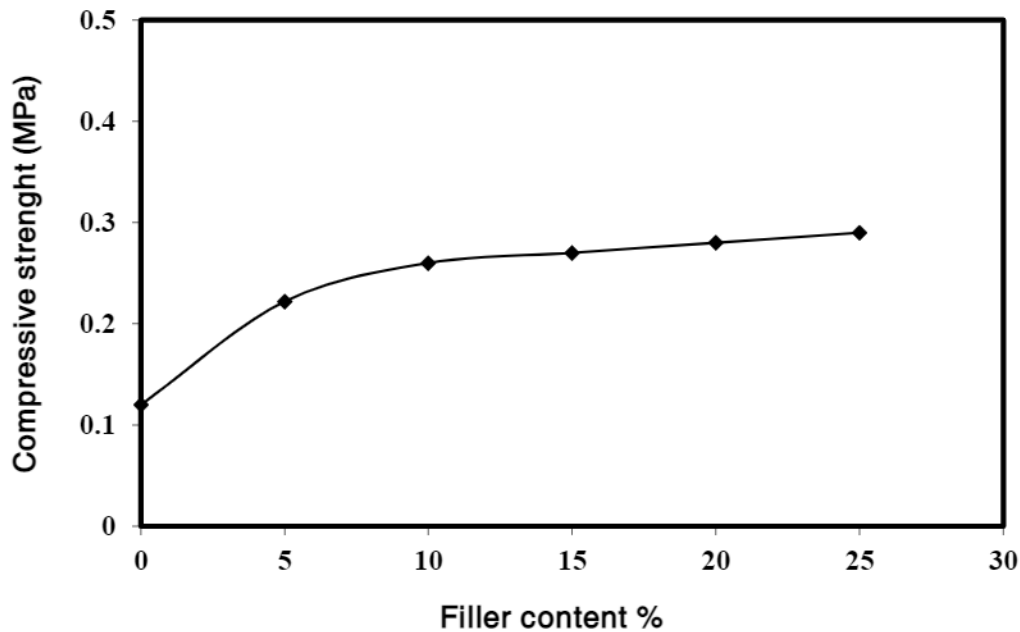


Figure 9: The relation between compressibility modulus and filler content

### 3.3 Average Time of Burning (ATB):

Combustion-resistant polymers are used to prevent or reduce the time of burning. It has two main ways: chemical and physical [23]. The current study includes a study of the influence of vulcanized rubber powder on the average time of burning for polyurethane. The relation between the average time of burning and the filler content is shown in Figure. 10. The practical study showed that the average time of burning decreases with increasing filler percentages; as was clearly observed at concentration 10%, which is 33 sec., and at ratio 30%, which is 52 sec., from a physical perspective, the created powder layer on the surface of the polymer does not form an insulating layer on the surface and does not form a solid protective layer, which prevents the spread of burning inside the matrix of polymer [24].

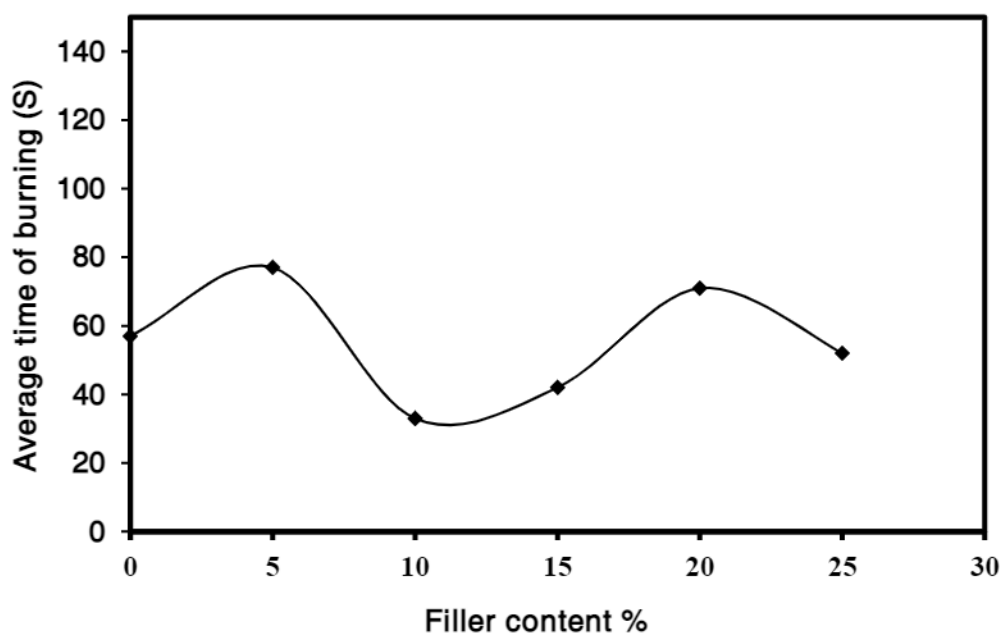


Figure 10: The relation between average time of burning and filler content

Table 1. Indicates the values of the percentage time of burning and the average time of burning, where the burning time percentage was calculated by using eq. 2.

$$\text{Burning time percentage} = \frac{A-B}{B} \times 100\% \dots\dots\dots(2).$$

Where,

A is the value of the rate time burning of polymer with filler and B is the value of the average time of burning for pure polymer without any fillers. The fast change was notice in the range of (5- 15) wt.%, in which the burning time percentage reduced rapidly about 61% time by adding 15 wt.% of filler content.

**Table 1.** *The relationship between the percentage of burning time and the concentration of the additive vulcanized rubber powder for a polyurethane.*

Additives % Test	0	5	10	15	20	25
Average Time of Burning ATB (Sec.)	57	77	33	42	71	52
Burning Time Percentage%	-	35	- 42	- 26	24	- 8.7

#### 4. Conclusion:

In the present study, adding vulcanized rubber powder to Polyurethane (TRITOSIL H10 PU) had an important effect on its mechanical and thermal properties. The results of the experiment showed that a percentage of 25% of the powder additive was the best ratio for the hardness of the polymer, which is 0.489 MPa. Blend elongation begins at the highest value of the percentage 5%, which is 438.2%, and the experimental results indicated that the best values recorded for the compression and young's modulus of the polymer with additive were at the ratio (25 wt.%), which is (0.29 MPa, 0.32 MPa), respectively, while the best values recorded for the average time of burning were at the ratio (5 wt.%), which is (77 sec.). The practical study showed that the best filler concentrations were acquired in the measurements of the ratios (5 wt.%, 50 wt.%) in terms of the greatest value of average time of burning and the young's modulus as well as tensile strength, respectively. Additionally, the additive is vulcanized rubber (car tire rubber powder waste). strengthens the polymer Polyurethane (TRITOSIL H10 PU) by forming a link with the polymer chains, which leads to a decrease in the flexibility of the polymer and limits its movement, and the tensile strength increases when the percentages of the additive increase, especially at the ratio of 25%.

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