RUBBER CREEP BEHAVIOR INVESTIGATION
WITH MULTI WALL TUBE CARBON NANO PARTICLE MATERIAL EFFECT

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ABSTRACT

The rubber materials is very important materials its using in large engineering application, therefore, the modified for mechanical properties and behavior for its materials investigation form many researchers. But, more researchers were focused on the investigation for properties of its materials by variable the amount for each compound adding in composition of the rubber material. But, this processing given modifying for properties and behavior did not exceed about (20%). Therefore, from previous my paper presented for modified materials by reinforcement with Nano particle materials shown that the mechanical properties and behavior increasing with high value lead to about (60%), as in composite materials. Then, in this paper, investigation the modified for mechanical properties and creep behavior for rubber materials by reinforcement with carbon multi wall Nano particle materials. Where, the investigation include evaluated the mechanical properties (strength for rubber) and mechanical creep behavior with various weight fraction effect for Nano particle materials. There, the study was achieved through experimental technique by manufacturing multi rubber samples with different Nano particle weight fraction, and then, test its samples by tensile and creep machines to evaluate mechanical properties and behavior for its materials. There, the weight fraction for Nano particle used are (0, 0.2, 0.4, 0.6, 0.8, and 1% wt). In addition, the creep behavior investigation numerically by using finite element technique with using Ansys package, and then, comparison the results evaluated together with experimental calculated results. Where, the comparison shown that the maximum error not exceed (8.36%). Finally, the investigation shown that the mechanical properties and creep behavior for rubber materials modified to about (65%) with reinforcement by (1%wt) for multi wall carbon Nano material.
1. INTRODUCTION

The rubber materials are used in large engineering application, therefore, it was necessary to modified the mechanical properties and behavior for its materials. Thus, since one of engineering application is applied load with long time, then, its load lead to deformation the rubber materials with time, this behavior can be called a creep behavior for rubber materials. Therefore, more application for rubber material is using as damping part, there, the increase for damping rubber lead to decrease the resonance for structure, in addition to, other important application for rubber material is using for control on the vibration system. Then, the vibration for rubber lead to deformation the rubber with time, its behavior called creep behavior. Then, the modified for creep behavior for rubber is very impartment main of rubber investigation. There, one way to modified the rubber creep behavior is reinforcement by carbon particle, since, the carbon particle given the rubber chemical stable production and other modifying. Also, since the Nano particle reinforcement modifying the mechanical properties and behavior for structure with high value, then, using the Nano particle carbon multi wall materials as reinforcement to rubber materials to modified the mechanical properties and behavior for its materials.

Thus, the creep behavior for rubber is accordant on the time for applied stress and temperature applied. Then, the creep behavior regions are dividing to three parts, as, firstly, the creep primary region, second, the constant rate for creep, and finally, the tertiary creep region. Therefore, the important region for creep material is the secondary region, then, main investigation goal is modified the second region for creep behavior by different techniques. Therefore, due to important for rubber materials, then, many researchers were investigation the modified for its materials by different techniques, there, the following researchers are shown same techniques used for modified the mechanical behavior and properties for its material, as,

Firstly, at 2010, A. Mostafa et. al, [1], investigated for the filled vulcanizates behavior and properties with effect of filler particle and matrix rubber materials. Where, the filler particle materials added as reinforcement to the rubber for modifying of multi mechanical properties as tensile, distortion for heat, stiffness and other characterizations. Thus, the experimental technique was used to investigate the mechanical characterizations for rubber materials with effect for the filler reinforcement materials. Then, at, 2012, Z. Ahmad et. al, [2], presented the overtime change for the adhesives material change with long loading subjected. Where, the investigation included study for the rubber creep material with effect for the Nano particle materials. Where, the investigation studied two types for adhesives epoxy based with Nano particle materials effect. In addition, the experimental technique was used to shown the creep behavior for its effect. Also, the results were shown that the creep deformation for rubber material decrease with reinforcement Nano materials. Also, at same year, Y. Jia et. al, [3], investigated the effect for Nanotube carbon materials on the creep behavior and mechanical properties for the polyurethane materials. In addition, the mechanical properties, strength and modulus of elasticity, are investigation. Thus, the investigation shown that the
reinforcement by Nano particle lead to modified the mechanical properties and creep behavior for materials.

