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Modifying of fatigue characterization for natural rubber materials by carbon Nano-particle tube (CNT) reinforcement

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Abstract
The main purpose of this paper is modified the strength and fatigue characterizations of natural rubber materials by reinforcement with Nano particle materials. Where the Nano particle used is carbon Nano-particle tube with various volume fractions, as (0.2% to 1%). Therefore, the strength on rubber materials, with various Nanoparticle volume fractions, is evaluated by using experimental technique by testing the tensile sample with universal test machine. After this, evaluate the fatigue characterizations of rubber materials, with various Nano particle volume fractions, by two techniques, first, experimental technique with manufacturing the fatigue test sample and then using rubber fatigue machine to testing its samples to evaluating the fatigue strength and life, and second, numerical technique by using finite element method with using Ansys program technique. Where, the experimental results of fatigue characterization are comparison with numerical fatigue results to shows the agreement between experimental and numerical technique. Therefore, its comparison shows the good agreement of fatigue results with maximum error between the two techniques use is about (10.28%). Finally, the results for strength and fatigue are shown that the strength and fatigue characterization are modifying with reinforcement by Nano particle carbon materials. Then, the increasing of Nano particle is lead to increase the strength and fatigue characterizations of natural rubber materials.

Keywords: Fatigue rubber; Carbon Nanoparticle; Rubber strength; Nano-fatigue; FEM fatigue.

1. Introduction

Many application can be using for rubber materials, since; the rubber is polymeric material have cross linked and high filled. In addition to, the rubber materials has the characteristic of damping and variable elastic. Also, the rubber has the characteristic of stability under dynamic cyclic loading. The rubber is based on the natural rubber that is active with black carbon. Therefore, to modifying the strength and dynamic characterizations of natural rubber materials can be using the carbon Nano tube (CNTs) as reinforcement to the natural rubber. Thus, the Nano carbon tube is production by rolling up for graphene sheet in to a cylinder. Then, the structure of CNTs derived from the graphene sheet.
The lasts papers describe the fatigue behaviors for rubber materials with various parametric effects. Where, the following researchers presented some of its studying, as;

At 1997, Hanafi Ismail, et. al. [1], investigated the comparison of fatigue behavior between white rice husk ash filled ENR-50 compounds and other materials as silica and carbon black filled compounds. In addition the investigation included studied the scorch time and the Mooney viscosity with effect of white rice husk ash loading. There, the studied shows that the scorch time is reduce with incorporation of white rice husk ash in ENR-50 compounds. Also, the result shows that the fatigue life is reduction with increment of filler loading. In addition, the investigation of paper show that the highest fatigue characterization with silica filled comparison with those white rice husk ash and carbon black.
Then, at 2004, J. B. Le Cam et. al. [2], investigated of fatigue scenario of crack growth for rubber with a carbon black filled under relaxing loading. Where, the paper used the 'microcutting' method to observe the affect phenomena of growth of the crack by observe it microscopic. There, the investigated evaluated the cavitation production between rubber matrix and zine oxides.
After this at 2007, F. Hernandez Olivares et. al. [3], presented the investigation the bending fatigue test for tyre rubber filled concrete with various rubber volume fraction. Where, the results included evaluated the minimum thickness of tyre rubber filled concrete by using experimental technique and developed the analytical model equation based on classical Westergaard well. Where, this paper using the modulus of subgrade reaction for design.
Then at 2014, Abdullah Mohammed et. al. [4], presented the effect of carbon black contents on the fatigue life of rubber materials. Where, the fatigue testing included applied two cycle load, non-relaxation tension and namely full relaxation. Therefore, the fatigue testing shown that the fatigue life of rubber materials is increase with decreasing the maximum strain, in full relaxation, in addition to decrease in maximum stress and strain amplitude. Then, the paper shows that the increase of black carbon led to increasing of the fatigue life of rubber.
Also, at 2015, Pierre Yves Le Gac et. al. [5], studied the fatigue life of rubber in the sea and then comparison the results with results of fatigue life in air. Then, the results showed that the fatigue life of rubber in the sea water is less than the fatigue of rubber in the air. Where, the results show that the effect of antioxidant has same affect in sea water and air. Then, the fatigue life is non-reduction when used rubber materials in the sea water.
Finally, at 2017, M. J. Jweeg et. al. [6], presented the experimental investigation of various volume fraction of black carbon filler reinforcement effect on the tensile strength and fatigue characterization of natural rubber materials. Therefore, the results are shows that the mechanical properties and fatigue characterization of rubber materials are increase with increasing the volume fraction of carbon filler.
Therefore, from presented researchers shows that the mechanical properties and fatigue behavior modified by variation percentage combined of rubber, as black carbon filler and other combined. But, the presented papers are not investigation the effect of Nano carbon particle reinforcement on the strength or fatigue characterization of rubber materials. Then, in this paper investigation the effect of various Nano carbon tube volume fraction on the mechanical properties and fatigue characterization. Where, it investigation can be studying by experimental technique by tensile and fatigue testing of rubber samples tensile and fatigue with various Nano particle volume fraction. In addition, the investigation included numerical technique by using finite element method with using Ansys program, to comparison the experimental fatigue results to shows the agreement of evaluated results.

