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EVALUATION OF IMPACT OF VARIOUS MATERIAL COMPOSITION ON FATIGUE LIFE OF RUBBER BUSH

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Abstract

It is vital to absorb the vibration because it occurs frequently during mechanical engineering operations and lowers the efficiency of the machine. This can be done by any shock-absorbing instrument like a Damper, Rubber etc. This paper explores shock-absorbing activity between Leaf springs in automobile and their endpoints. Here, the main emphasis is placed on the Fatigue Life Analyses of four different rubber materials: Silicon Rubber, Hydrogenated Nitrile Butadiene Rubber, Styrene-Butadiene Rubber, and Neoprene Rubber. Maximum deformation, stress and fatigue life are the main parameter to decide which rubber is best. Thickness of Rubber bush is varied between 6.5mm and 8mm. On the basis of fatigue life and stress criteria, all of this rubber materials are compared. Rubber bush fatigue life is significantly influenced by the SN curve. Leaf Spring loading conditions are taken into account for evaluating the performance of Rubber bush. The numerical analysis using ANSYS software is performed to determine fatigue life and stress in rubber bush with different material. The stress developed in rubber bush is observed to be affected by variations in thickness, and fatigue life is found to depend on material composition.

Keywords: - Fatigue Life, Deformation, Stress, Leaf Spring, Noise, SN Curve

1. INTRODUCTION

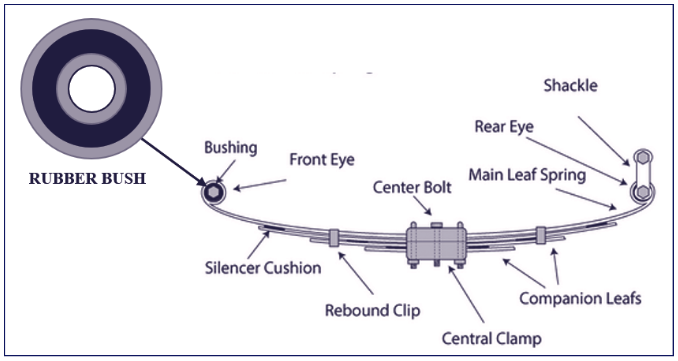
Various machines produce a significant amount of vibration during their functioning. Due to this life of machine and efficiency of machine reduces. Therefore, it becomes necessary to take care of these vibration and these can be done by rubber bush. Rubber bushes increases the lifespan, functionality and reduces the noise in operation. Rubber bushes have more scope in vibration absorption on the ground of low cost, low weight, long life and good rubber properties, easier installation, no need of lubrication. However major disadvantage associated with of application of rubber bush is Rubber fatigue failure. Rubber bush is a synthetic material whose properties are mostly influenced by its composition, which may include natural rubber, carbon black as a filler, sulphur as a curing agent, anti-oxidants, and adhesive agents. The effect of changing the ingredients on common physical qualities. It becomes essential to have rubber with the appropriate composition. Rubber's performance is affected if any of its properties change. This paper focuses on estimating the fatigue life of various rubber bush materials.

Kubat Naryambek Ulu [1] presented the fatigue analysis of HNBR blends also study the effect of thermal ageing on it. It shows that poor fatigue resistance is provide by HNBR with 24% ACN composition. Higher percentage of hydrogenation seems to increase fatigue resistance in terms of hydrogenation. Oscar J. and Cento G. [2] employed finite element modelling to simulate a crash using a rubber bushing, and they came to the conclusion that the Yeoh model was stable under high strain rates and could be used with these material parameters. C10 = 0,55, C20 = -0,05, C30 = 0,95. Using finite element analysis and material property tests, Qian Li and Jian-cai Zhao [3] assessed the prediction of rubber mount's fatigue life; Their research showed that the suggested fatigue life prediction method might significantly reduce design and product costs while also shortening the product design cycle and enhancing the rubber mount's quality. Samuel Asare [4] provided an example of a rubber component failing under fatigue, and it is found that the maximum average strain energy density approach allowed for the prediction of cyclic stress relaxation in a genuine component from the findings of a small test piece. Fatigue lifespan prediction methods of rubber components was presented by C.S. Woo and W.D. Kim [5]. They concluded that, maximum Green- Lagrange strain is utilised to estimate component fatigue lives in order to produce accurate results. Predicted fatigue lives of rubber components were shown to be in good agreement with experimental lives. According to an experimental study by Qiang Yang and Yunlai Zhou [6] on the hysteresis characteristics of fluorosilicone rubber dampers, the stiffness of the damper increases as rubber hardness increases. When rubber hardness increases, the damper's damping loss factor first rises and then falls. Although it doesn't change much when the loading displacement is large, the damper's damping loss factor decreases as the loading displacement increases. Automotive bushing made of fe-safe rubber was created by Jing Bi and Gergana Dimitrova [7]. It is found that the non-parametric form optimization increases fatigue life by 77%. This paper provides best suitable rubber bush material on the basis of fatigue life and deformation analysis with optimized thickness.

