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# Experimental Investigation on a Heavy Duty Engine Mount Elastomer

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**A B S T R A C T**

Elastomeric engine mounts are being used in heavy vehicles as well as passenger cars to absorb the vibrations of the engine, carry its weight and reduce its movement while driving. The aim of this research is some studies that have been done to find the components of the elastomeric compound. Moreover, the feasibility study of constructing three different specimens with different percentages of soot and oil has been carried out in order to achieve the desired characteristics in the heavy vehicle engine mount. A rheometric test was then performed to determine the temperature and time of sintering. The tensile strength test has been used to determine the elasticity of the rubber specimens and to achieve high damping coefficients. Also the tensile strength test was performed with the aim of obtaining a specimen with a suitable stress-strain relationship and comparing the results with the reference engine mount. Consequently, the elastomeric compound is used to make the elastomeric engine mount of heavy duty vehicle in the form of rubber and reverse engineering.

## 1. Introduction

Elastomeric engine mounts are used widely nowadays in the automotive industry given their special properties like bearing engine weight, absorbing engine vibration and preventing excessive engine movement because of road bumps, acceleration or braking. Engine mounts are one of the components involved in the dynamics and vibrations of vehicles which have a significant role in absorbing vibrations, directly associated with the passenger comfort and stability and drivability of a vehicle [1].

The dynamic hardness of the elastomeric engine mounts increases at high frequencies; making their design very complicated. Moreover, high hardness and damping are useful at low frequencies to absorb vibrations, yet are not effective at high frequencies [2].

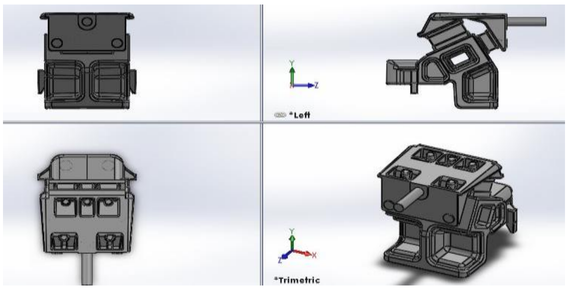


**Figure 1:** Heavy vehicle elastomeric engine mount

There have been many studies on elastomeric engine mounts, where the physical and mechanical properties of the engine mounts have been examined using experimental methods and numerical simulation. Among these studies, one can state the study by Feng et al. [3] (2018), which examined the properties of rubber elements based on the nonlinear mechanical properties that are affected by frequency, excitation range, temperature, etc. In this study, by developing a finite element model, various forms of properties like viscoelasticity, model-dependent frequencies

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and elastoplasticity have been compared in modeling. Experimental studies have been conducted on rubber cylindrical bushings involved in absorbing vibrations. Liu et al. (2018) [4] used a density-based topology optimization approach to examine the displacement boundary conditions and designed an elastomeric engine mount. In this study, the effect of many design parameters on the static hardness of the vehicle elastomeric engine mount has been examined. The designs done and the results obtained could be used as a reference to reach the desired hardness of engine mounts. Their results indicated a difference of about 9% between the hardness values of the numerical models developed in the MATLAB environment and the LS_DYNA software. Chen et al. (2016) [5] studied the nonlinear parameters of the vibration isolation systems and rubber engine mounts, they conducted some simulations using Runge–Kutta numerical method on some parameters like damping coefficient, resonant frequency and so on, and the results were compared with experimental tests. . Boral et al. (2010) [6] studied hydraulic and elastomeric engine mounts and they studied effect of dry friction on elastomeric engine mounts. The results indicated that adding dry friction to elastomeric engine mounts significantly enhances transmissibility over a wide range of frequencies, with the best results obtained at resonant frequency. Valid et al. (2010 examined the characteristics of existing elastomeric engine mounts with various geometries and dynamic parameters to enhance their properties, which was done by parametrically studying various engine mounts. The analysis of the rubber components of the engine mount must be accompanied by the vibrational analysis of the engine mount system. The study was conducted to enhance and study the elastomeric engine mounts.

The paper examined in vitro study of the constituent compounds in elastomeric engine mount of a heavy vehicle. At first, some studies were conducted to find the components of elastomeric compounds in the engine mounts of a heavy vehicle and to examine the behavior of these materials to make an elastomeric engine mount sample. Moreover, the feasibility of developing three various samples with different soot and oil percentages were examined to reach the desired hardness in the heavy vehicle engine mount. Then a rheometric test was used to determine the temperature and rubber cooking time. Rubber resilience tests and tensile strength have been used to achieve the desired sample, with the results of these tests compared to those of the original sample of the heavy vehicle engine mount to enhance its elastomer. Given the characteristic of energy absorption in rubbers, rubber resilience test has been used to determine the elasticity of the samples and to obtain samples with high damping coefficient.