2. Experimental work

The experimental technique divided to two parts, the first are calculate the strength of rubber materials with various carbon Nano tube reinforcement by manufacturing the tensile test samples, and then , testing its by tensile test machine and evaluating the strength of natural rubber materials. Second, are evaluated the fatigue characterization, as fatigue strength and life, of natural rubber material with various carbon Nano particle reinforcement materials. Therefore, the Nano particle volume fractions are variable from (0.2 to 1%) for strength and fatigue samples. Also, the rubber materials used are combined from multi materials, as shows in [6].

2.1 Strength of rubber

To evaluating the strength of rubber materials with various volume fraction of carbon Nano particle reinforcement, manufacture the tensile test sample dependent on the ASTM D412 stander, [6, 7], as shows in Figure 1. Then, for each volume fraction reinforcement must be testing about five sample and then taking the average value of its test sample to evaluated the strength for each sample, where, the rubber tensile sample with various carbon Nano particle volume fraction shown in Figure 2.

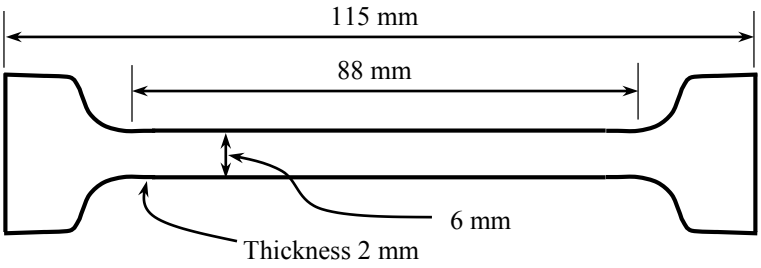


Figure 1. ASTM D 412 stander for rubber tensile test sample.

Figure 2. Tensile samples of rubber sample.

The steeping of manufacturing the tensile sample includes mixing the carbon Nano particle materials with rubber combined materials by using the rubber mill rolls. After this, were cutting the producing sheet rubber, for each carbon Nano particle volume fraction, to five tensile samples. Then, by testing its sample with tensile test machine, shown in Figure 3, and with using the average value to five samples for each volume fraction of carbon Nano particle sample, calculating the strength of rubber materials with various carbon Nano particle reinforcement volume fractions.