2. OBJECTIVE

In order to choose the optimum rubber bush material, fatigue life must be evaluated. Four distinct materials' fatigue life, including silicone rubber, Neoprene rubber, HNBR rubber, and SBR rubber, are compared by using Finite Element Analysis. The study evaluates rubber bush with two distinct 6.5 mm and 8 mm thicknesses. Rubber bush in two different thicknesses, 6.5 mm and 8 mm, is used for their deformation analysis [8]. A moment of 250 N-mm, a transverse load of 20 N, and a radial load of 5 N are all applied to the outer sleeve of rubber bush under consideration for analysis. Finally, a rubber bush material with the right thickness is suggested for support. The Fig.1 shows the position of rubber bush in Leaf spring.

Fig.1: Rubber bush in Leaf Spring



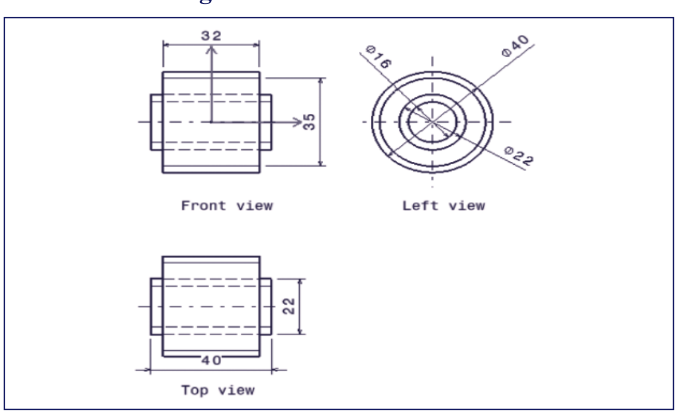
3. METHOD

To draw conclusions from the FEA study of the Rubber Bush, the following processes must be taken in order to obtain the final result values. The general steps used to obtain the best result are briefly outlined here.

Step 1 Design

The first and most crucial phase in FEA analysis is product design [8]. To analyse a rubber bush, a CAD model of the bush is created in the CATIA software using the standard specifications of bush. A bush is typically made up of three main parts an inner sleeve, rubber part, and an outer sleeve. For inner sleeve the inner diameter is 16 mm and outer diameter is 22 mm respectively. Two rubber thicknesses 6.5 mm and 8 mm are taken into account for analysis of bush. The design of the rubber bush is shown in Fig. No. 2.