## 2. The steps of making a heavy-duty vehicle engine mount elastomer

This section has examined the experimental study of the behavior of elastomers used in the engine mount of a heavy vehicle. Overall, the properties of elastomers highly depend on their constituent components. Because of this, at first the factors effective in the composition of the material are introduced. Then some rubber samples were prepared for testing. Several factors are involved in rubbers compounds that can improve or weaken the elastomers properties. The main and most effective ingredient in the composition of elastomers is its caoutchouc. These include activators, accelerators and deterrents, peroxides and fillers. This study examines the amount of soot and oil as fillers in the elastomer structure and the effects that it has on the physical properties of the engine mount. Later on, hardness tests are done on elastomeric samples and the results are compared. The difference between these samples is the amount of soot and the aromatic oil used in them, the engine mount with the desired characteristics is obtained by changing the percentage of these materials.

### 2.1. Preparing the composition

Various compositions are available for blends according to the various applications of the elastomer, with the percentage of elements and their types varied. In this section, the desired composition for the elastomeric engine mount in the heavy vehicle is selected according to its application and by conducting experiments to determine the rubber polymer base of the engine mount and after consulting with polymer researchers in Iran Polymer Research Institute. After identifying and preparing the needed materials in the elastomeric composition, in the first stage, the weighing of the materials is done separately, as is seen in Figure 2 of the materials used in the composition.

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**Figure 2:** The components of the elastomeric composition of the heavy vehicle's

Tables 1 and 2 list the materials used in the compounds. The difference between these compounds is in the amount of soot and aromatic oil. The hardness, elasticity of the rubber and tensile strength have been examined with different percentage of soot and oil. To obtain a combination with desirable features.

**Table 1:** first elastomeric compounds

| compounds | Mass percentage |
|---|---|
| Natural rubber | 100 |
| Soot 990 | 90 |
| Soot 550 | 15 |
| Aromatic oil | 15 |
| Zinc oxide | 3 |
| Stearic acid | 1 |
| Antioxidants | 1 |
| Thiuram | 0.5 |
| Sulfur | 0.5 |

These materials are fillers, accelerators, deterrents or activators, which the percentage and type of each them are determined by studies on the behavior of the engine mounts. In order to increase the hardness, a second elastomeric composition was considered by reducing the amount of aromatic oil by ten units and increasing the amount of soot by ten units. Aromatic oil has been used for easier dissolving of the soot and by increasing the soot, the value of oil was reduced to increase the hardness.

**Table 2:** second elastomeric compounds

| compounds | Mass percentage |
|---|---|
| Natural rubber | 100 |
| Soot 990 | 100 |
| Soot 550 | 25 |
| Aromatic oil | 5 |
| Zinc oxide | 3 |
| Stearic acid | 1 |
| Antioxidants | 1 |
| Thiuram | 0.5 |
| Sulfur | 0.5 |

**Figure 3:** Raw natural rubber

## 2.2 Production of raw mixture

The production of raw mixtures consist of the following steps:

### 2.2.1. Breaking down

At the beginning of breaking down stage, the temperature of the Banbury mixer is set to 30°C, considering that the rubber polymer base is from natural caoutchouc. At the break down stage, the base rubber is soft and broken. The break down operation makes the rubber ready to accept the additives. The viscosity of natural caoutchouc is reduced during the break down stage by opening or separating polymer chains. For natural and synthetic caoutchouc, the breakdown operation





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would become easier by adding softeners. Figure 4 shows the break down stage of rubber by machine rollers.

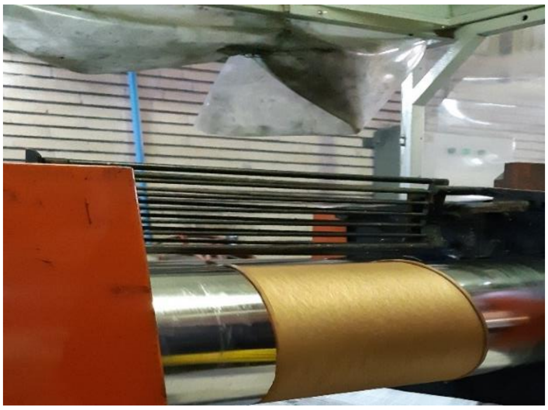

**Figure 4:** Break down of natural rubber in a roller machine

This break down is done in the internal mixer or Benbury or roller general as shown in Figure 5. Firstly, the distance between the two rollers of the device is reduced to enhance the mixing.

