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Influence of heat aging on tensile test in rubber-epoxy composites

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A R T I C L E I N F O

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A B S T R A C T

Composite materials using natural rubber as the main matrix are popular these days because of the wide applications of rubber materials in modern industries. Rubber materials also have damping properties, energy absorption, and exposure to continuous loads and different environmental conditions. In this research, the effect of temperatures on the rubber-epoxy composite with different ratios (0%, 10%, 20%, 30%, 40%, and 50%) of epoxy has been studied. Where comparison was made between heat-aged and un-aged samples using the tensile test. To know the effect of high temperatures on the rubber-epoxy composite, it was done in a heated oven at a temperature of 70°C. The results obtained from the tensile test observed a decrease in tensile strength and elongation when exposed to thermal aging.

1. Introduction

Natural rubber has been widely used in the twentieth century and that has led to a huge increase in its sophisticated applications. Thus, the industrial rubber sector was resorted to in World War II, because of its ideal characteristics such as flexibility, lightweight, resistance, deformation capacity, or vibration isolation. It was also used as a basic material in composite materials, in which natural rubber is blended with various additives to make it more suited for the applications for which it was designed [1-5].

Rubber composites' mechanical characteristics are affected by temperature and time. Where the crosslinking and chain disintegration are both caused by thermal aging. The expandability decreases and the modulus of the material increase due to the crosslinking. The unsaturated carbon-carbon double bonds in the backbone of rubbers make them sensitive to oxidative aging. This type of oxidative aging is generally aided by high temperatures [6, 7].

Toughened epoxy has a popular addition in research because of its ability to boost composite strength. Epoxy resins have a hard form, an anti-slip coating, minimal cure shrinkage and good electrical properties. Also, its compatibility with a wide range of materials, dependability, and the ability to cure under adverse conditions. It is also employed as an adhesive in composites Almuramady, et al. [8]. Potting, building construction, chemical-resistant equipment, weathering, boats, and other applications, thus it has acquired widespread popularity in the industrial field over the last 20 years [9, 10].

The effect of temperature on rubber compounds was one of the important topics that many scientists touched upon, as the increase in the temperature of rubber leads to a loss of its ductility and ability to dampen and increase its hardness as a result of repeated use for a long time, which affects the life of the sample. Among the characteristics that were affected by aging was the ability of the material to stretch and elongate and that will be addressed in this research [11-13].

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2. Experimental work

2.1. Materials

The practical side was implemented in several stages where natural rubber was used as a matrix material in this work, and (epoxy resin) and (carbon black) were used as reinforcing materials.

First step: The natural rubber paste was prepared by adding (carbon black) only as a hardener with what is mentioned in Table 1 below, where the work was done in the General Company for Tire and Rubber Industry in Diwaniyah - Iraq.

Table 1. Materials used in the preparation of rubber dough without epoxy.

material	Occupation
Rubber RSS1	basic material
zinc oxide	tonic
stearic acid	tonic
sulfur	vulcanization agent
DCBS Accelerator	accelerated
TBBS Accelerator	accelerated
N_{326}	reinforcement filling
N_{110}	reinforcement filling
Renacit	digestive substance
Struktol 40 ms	homogenizing substance
Wax	Oxidation protection
IPPD	Oxidation protection
Escorez 1102	Adhesive
Resorcinol melt	Adhesive
PVI	cathodic substance
HMT	Adhesive

Second step: is to mix natural rubber with epoxy, where the epoxy is first prepared.

The epoxy that was used in this work is sikadur-52 produced by sika Egypt for construction chemicals and consists of two components of high grade, low viscosity (1000-250) MPa.s, yellow in color, density at 20°C is about 1.1 kg/l and has a mixing ratio of 2R:1H based on weight.

At room temperature (25°C), the epoxy resin and the hardener were mixed manually in a ratio of 2R:1H. Mixture has been mixed and moved continuously until it becomes homogeneous and air bubbles have been disappear, then it was added to the natural rubber in different proportions (0%, 10%, 20%, 30%, 40%, and 50%) of epoxy.