Fig 2: Rubber bush 2-D view



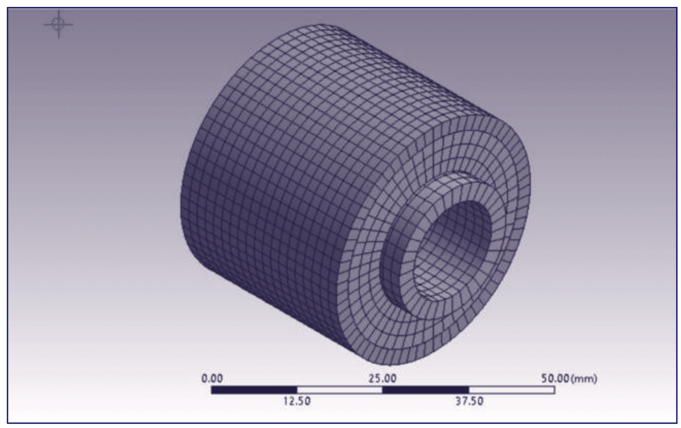
Step 2 Material Selection

The ANSYS software is used to analyse rubber bush, which is subjected to static structural analysis. The first step in ANSYS is material selection. Stainless steel is taken into consideration for the inner and outer sleeves of bush, and various rubbers are taken into account for the rubber part, including Neoprene rubber, Styrene-butadiene rubber (SBR), Silicon rubber, and Hydrogenated Nitrile Butadiene Rubber (HNBR), in order to select the best suitable material to absorb vibration. To obtain fatigue life, deformation, and stress, several material properties such as the S-N curve [1], young's modulus, Poisson's ratio, and rubber density are added to the list of material properties [9].

Step 3 Meshing

The most important phase of analysis is meshing. Solid finite elements are used to mesh the inner and outer sleeves as well as the rubber part. For the rubber bush to provide the desired results, the face meshing is applied to the bush faces with an element size of 1.75 mm and the refining meshing is applied to the outer surface of rubber bush as illustrated in fig.3

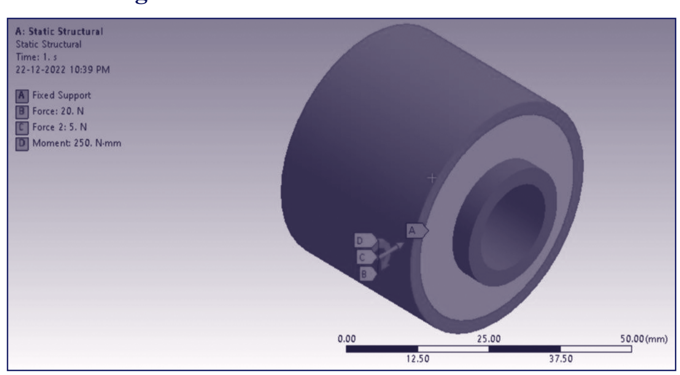
Fig.3: Meshing of Rubber Bush



Step 4 Boundary Conditions

The rubber bush is subjected to several forces throughout operations, so it's critical to establish suitable boundary conditions for the bush. Inner sleeve is fixed while a twisting moment of 250 N-mm is applied to the outer surface of rubber bush along with tangential and radial forces of 20 N and 5 N respectively as shown in Fig. 4.

Fig. 4: Load Conditions on Rubber Bush



Step 5 Solution

The stated objective of the analysis is to calculate how much rubber deformed, stresses generated in the bush, and fatigue life of the rubber. The results from ANSYS give the minimum and maximum deformation that occurred in bush (in mm), as shown in the Fig. 5, 6, 11, 12 and the minimum and maximum Equivalent Von-Mises stress generated in the bush, as shown in the Fig. 7, 8, 13, 14. The most crucial factor, however, that we can obtain from the analysis is fatigue life of rubber, which is shown in Fig. 9, 10, 15, 16. For different rubber bush materials and varied thicknesses, the steps from steps 2 to 5 are repeated. Consequently, Table No. 1 compares the analysis results of the study for the different materials, and it reaches the following conclusion.

4. RESULTS

The next step after developing the FEA model and applying the necessary loading is to examine the outcomes in order to assess the bushing's performance under the specified loading circumstances. Deformation Analysis, Equivalent Stress Analysis, and Fatigue Life Analysis are the criteria used to evaluate the bushing performance. Two cases are taken into consideration when analyzing the aforementioned parameters. These situations are based on the inner rubber part's thickness.

i) Case 1: The inner rubber portion has a 6.5 mm thickness, while the other dimensions remain the same. For the sample data study Neoprene Rubber and Hydrogenated Nitrile Butadiene Rubber (HNBR) are employed. However, the results for the other two rubber materials, SBR and Silicon rubber, are shown in Table 1.

a) Deformation Analysis:

Deformation analysis involves applying a total deformation to the intended rubber bushing and analyzing the results depending on the given loading circumstances.