Y. Nakaramontri et. al, at 2014, [4], studied the modified for the mechanical properties for natural rubber materials by reinforcement with Nano tube carbon particle material. Where, the investigation include used the experimental technique to evaluate its properties for rubber composite materials. Thus, the in situ technique was used in this investigation, with using for internal mixing process to adding the Nano carbon particle material. Also, with and without silane modification was used to characterized the interaction between the molecules of rubber material and carbon Nano materials surface, by using measurement with ATR-FTIR. Then, at 2015, M. A. Ahmed et. al, [5], presented the effect for Nano particle rubber material on the mechanical properties of epoxy material. Where, the investigation included evaluate the strength and modulus of elasticity of epoxy resin materials with effect for rubber Nano materials.

Then, F. Daver et al, at 2016, [6], presented investigation for Nano particle materials effect on the composite rubber materials. Where, the study included evaluate for creep and time deformation behavior for rubber materials with Nano composite effect by using experimental technique. In addition, used numerical technique, by using finite element method, to calculate the strain-time behavior for rubber material with Nano material effect. Thus, the numerical technique include used for Abaqus package to study the creep of composite. Also, the investigation, include using analytical solution by using model for four element mechanicis to analysis the creep behavior for composite. Therefore, the results evaluated shown that the creep and other characterizations investigation for rubber materials dependent on the, composition compound for composite, Nano materials reinforcement, and other parameters.

After this, at 2017, J. Su et. al, [7], investigated the effect of the Nano carbon particles material on the mechanical properties for composite rubber materials. Thus, they yellower, darker bluer, greener and other characterizations for composite rubber materials were investigated with effect for the Nano carbon material by using experimental technique. Finally, the results showed that the change for the total color were accepted with Nano particle reinforcement (2 wt%), and the maximum tensile strength for rubber materials was occurred for Nano reinforcement (3 wt%). Also, at same year, M. J. Jweeg et. al, [8], investigation the fatigue behavior and tensile strength for rubber material with various carbon filler particle material effect. Where, the studied included investigation three values for weight fraction carbon filler effect on the tensile and creep rubber materials by using experimental technique. Therefore, by investigation evaluated that the tensile and creep behavior modified by reinforcement with carbon filler particle.

Finally, at 2018, M. Al-Waily et. al, [9-10], presented investigation for Zinc oxide Nano particle materials on the mechanical properties for composite rubber material, [9], and effect of its Nano materials on the wire cord lead for rubber material, [10]. Where, the investigation included using experimental technique to evaluate this properties and characterizations for rubber materials with effect for weight fraction zinc Nano particle materials. Thus, the investigation shown that the adding for Nano materials increase for the mechanical properties and behavior for rubber. In addition, the investigation presented for effect of Nano zinc materials on the wire core load for rubber materials, [10], included also study the effect of temperature parametrical on the its characterization, and, shown that the temperature applied on the rubber materials can be increasing when reinforced the rubber materials by Nano particle zinc material.

Then, from the previous researches can be shown that the investigation for Nano particle materials effect were presented to shown the modified for mechanical properties and behavior...
of rubber materials with experimental technique. Therefore, in this work investigating the effect of carbon Nano particle multi wall material on the mechanical properties, strength for rubber, and creep behavior for rubber material, with various weight fraction Nano materials effect (0.0, 0.2, 0.4, 0.6, 0.8, 1wt%). Where, the investigation presented by using experimental technique to evaluate the rubber strength and creep behavior, in addition to, using numerical technique, by using finite element technique with using Ansys package, to evaluate the creep rubber materials behavior with Nano particle effect, and then, comparison the results for creep behavior together. Also, the investigation included manufacturing for creep machine to testing the creep rubber sample, and then, testing the rubber samples by its machine. Where, the tensile and creep samples are manufacturing experimentally accordant on the ASTM stander.