2.2. Samples Preparation

After the dough preparation, it was placed in the rolling machine Fig. 1a to make it a more homogeneous dough. Equipment's have been used to control the distance between the two rollers so that the distance ranges from the lowest distance of 2 mm to the highest distance of 8 mm, and the final thickness of the dough that got from the rolling machine was 3mm. then The dough has placed in the heat press Fig. 1b by using special molds for testing, under ideal conditions (pressure of 3.5 MPa and temperature of 146 °C for a period ranging from 15 to 20 minutes) to obtain vulcanized composite rubber.

a **b**

Figure 1. (a) The rolling machine; (b) Heated press machine

2.3. Tensile testing

In order to prepare tensile specimens, a special mold has been used to obtain a composite material specimen with the required dimensions to fit with the tensile test device. The template which was used to obtain the tensile samples are shown in Fig. 2 Tensile test has been studied according to ASTM D638 − 14 Type IV [14, 19].

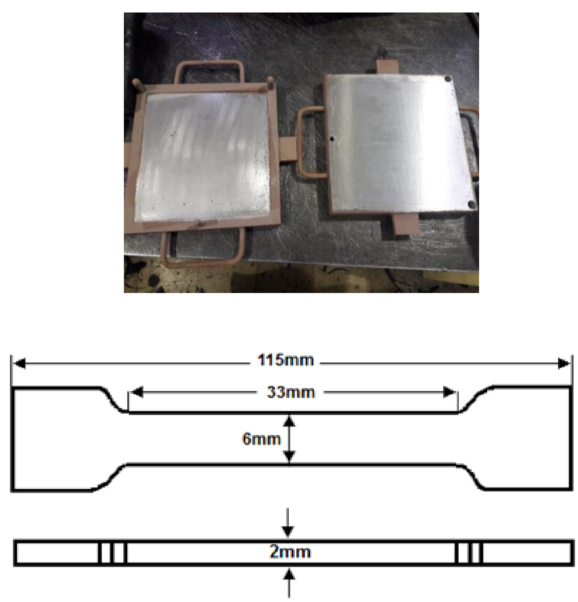

Figure 2. Tensile test specimen according to ASTM D638 − 14

Type IV.

The tensile test was performed at room temperature in the laboratories of the University of Babylon / College of Materials, using a microcomputer-controlled electronic universal testing machine) of Chinese origin, model (WDW-5E) that was controlled by a computer, shown in Fig. 3. The force was applied (load control) at a speed of 100 mm / min until a failure of the sample was occurs and then the stress-strain curve was plotted.

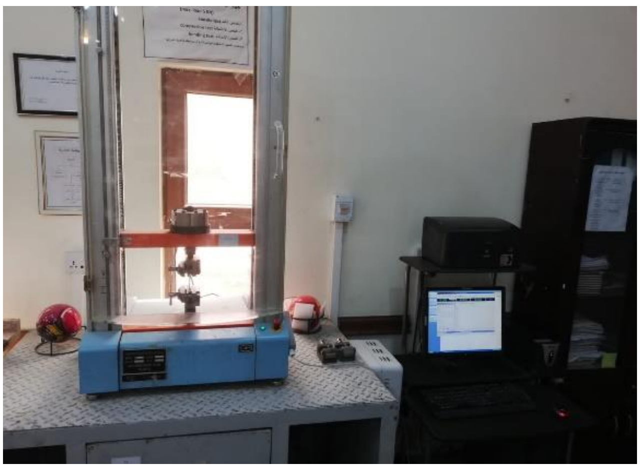

Figure 3. Tensile test device.