**Figure 5:** Benbury device

This device has two metal rolls as shown in Figure 5. These rolls are usually made of scratch, abrasion and chemical-resistant cast irons. The front roll usually rotates slower and is more movable, whereas the rear roll is faster and fixed. The distance between the two rolls is adjusted by moving the front roll. These metal rolls are double-walled to control the temperature and raw materials are fed in from above.

### 2.2.2. Addition of soot.

At this phase, as shown in Figure 6, soot along with oil is added to the raw mixture. It should be noted that given the high soot content, the oil is added slowly and in combination with the soot at this stage, so that the mixture becomes more homogeneous and the mixing process is better.

**Figure 6:** Addition of soot and oil to the mixture

### 2.2.3. Retempering on the mill

At the end of the mixing operation because of improper distribution or high viscosity, the mixture is sent back to the roller machine as shown in Figure 7 to enter the next phase. Retempering is usually done for mixtures that have natural caoutchouc with high soot and low oil content like the combination considered for heavy vehicle engine mount elastomer due to its high hardness.

**Figure 7:** Retempering

### 2.2.4. The final stage of mixing

In the final stage of mixing, the raw mixture is prepared by increasing the distance between the Banbury rollers. This operation goes on until the mixture is sufficiently homogeneous and reaches a certain thickness. The two prepared mixtures as shown in Figure 8 are ready for the next steps.

**Figure 8:** The obtained raw mixture


**Figure 9:** Rheometeric test device

## 3. Rheometeric test

The results of the rheometeric test determines the time required for the cooking operation. Raw rubber cannot be used in industry due to its undesirable mechanical properties, yet by combining it with proper additives and cooking it, countless applications are emerged [8]. The cooking time of elastomers is essential in the formation of rubber in the mold and the injection process. After cooking the rubber, it is not possible to add any ingredients to it and the rubber cannot be reshaped. The cooking agent, sulfur, must be added at the last stage after all additives have been added [9]. The procedure of this test is that as soon as cooking process of the mixture starts, its viscosity increases and more force is required to move the rotor in the rheometer. This instrumentation plots a continuous curve of increasing torque per time. From this curve, one can estimate the viscosity of the raw mixture, the premature cooking time, the cooking speed and the cooking quality [8].a moving die rheometer has been used to determine the temperature and cooking time of the raw mixtures. Cooking operation has been done on the samples according to ASTM D 5289, ASTM D 6204 and ISO 6502 standards [10].

In the graph shown in Figure 10 which is an example of a rheometeric test, the value of $M_L$ is the minimum torque and represents the uncooked mixture. $M_H$ is the maximum torque and is a measure of cooking and $t_{50}$ and $t_{90}$ are the time to reach the 50% and 90% of the maximum torque, respectively. The cooking time of the mixture used in the study was $t_{90}$, meaning that its torque is 90% of the maximum torque. Figure 10 shows an example of a rheometeric test result.

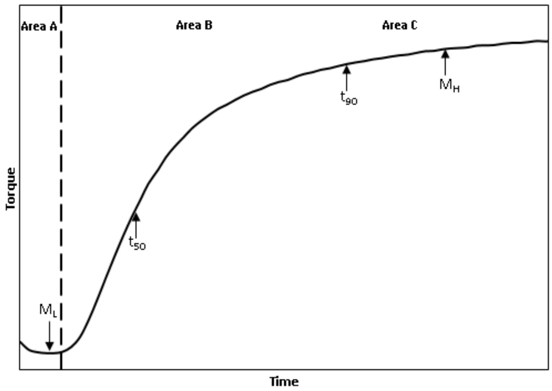


**Figure 10:** Graph of the rheometeric test

The graph has three different areas as follows

- Area A, represents a definition for the viscosity of the mixture.
- Area B, defines the cooking speed of the mixture.
- Area C, determines the cooking quality of the mixture.



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The results of rheometeric test of elastomers with various percentages of soot and oil for all three compositions are shown in Figure 11 The time to reach 90% of the maximum torque which is the cooking time is marked in these figures.