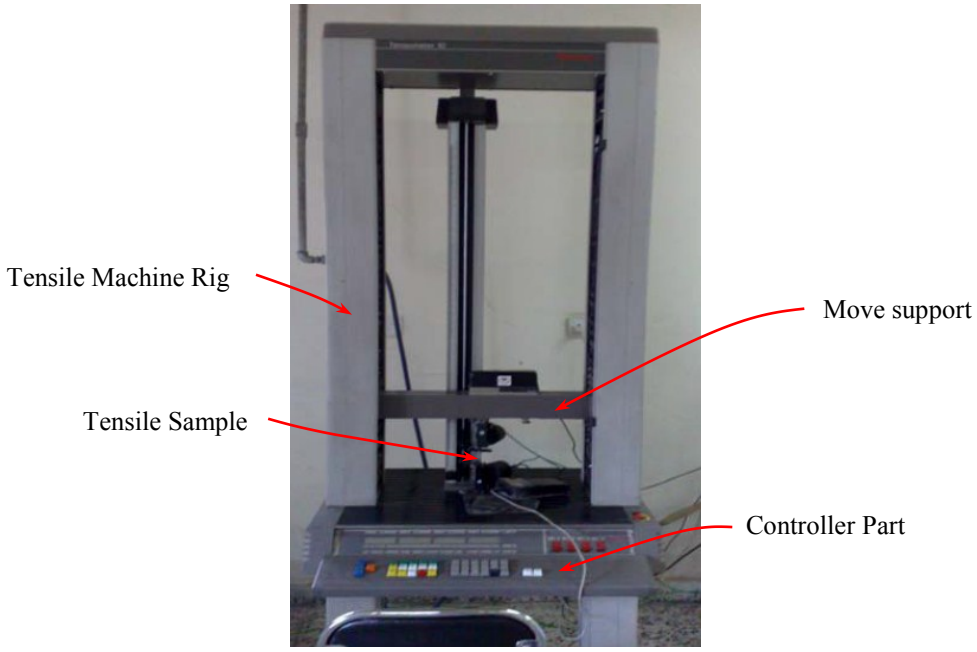
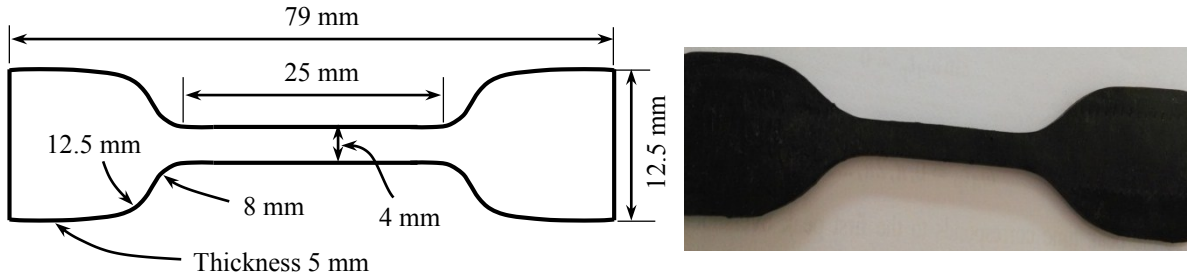


Figure 3. Tensile test rubber machine.

2.2 Fatigue of rubber

The fatigue characterizations of natural rubber materials, as fatigue strength and fatigue cycle life, are measuring by testing eight samples for rubber materials for each carbon Nano volume fraction sample. Therefore, the test included manufacturing eight fatigue samples for each volume fraction of reinforcement carbon Nano particle, dependent on ASTM standard D 4482, [8], as shown in Figure 4. Then, test the fatigue sample by fatigue test machine to evaluating the fatigue strength and life for rubber materials with various carbon Nano particle reinforcement volume fractions. Therefore, the fatigue results by experimental work are comparison with numerical fatigue results evaluating by using finite element method with Ansys program.



(a) ASTM fatigue sample (b) Manufacture rubber sample

Figure 4. Fatigue sample.

Where, the experimental fatigue test included applied various load on the fatigue sample and evaluating the fatigue number of cycle of each applied load. Then, sketch the fatigue strength with number of cycle relation, and then, using the value of fatigue strength and number of cycle form it relation at cross point for two lines tangent, as shown in Figure 5.