2.4. Aging test

Some samples of dumbbells were taken and placed in an aging oven (O7E Multi-cell Aging Oven) produced by Wallace Test Equipment Company according to ASTM D573-99 specification [15]. Where the oven consists of 7 cells isolated from each other to prevent contamination of the knees with volatile materials [16-18]. The samples have been placed for 7 days at a temperature of 70 degrees Celsius by means of an automatic timer and as in Fig. 4. Where the work was done in the General Company for Tire and Rubber Industry in Diwaniyah - Iraq. To find out the effects of thermal aging on the rubber compound and the extent of its resistance to wear over time, a tensile test was conducted for the aged samples and compared with the tensile test for the original unaged samples.

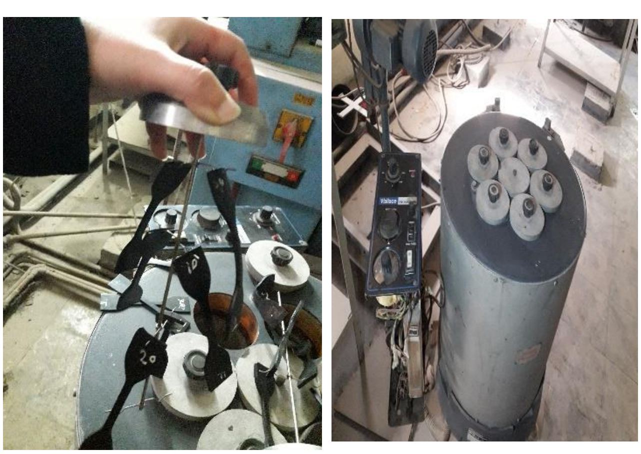

Figure 4. The oven aging.

3. Results and discussions

The 24 tests of the successful tests have been conducted to calculate the tensile resistance of natural rubber composite mixed with epoxy resin with different ratios (0%, 10%, 20%, 30%, 40%, and 50%) of epoxy. where the results test for all the percentages were compared with the purely natural rubber sample. as shown in Fig. 5, represents a graph of the true stress-strain curve of the rubber-epoxy compound. Where a discrepancy was observed in the results between the different percentages of the rubber-epoxy composite that was not aged by heat. Where an increase in stress was observed as the percent of epoxy increased, and decrease in elongation when the epoxy ratio increased and this was due to the hardness property of epoxy, which increases the hardness of the composite, which makes it resistant to stress and elongation.

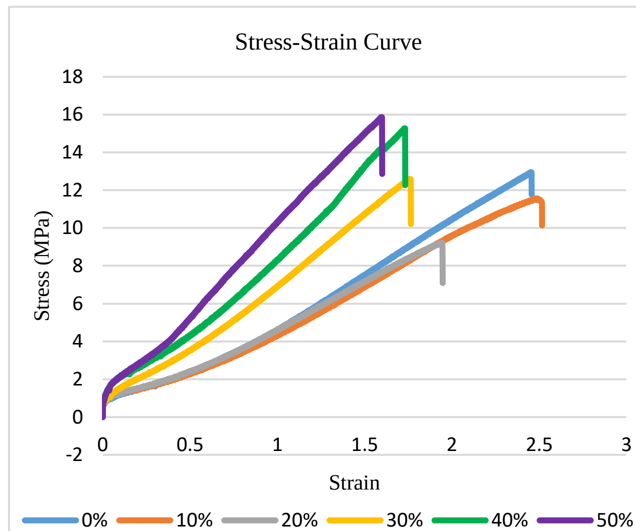

Figure 5. Stress-strain curve.

Fig 6. Represents the difference in tensile strength between the composites that have different percentages of epoxy (0%, 10%, 20%, 30%, 40%, and 50 %) of the samples that were tested in the tensile testing device without aging and the samples that were tested in the tensile device and were aged in an air oven. Where we notice a discrepancy in the results, where the results are divided into two parts, the first part, in which the tensile strength and elongation are in a descending state, i.e. decreasing with the increase in the percentage of epoxy. As for the second part, there is an increase in tensile strength with a decrease in elongation when the ratio of epoxy in the composite increases for the first test (without aging).