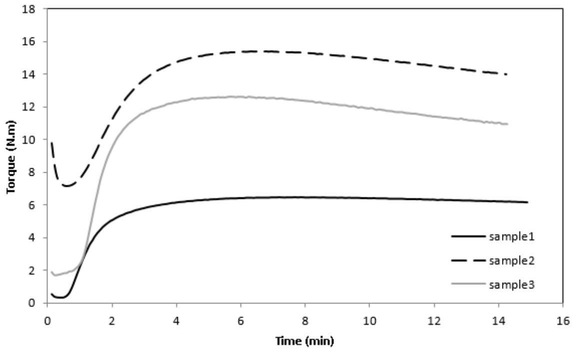


**Figure11:** Comparison of rheometeric tests of three samples

**Figure 12:** rheometeric test sample

Cooking is the process by which a thermoplastic caoutchouc or raw rubber significantly changes into an elastic state [13]. The raw mixture is placed in press molds in the cooking machine and cooked at the right temperature for the required time, which is the result of the rheometeric test. Dumbbell and cylindrical samples are then prepared for resilience and tensile tests.

**Figure 13:** cooked sample

## 4. Shore hardness test

Shore hardness test is used to calculate the hardness of rubbers. This test has two types, each of which is used to calculate the hardness of various types of rubbers, both very soft and soft, as well as hard rubbers and thermoplastics. Shore A Hardness device used to measure the hardness of rubbers according to the standard ASTM 2240, DIN 53505 and ISO 868 [11].The digital shore hardness device is shown in Figure 13. . After hardness testing of the cooked rubber samples, the shore values 60 and shore 78 were obtained. Thus, a model with the characteristics of both of the above elastomeric combinations would make it possible to reach the hardness of the reference heavy vehicle elastomer engine mount, which has a hardness value of 68 shore.

**Figure 14:** cooked sample



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The N550 soot in the new composition has been reduced by ten units in order to decrease the hardness compared to the second composition, and 5 units have been added to the aromatic oil. The rest of the constituents' have remained unchanged. The new composition which has a hardness of 68 shore, is listed in table 3.

**Table 3:** third elastomeric compounds

| compounds | Mass percentage |
|---|---|
| Natural rubber | 100 |
| Soot 990 | 100 |
| Soot 550 | 15 |
| Aromatic oil | 10 |
| Zinc oxide | 3 |
| Stearic acid | 1 |
| Antioxidants | 1 |
| Thiuram | 0.5 |
| Sulfur | 0.5 |

## 5. Rubber resilience test

The resilience test is used to determine the elasticity of the rubbers. Rubbers are good energy absorbers and are used to reduce back impact and dampen vibrations. Figure 14 shows resilience test device which is employed according to ASTM D7121, DIN5312 and ISO4662 standards. This device has a precise pendulum and a strong anvil on which samples of various thicknesses can be placed. The pendulum strikes the rubber sample after releasing and the screen shows some numbers, which are inversely related to the damping coefficient of the rubber [12].

**Figure 15:** Rubber resilience device

The resilience test is repeated three times on each sample to ensure the results obtained, and the results of the average of the calculated numbers are as follows:

- First sample: 47%
- Second sample: 26%
- Third sample: 34%

## 6. Tensile test

The tensile test is used to extract the stress-strain relationship. The device is HIWA 200 which is a multifunctional device used for different tests like traction, pressure, rupture, adhesion, bending, cutting, and etc. Tensile tests have been repeated three times to ensure the accuracy of the results, and the closeness of the results shows their reliability. The samples to be tested for traction after cooking were created in the form of dumbbells with the punch device after being cooked. Before cooking the rubber, its tensile strength is low, so the tensile test is performed on the cooked specimens. The tensile test of the dumbbell samples was continued until their rupture. The ultimate elongation and the tensile strength are the results of the test. The elongation was reported as a percentage of the initial length of the sample. The tensile test results of the three samples are shown in Figure 15, 16 and 17 respectively.



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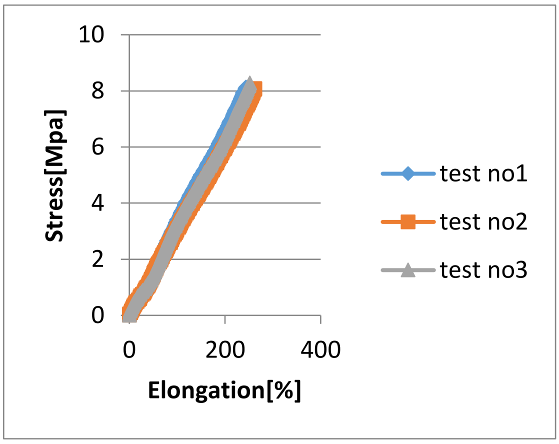


**Figure 16:** The triplicate tensile test results of the first sample

The test is repeated on the second sample and the results are as follows.