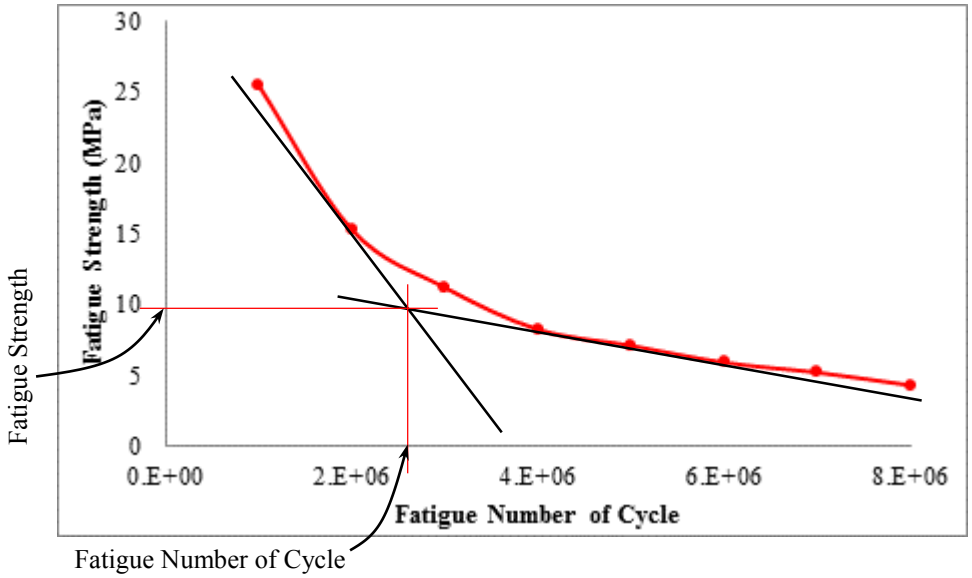
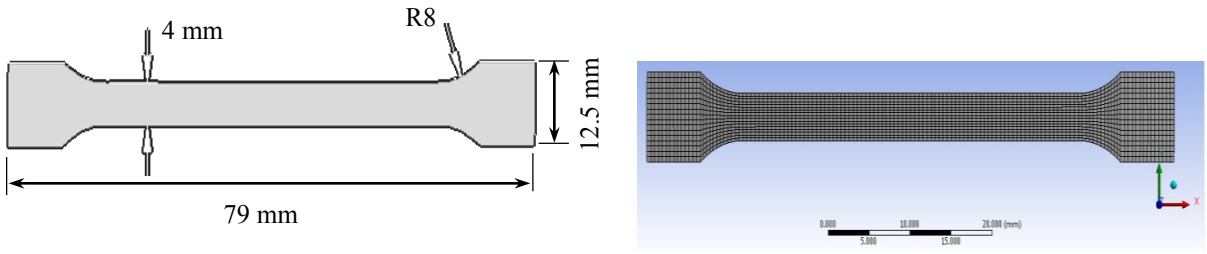


Figure 5. Fatigue –number of cycle relation of natural rubber materials.

3. Numerical technique

The numerical part include evaluating the fatigue strength and number of fatigue cycle of natural rubber materials with various carbon Nano particle tube materials by using finite element method with Ansys program (workbench part). Where, the numerical part needs to input the strength of rubber materials evaluated by experimental work. In addition, the numerical part needs the fatigue-number of cycle relation evaluated by experimental work as an input data. Therefore, the by numerical part calculate the fatigue-number of fatigue cycle of rubber materials. Then, the results evaluated by experimental work are comparison with the fatigue results evaluated by experimental work to shows the agreement of

experimental work to evaluating the fatigue characterization of rubber materials. Thus, to evaluating the fatigue characterization by numerical technique, first must be sketch the fatigue sample of rubber materials, as shown in Figure 6a. Then, mesh the sample with number of mesh given stability of results with variable the number of element used. Then, after selected the number of mesh used, as shows in Figure 6b, input the strength and fatigue characterization of rubber material as an input data, and then, calculated the numerical values of fatigue characterization as an output data of numerical work.