I. For neoprene rubber, the inner rubber part has a maximum deformation of 4.27 mm when subjected to a moment of 250 N-mm. The minimum deformation is 0.534 mm at the portion of the rubber part connected to the inner sleeve as shown in Fig. 5

II. Similarly, for HNBR rubber, the inner rubber part has a maximum deformation of 0.0182 mm when subjected to a moment of 250 N-mm. The minimum deformation is 0.0022 mm at the portion of the rubber part connected to the inner sleeve as shown in Fig. 6

Fig. 5: Deformation of Neoprene Rubber with thickness 6.5 mm

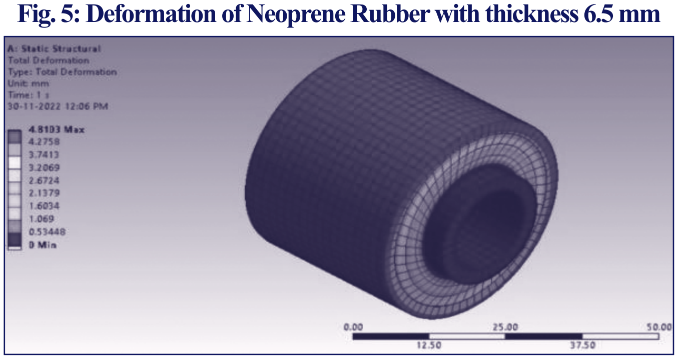
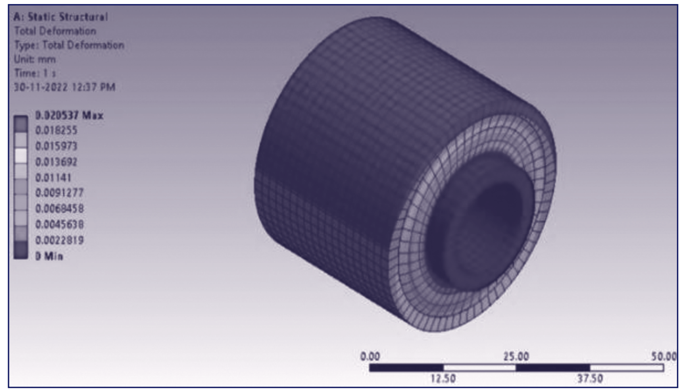


Fig. 6: Deformation of HNBR Rubber with thickness 8 mm



b) Equivalent (Von- Mises) Stress **Analysis:**

Equivalent (Von- Mises) Stress Analysis is based on the Equivalent von Mises theory which defines that maximum equivalent stress acting on a material or part must be smaller than the yield strength of that materialtaken into consideration.

I. For neoprene rubber, the inner rubber part has a maximum stress of 0.0375 MPa when subjected to a moment of 250 N-mm. The minimum stress is 0.0125 MPa at the portion of the rubber part connected to the inner sleeve as shown in Fig. 7

Similarly, for HNBR rubber, the inner rubber part has a maximum stress of 0.025 MPa when subjected to a moment of 250 N-mm. The minimum stress is 0.0084 MPa at the portion of the rubber part connected to the inner sleeve as shown in Fig. 8