2. MATERIALS SPECIFICATIONS

The materials used were natural rubber materials reinforcement by carbon Nano particle materials and other materials combined to modified the mechanical properties and behavior for its materials. Then, application its materials with various engineering application, in addition to, used its materials with same application for rubber materials without reinforcement by Nano materials but with properties better than for natural rubber. Therefore, the specified for rubber materials used can be conclusion, as, the transition temperature for rubber materials about (73 °C). Also, due to the molecular structure regularity for rubber materials, the rubber materials have high strength and height abrasion and tearing resistance. Therefore, due to this specifications for rubber materials, then, its materials application with various engineering applications, as, wire insulation, toys, belts, tire for car and light truck, belts for conveyor, heels for shoe, mats for the vehicle, various belts types, the flooring and other productions.

There, the best materials adding for the natural rubber material is black carbon material, where, its material is a pure powder carbon production by various processes as, incomplete combustion, gaseous thermal decomposition, and controlled condition for hydrocarbons liquid. There, the best reasons for adding the carbon black for rubber materials can be conclusion, as,

1. The black carbon have most stable for the chemical production.
2. The black carbon have high surface area and extreme fineness.
3. Pigment the rubber with black.
4. Electrically properties for conductive.

Then due to presented specifications for carbon black, then, the carbon is the Nano materials most widely used for rubber materials to given more modified for mechanical properties and behaviors of its materials with various applications. There, the specified for Nano carbon multi tube materials used, [11], are,

1. Length for Nano materials tube about (5 μm),
2. Outer diameter for Nano tube about(6 − 9 nm),
3. The materials adding as a filler particle materials, and, the range used about (0 to 1wt%).

Therefore, the rubber materials used to reinforcement by carbon Nano materials is compound from natural (NR) rubber, styrene butadiene (SBR) rubber, black carbon filled (N330), sulfur, filler, and other compound materials, in addition to, multi wall carbon Nano material. Where, the characterizations for rubber used to reinforcement by Nano materials and same compound to its rubber can be presenting in Tables 1 to 3. The mechanical properties and behavior dependent on multi parameters, but the best parametric is the compounds for rubber materials. Therefore, the reinforcement for rubber materials with Nano particle lead to change for rubber mechanical properties with significantly. Where, the important mechanical
properties must be investigation is the tensile properties behavior for rubber material, where, the tensile behavior for materials can be calculating by tensile test machine. Since the rubber materials are polymer materials, then, the behavior for rubber materials compatible to polymer stress-strain behavior, therefore, the output for tensile test for rubber materials are given the following data, as,

1. Break tensile strength materials.
2. Elasticity modulus for rubber materials at various elongation, as, 100%, 200%, 300%.

Where, the its tensile results values are dependent on the rubber compound, where, the investigation required modified for its properties with minimum cost for rubber manufacturing and with low weight. In addition, the investigation required modified its properties with the simplest techniques of manufacturing without complicated procedures. Also, safety during manufacturing is one of the essentials to be considered.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NR Rubber</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>0.941</td>
</tr>
<tr>
<td>Transition Temperature( °C)</td>
<td>-72</td>
</tr>
<tr>
<td>Color</td>
<td>Red</td>
</tr>
<tr>
<td>Hardness</td>
<td>20-100</td>
</tr>
<tr>
<td>Strength (MPa)</td>
<td>17.18-25</td>
</tr>
</tbody>
</table>

Table 2 Sulfur Materials Characterizations.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Specific Gravity</th>
<th>Volatiles at 80 °C%</th>
<th>Ash at 550 °C%</th>
<th>Sulfur Content (%)</th>
<th>Iron Content (mg/kg)</th>
<th>Arsenic Content (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values</td>
<td>2.1</td>
<td>0.5 Max.</td>
<td>0.2 Max.</td>
<td>99 Min.</td>
<td>300 Max.</td>
<td>5 Max.</td>
</tr>
</tbody>
</table>

Table 3 Black Carbon Characterizations.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Ash Content Max.%</th>
<th>Iodine Adsorption (g/kg)</th>
<th>PH</th>
<th>Pour Density (kg/m³)</th>
<th>Sulfur Content Max.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values</td>
<td>0.75</td>
<td>122</td>
<td>6-9</td>
<td>360</td>
<td>1.5</td>
</tr>
</tbody>
</table>