(a) Dimensions of sample (b) Mesh of sample

Figure 6. Numerical sketch of fatigue sample.

4. Results and discussion

The results of this work include calculate the strength and fatigue characterization of natural rubber materials with various carbon Nano tube (0.2, 0.4, 0.6, 0.8 and 1%). Therefore, the results were evaluated experimental work and then it's evaluated by numerical technique with using finite element method to shown the agreement of results. Then, the first results are the strength of rubber materials with various Nano volume fractions, as shown in Figure 7. Where, the value of strength of each rubber sample is the average value for five sample testing by tensile test machine. Thus, from figure can be show that the strength of rubber materials is increase with increasing the volume fraction of reinforcement Carbon tube Nano particle materials, where, the increasing the strength for rubber materials with (1%) Nano particle reach to 2.25 times from the value of strength of rubber without reinforcement Nano particle.

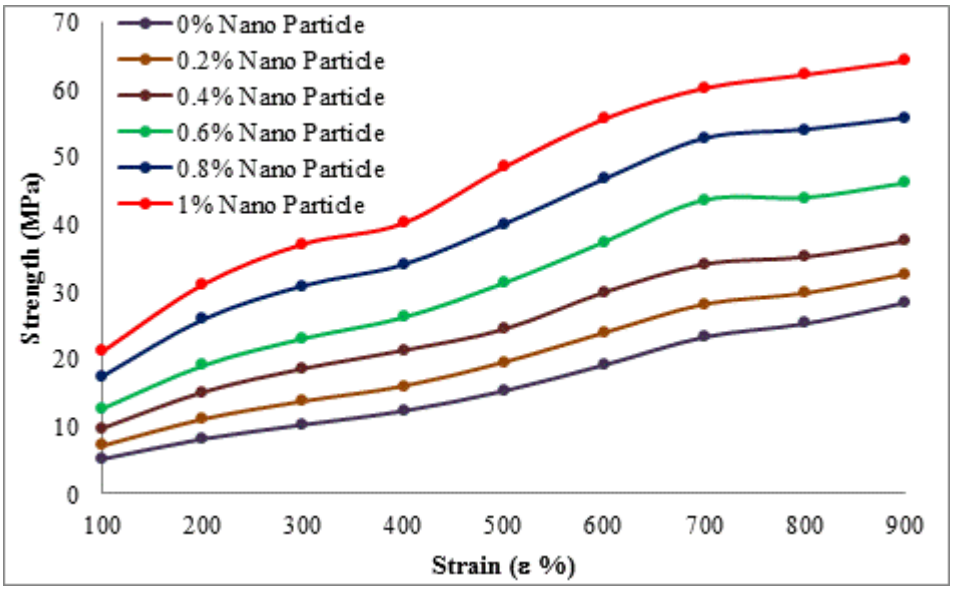
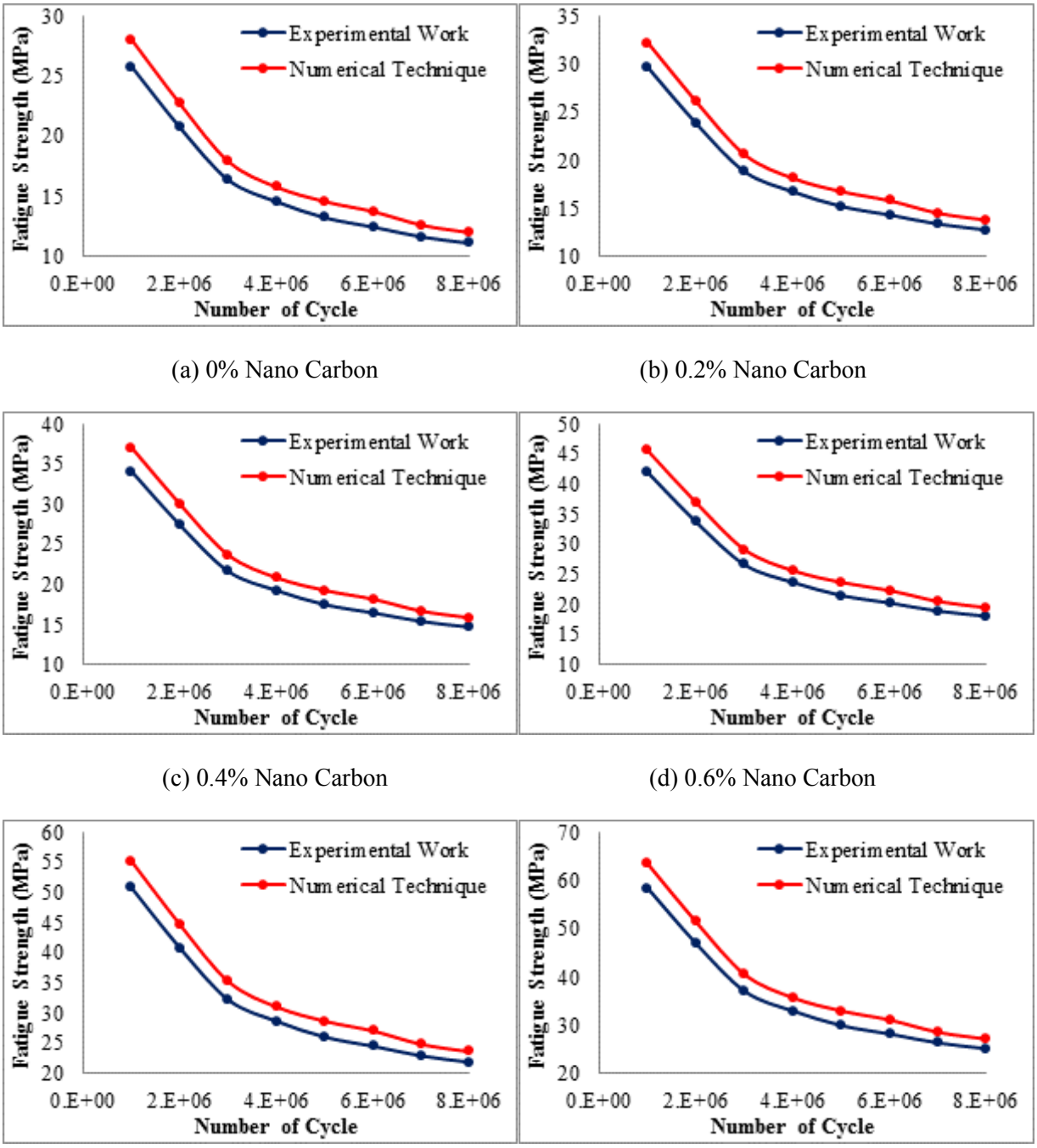