As for the second test (samples that were previously aging), noticed a discrepancy in the results, as the effect of the rubber-epoxy composite, was observed in temperature as in Figs 6 and 7, where a decrease in the values of stress resistance and elongation when the ratios of epoxy resin increase more than the test the first. But when the epoxy ratios were increased to 40% and 50%, there was an increase in the stress resistance for the samples that were aging, however less than in the first test. This change was attributed to the effect of increasing the amount of epoxy in the composite and also to the effect of the high temperatures on the composite, which affected it was viscous properties and decreased and hardness slightly.

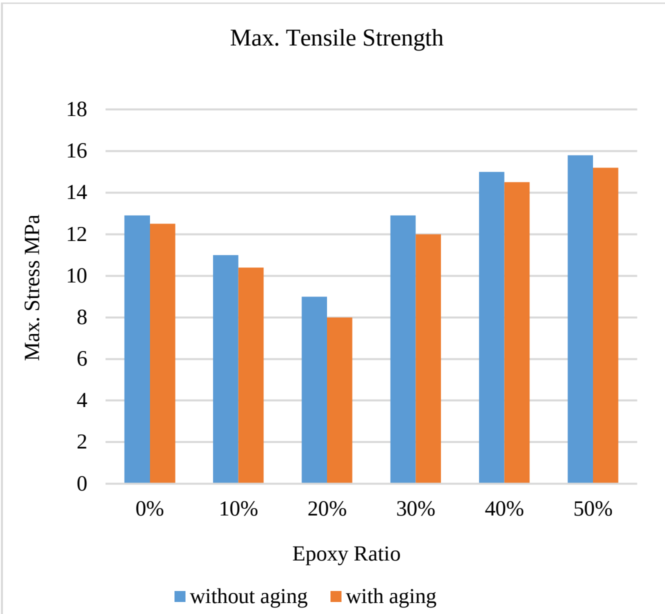

Figure 6. Effect the heat aging on the max tensile strength.

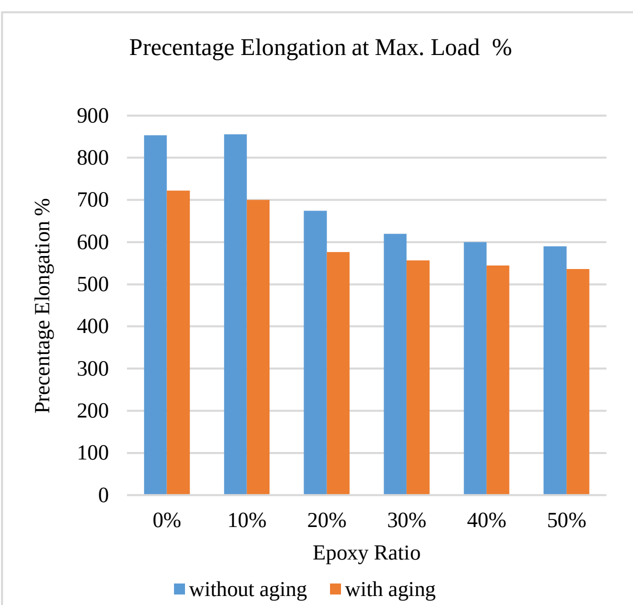

Figure 6. Effect the heat aging on the elongation.

4. Conclusion

In this research, the effect of temperatures on the rubber-epoxy compound with different epoxy resin ratios (0%, 10%, 20%, 30%, 40%, and 50%) were studied. The original samples were compared with the heat-aged samples by conducting a tensile test for them. A decrease in the tensile strength and elongation of the samples was indicated in the beginning by an increase in the percentage of epoxy, then it will be increased with an increase in the epoxy ratio. Also, a discrepancy was observed in the results with the heat-aged samples due to the added quantities of epoxy rubber and it was the effect of high temperature. And due to the rubber being also affected by heat for periods and loss of flexibility, Ali [8].

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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