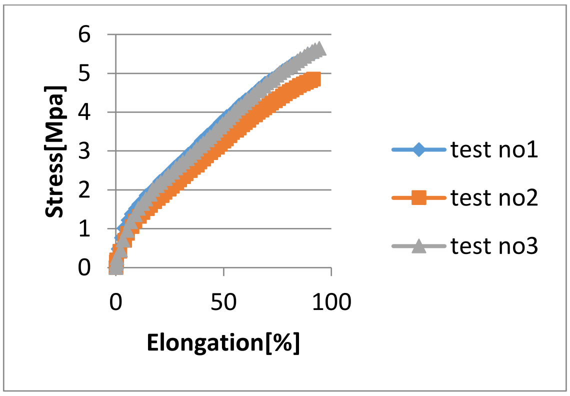


**Figure 17:** The triplicate tensile test results of the second sample

As it can be seen in Figure 17, the third sample, which its composition of the first and second samples ’ composition , has a larger elongation and its tensile strength and its tensile strength is more suitable for engine mount of the heavy vehicle in question.

Then the results of the three-sample tests with the main engine mount tests were compared.

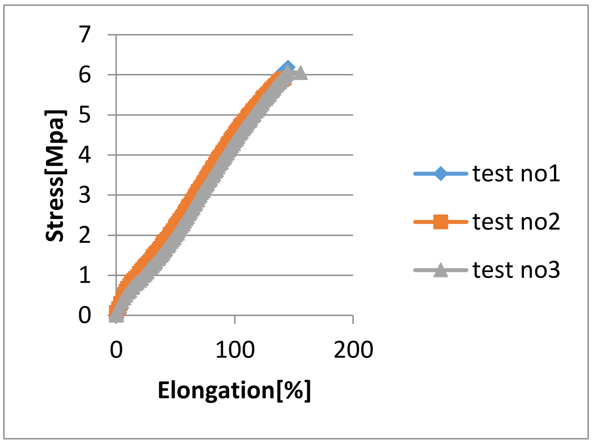


**Figure 18:** The triplicate tensile test results of the third sample

The stress at 100% elongation is about 5 MPa. Figure 19 shows the tensile test results of the reference engine mount.

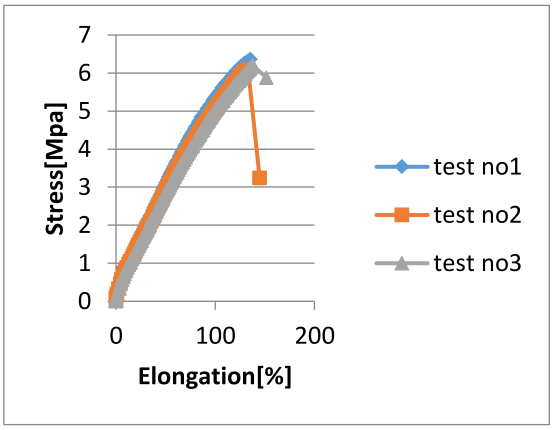


**Figure19:** The triplicate tensile test results of the reference engine mount

## 7. Conclusion

It can be seen that the third sample has a behavior between samples one and two, and its behavior is very close to that of the reference elastomeric engine mount.

The following are the rheometeric and tensile test graphs and the results obtained from the shore hardness and resilience tests of the elastomeric engine mount sample examined.

The results of the tensile test indicated that the effect of loading rate can be neglected in small deformations, yet higher stresses have been applied to the material at higher loading rates when large deformations have occurred.

Moreover, it is seen that the material can withstand higher stresses by increasing the percentage of carbon at the same deformation.





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A stress of approximately 3 MPa has been tolerated when a 100% strain has occurred in the material in the first sample. However, the stress at the same value of elongation for elastomers of the second and third samples are 5.5 and 4.5 MPa, respectively.

It is evident that carbon has performed well as a reinforcement, boosting the tensile strength of the material. By comparing the test results of the third sample with the reference elastomeric engine mount, it can be said that the third sample has a high similarity to the behavior of the reference sample.

Moreover, the reference elastomer engine mount has 36% resilience, and the hardness value of shore 68, which is very close to the third sample. As the result of this study, a sample with hardness of 68 shore A and resilience of 34% and relatively suitable tensile strength compared to the reference sample was obtained by making three elastomeric samples with different compositions and performing shore hardness, resilience and tensile strength tests. The results indicate that by designing the rubber injection mold and using the resulting composition, one can produce elastomeric engine mounts in Iran with similar properties to the reference sample and cheaper compared to foreign engine mounts.



[ DOI: 10.22068/ase.2021.539 ]

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