Fig.7: Equivalent Stress of Neoprene rubber with thickness 6.5 mm

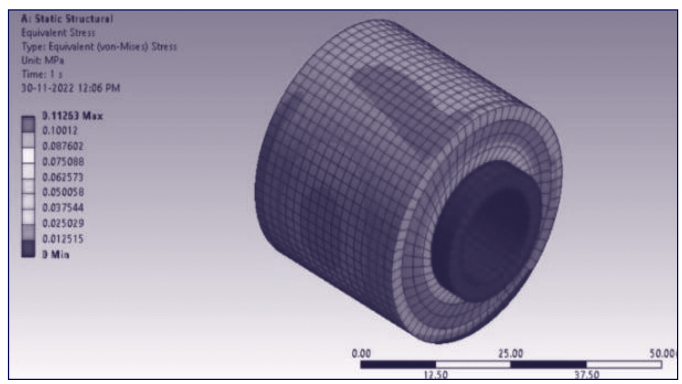
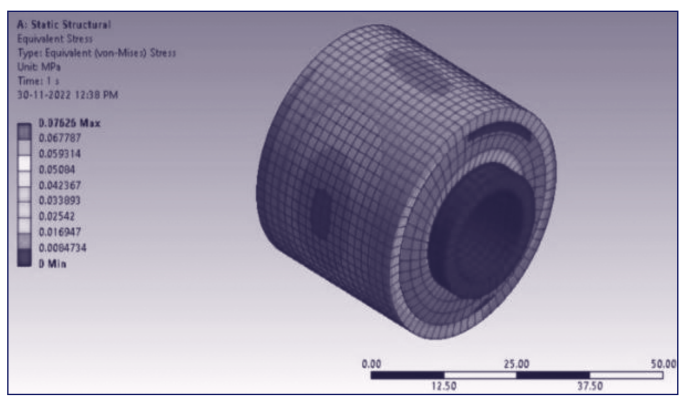


Fig.8: Equivalent Stress of HNBR rubber with thickness 6.5 mm



c) Fatigue Life Analysis:

Fatigue life is the available life for the given fatigue analysis**.** The analysis contour results show the no. of cycles until failure due to fatigue loading. It helps to estimate the life cycle of a component or part[10].

I.For Neoprene rubber, the inner rubber part has a maximum fatigue life of about 8.91E +06 as the moment of 250 N-mm takes place in the outer sleeve. The outer sleeve has a fatigue life of about 1E+06 as shown in Fig. 9

II.Similarly, for HNBR rubber, the inner rubber part has a maximum fatigue life of about 6.49E+06 as the moment of 250 N-mm takes place in the outer sleeve. The outer sleeve has a fatigue life of about 1E+06 as shown in Fig. 10

Fig. 9: Fatigue Life Analysis of Neoprene Rubber with thickness 6.5 mm

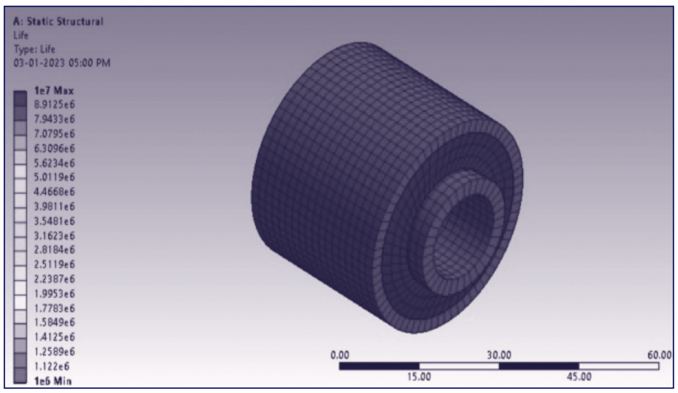
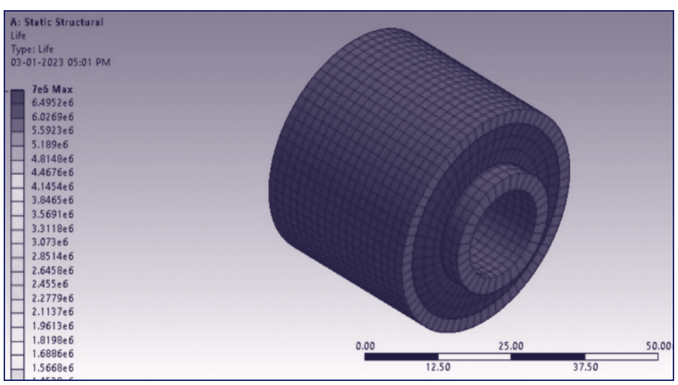


Fig. 10: Fatigue Life Analysis of HNBR Rubber with thickness 6.5 mm



ii) Case 2: The inner rubber portion has an 8 mm thickness, while the other dimensions remain the same. For the sample data study, Neoprene Rubber and Hydrogenated Nitrile Butadiene Rubber (HNBR) are employed.