Figure 7. Stress strain relation for natural rubber with various volume fractions nano particle.

Then, after evaluated the strength of rubber materials with various Nano particle volume fraction, evaluate the fatigue characterizations of rubber materials by experimental technique, and then, evaluating the fatigue characterizations by numerical technique. Where, the experimental results are comparison with numerical fatigue results, as shows in Figure 8. There, the comparison of fatigue results shows in Figure 8, are shown a good agreement between the experimental and numerical technique with various volume fraction

reinforcement Nano particle carbon tube materials. Thus, the maximum error of evaluated results are about (10.28%), form various samples of rubber materials.



(a) 0% Nano Carbon (b) 0.2% Nano Carbon

(c) 0.4% Nano Carbon (d) 0.6% Nano Carbon

(e) 0.8% Nano Carbon (f) 1% Nano Carbon

Figure 8. Comparison between experimental work and numerical technique of fatigue strength-number of cycle relation, for natural rubber materials, with various volume fractions of carbon nano particle reinforcement materials (0.2 to 1%).

Then, the investigation of Nano particle reinforcement effect on the fatigue characterizations of rubber materials can be shown in Figure 9. Where, from the figure can be show that the fatigue strength of rubber materials is increase with increasing the volume fraction of carbon Nano particle volume fraction. Since, the increases of Nano particle materials are lead to increasing the strength of rubber, then, increasing the fatigue strength of rubber materials. Therefore, from present work can be shown that the reinforcement by Nano particle lead to increasing the strength of rubber materials and increasing the fatigue characterizations

of natural rubber materials. In addition, the present work show that the experimental work is a good tool can be used to evaluated the mechanical or fatigue characterizations of rubber materials with different effect of Nano particle.

Finally, can be shows the present work shows that the reinforcement with a small amount of carbon Nano particle tube lead to increasing of strength and fatigue characterizations for about 2.5 times from its properties without Nano particle. Where, the increasing of mechanical properties and fatigue characterizations in other researchers not up to (1.5%) with variable in the combined of rubber materials, as presented in same researchers as shown in introduction section of this paper.

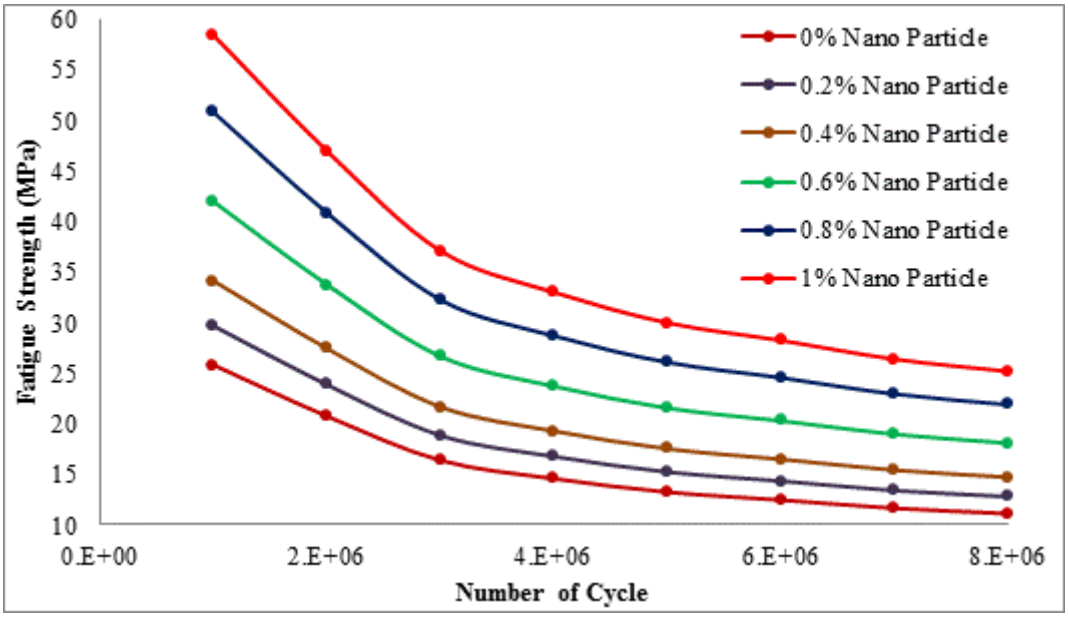


Figure 9. Fatigue strength-number of cycle relation of natural rubber materials with various volume fraction reinforcement carbon nano tube particle materials.

5. Conclusion

The presented work is shows the modified of fatigue characterization of natural rubber material by reinforcement with carbon Nano tube. Where, the work included experimental and numerical technique. Therefore, from its work can be listing the following conclusion evaluating,

1. The experimental work used was a good technique can be used to calculating the fatigue characterization for natural rubber material with various volume fraction of carbon Nano tube.
2. The comparison between experimental and numerical technique are given a good agreement of fatigue characterization results with maximum error about (10.28%).
3. The reinforcement by carbon Nano particle tube is lead to increase the strength of natural rubber materials with various volume fraction of Nano particle.
4. Also, from results evaluated can be shows that the increases of volume fraction for carbon Nano particle tube lead to increasing the fatigue strength and life.

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