3. EXPERIMENTAL TECHNIQUES
The experimental technique used to evaluated the characterization for structure with accepted results comparison with other techniques, [12-18], then, its technique can be using to evaluated the mechanical characterization of rubber materials. Therefore, the its technique is using to evaluate the creep behavior for rubber materials, in addition to, evaluating the tensile properties for rubber materials, with various weight fraction for carbon Nano particle effect. Where, the weight fraction are reinforcement for rubber materials are 0.2 to 1wt%, [11].
Thus, the experimental work first, required manufacturing the samples types for tensile and creep behavior for rubber material. Therefore, the tensile and creep samples are manufacturing requirement manufacture its samples accordant on the ASTM stander, [19-28]. there, the tensile sample manufactured by using (D412-98)ASTM stander, [29], as shown in Fig. 1, also, the creep samples, manufactured by using (D2990) ASTM stander, [30].
Firstly, the manufacturing for rubber sample including the following steps, as, mixing, shaping, generally molding, and, vulcanizing. Thus, the manufacturing for rubber samples with various combined can be conclusion with the flow chart shown in Fig. 2, for multi steppes. Where, the mixing for rubber included master batch and then reinforcement the rubber by carbon black and carbon Nano material, and finally the mixing included the final batch process. Then, by using tensile test machine, shown in Fig. 3, and by test five tensile samples for each effect of Nano particle weight fraction and then using the average values for its samples, [31-40], can be evaluate the mechanical tensile properties for rubber materials with various Nano carbon weight fraction effect. Where, the tensile machine used with the characterizations, as,

1. The elongation of 100% use for modulus.
2. The elongation and strength use at the break.
3. The ASTM D412-98 stander used for vulcanizing at 20 °C temperature.
4. The tensile sample used accordant to ASTM D412-98.
5. The force applied of tensile machine was 1 kN.
6. The velocity for move part of tensile machine was 20 mm/min.

Also, the test for creep behavior made for three samples for each weight fraction Nano particle reinforcement effect, then, using the average values for its results, [41-48]. Then, by using creep machine, shown in Fig. 4, can be calculate its characterizations for rubber material with various Nano carbon weight fraction effect.
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Fig. 2. Flow chart for Rubber Manufacturing Steppes with Nano Particle Reinforcement

Fig. 3. Tensile Test Machine.
Where, the following characterizations for creep machine shown the steppes for creep test, as,
1. The test evaluate the properties for viscoelastic materials.
2. The creep behavior used for the creep- machine are accordant to the ASTM (D2990) stander.
3. The load applied by creepmachine about \((11 to 17 \, kg)\), where its load under the yield stress for materials test.

Then, After mixing the mixture components, for rubber materials with Nano particle, and conducting the process vulcanization the rubber processes will produce the following specifications for samples manufactured, as, the rubber chain become cross-linked, the rubber materials become strong elastic rubber materials, the rubber materials become insoluble materials in to solvent, and, the rubber become more strength for the heat and aging processes.

Therefore, the testing include evaluate the mechanical properties (strength for rubber materials), creep behavior for rubber materials with various weight fraction effect of multi wall carbon Nano particle materials effect, as, \((0\%,0.2\%,0.4\%,0.6\%,0.8\%,1\%)\).

3. CREEP FINITE ELEMENT TECHNIQUE

The numerical techniques used to comparison for results evaluated by other techniques its evaluated by analytical or experimental work, [49-57], to given the agreement for results evaluated. Therefore, the method for finite element is perfect techniques can be used to evaluate the mechanical behavior for various engineering application, [58-65]. Thus, the creep behavior for rubber materials analysis by using Ansys package with various effect for carbon Nano particle materials. Firstly, after modeling the creep sample by Ansys program, then selecting the required elements and nodes number by using mesh generation steeping,[66-70], as shown in Fig. 5, accordant on the element type required selected. Where, the element type selected is (solid 185), Fig. 6, therefore, the number elements and nodes are required about (250) and (2000), respectively. Where the following characterizations have for its element, are,
1. Application for three dimension engineering structure.
2. The element have eight nodes with three degree for freedom in each node, as translations displacement in x, y, and z-directions.
3. The element application for plasticity materials and behavior.
4. The element application to evaluate the stiffening stress.
5. The element application to evaluate large strain and deflection behavior for structure.
6. The element application for swelling and creep behavior.
7. Can be using anisotropic or orthotropic materials properties with application for its element.