a) Deformation Analysis

I. For Neoprene rubber, the inner rubber part has a maximum deformation of 2.72 mm when subjected to a moment of 250 N-mm. The minimum deformation is 0.3411 mm at the portion of the rubber part connected to the inner sleeve as shown in Fig. 11

II. Similarly, for HNBR rubber, the inner rubber part has a maximum deformation of 0.0219 mm when subjected to a moment of 250 N-mm. The minimum deformation is 0.0027 mm at the portion of the rubber part connected to the inner sleeve as shown in Fig. 12

Fig. 11: Deformation of Neoprene Rubber with thickness 8 mm

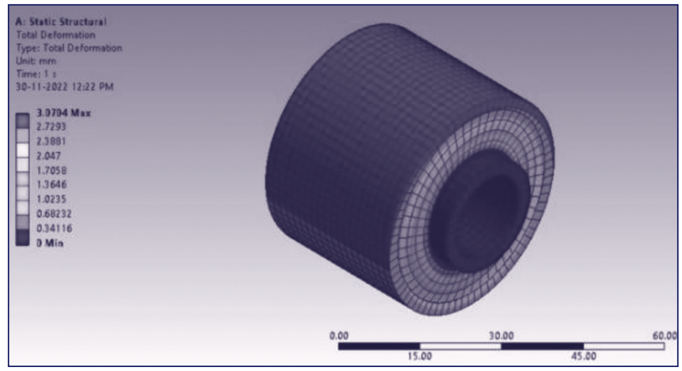
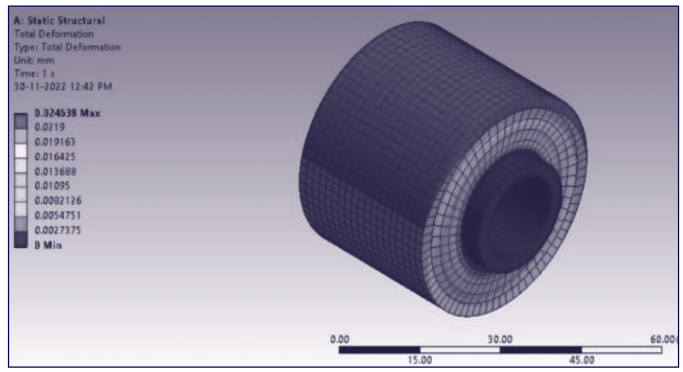


Fig. 12: Deformation of HNBR Rubber with thickness 8 mm



b) Equivalent (Von- Mises) Stress Analysis:

I. For neoprene rubber, the inner rubber part has a maximum stress of 0.0375 MPa when subjected to a moment of 250 N-mm. The minimum stress is 0.0119 MPa at the portion of the rubber part connected to the inner sleeve as shown in Fig. 13

II. Similarly, for HNBR rubber, the inner rubber part has a maximum stress of 0.02404 MPa when subjected to a moment of 250 N-mm. The minimum stress is 0.008 MPa at the portion of the rubber part connected to the inner sleeve as shown in Fig. 14.