![Graph](image)

**Fig. 5.** Mesh Generation for Creep Behavior to Select Element Type Solid 185 Numbers.

**Fig. 6.** Element Type Solid 185.

4. RESULTS AND DISCUSSION
The results for strength and creep behavior of rubber material with various carbon Nano particle Material weight fraction effect are presented by experimental and numerical techniques. Where, the results for its investigation can be divided to three parts, first, evaluated the strength for rubber materials with Nano materials effect by using experimental technique, second, evaluating the creep behavior for rubber materials, with Nano particle effect, experimentally. Finally, using the experimental results for rubber strength, evaluate experimentally, as input data for numerical techniques to evaluate the creep behavior for its
materials numerically, and then, comparison its results with experimental results to give the maximum error for results calculated.

4.1. Rubber Strength Results
To evaluate the strength for rubber material experimentally, testing five rubber samples for each weight fraction for Nano reinforcement effect, and then, using the average value for each weight fraction effect to calculate the strength value for rubber material with different Nano particle effect (0 to 1 wt%), as shown in Fig. 7. Therefore, in Fig. 8, presented the strength for rubber material with Nano particle materials effect, then, from its figure can be see that the strength for its materials increase with reinforcement by Nano material. In addition, the figure shown that the increase for strength lead to about (60%).

![Fig. 7. Five Samples for Test for Each Nano Particle Fraction Effect.](image)

![Fig. 8. Strength for Rubber Material with Nano Particle Effect.](image)

4.2. Creep Rubber Behavior
The creep behavior for rubber material with various weight Nano particle reinforcement effect, with time behavior, investigation at Fig. 9. Where, from this figure shown that the increase for reinforcement Nano particle lead to decrease the creep deformation for rubber materials. Thus, the modified for creep behavior for rubber materials by reinforcement with Nano materials lead to about (65%), as shown in Figs. 9 and 10. There, from figure can be see
that the modified for mechanical behavior for rubber materials, by carbon Nano reinforcement material, large than the modified for its behavior with other techniques. Thus, the main reason for the improvement in rubber creep behavior is due to the increased strength of chain to rubber due to the reinforcement of carbon Nano particle material. Also, the adding for Nano carbon material lead to improvement the strength for rubber materials due to same reason.

Fig. 9. Rubber Creep Behavior with Various Weight Fraction Nano Particle Effect.

4.3. Comparison Creep Results

To give an agreement for experimental results calculate, for creep behavior of rubber materials, shown in Fig. 9, make comparison for its results with other creep results calculating by using finite element technique, as shown in Fig. 11, for various weight fraction Nano material effect. Then, form this figure can be shown that the maximum error for evaluated results are not exceed (8.36%). Thus, this value for error accepted for mechanical results, therefore, form this results can be dependent on the experimental or numerical technique to evaluate the creep behavior for rubber material with various weight fraction for Nano particle material effect.

Fig. 10. Rubber Creep with Carbon Nano Particle Material Effect.
5. CONCLUSIONS

The investigation include using experimental technique to evaluate the mechanical strength and creep behavior for rubber material with various carbon Nano particle material effect. In addition, the investigation also, include using numerical technique to evaluate creep behavior for its material, and then, comparisons results with experimental results. Then, from its investigation can be conclusion the following impartment points, as,

1. The experimental investigation used was perfect technique can be using to analysis the effect of carbon Nano particle material on the mechanical properties and creep behavior of rubber materials, with using the average values for five tensile samples to evaluate the mechanical properties and average values for three creep samples to calculate the creep behavior.

Fig. 11. Comparison for Experimental and Numerical Rubber Creep Behavior with Nano Material Effect.
2. The comparison for creep results for rubber materials, with various Nano particle material effect, between experimental and numerical techniques are given a good agreement between its techniques used, with maximum error about (8.36%).

3. The three steeps for creep behavior of rubber material modified with adding carbon Nano particle material, where, the modified include reduced the creep deformation for rubber with increasing the Nano adding and increasing the time rang for secondary creep step. Where, the modified for creep behavior for its material lead to about (65%).

4. The reinforcement for carbon Nano particle material lead to modified the strength for rubber material with high value lead to about (60%). Where, the improvement for creep behavior and strength for rubber materials, due to increase for the temperature resistance for rubber.

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