Fig. 13: Equivalent Stress of Neoprene Rubber with thickness 8 mm

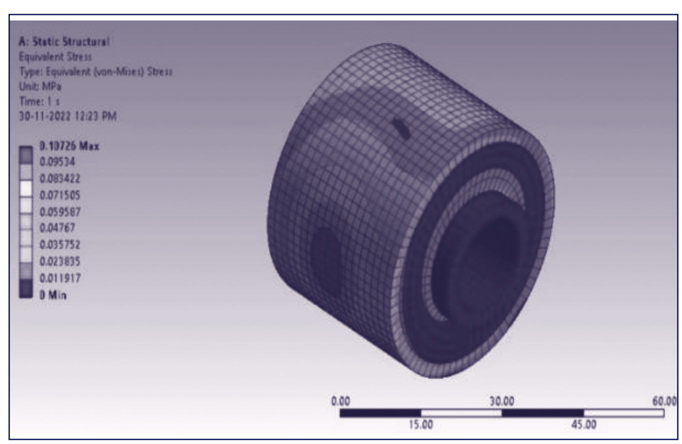
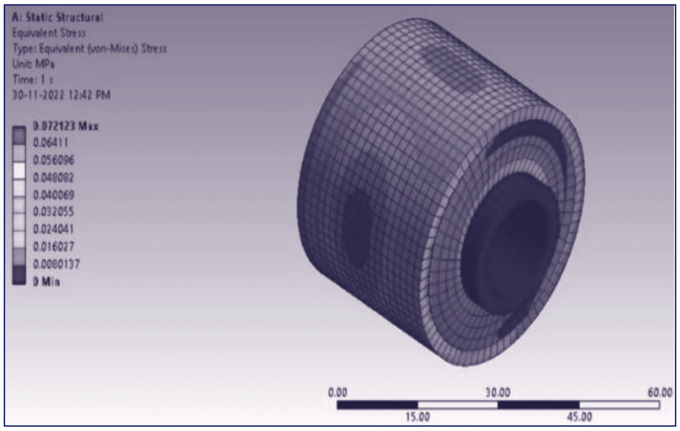


Fig. 14: Equivalent Stress of HNBR Rubber with thickness 8 mm



c) Fatigue Life Analysis:

I. For neoprene rubber, the inner rubber part has a maximum fatigue life of about 8.91E+06 as the moment of250 N-mm takes place in the outer sleeve. The outer sleeve has a fatigue life of about 1E+06 as shown in Fig.15

II. Similarly, for HNBR rubber, the inner rubber part has a maximum fatigue life of about 6.49E +06 as the moment of 250 N-mm takes place in the outer sleeve. The outer sleeve has a fatigue life of about 1E+06 as shown in Fig. 16

Fig. 15: Fatigue Life of Neoprene Rubber with thickness 8 mm

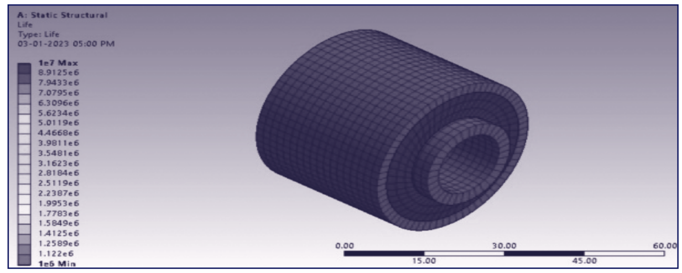
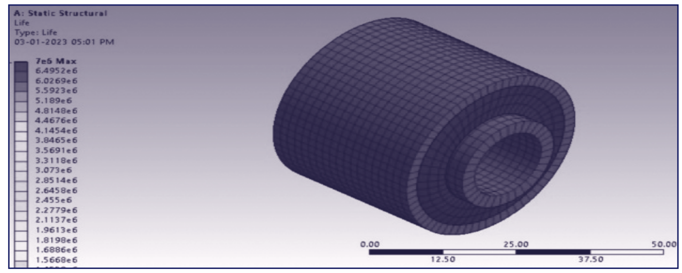


Fig. 16: Fatigue Life of HNBR Rubber with thickness 8 mm



RESULT ANALYSIS

After observing the sample data for Neoprene Rubber and HNBR Rubber a detailed analysis of deformation, equivalent stress and fatigue life of all 4 rubber materials i.e. (Neoprene, SBR, Silicon, HNBR) is exhibited belowin Table no.1.

Table no. 1: comparison of materials

Parameter	Neoprene Rubber		SBR		Silicon Rubber		HNBR	
Thickness (mm)	6.5	8	6.5	8	6.5	8	6.5	8
Max. Deformation (mm)	4.726	2.7293	0.0933	0.1122	0.1887	0.2264	0.0182	0.0219
Min. Deformation (mm)	0.5344	0.3411	0.0011	0.014	0.0235	0.0283	0.0022	0.0027
Max. Stress (MPa)	0.03754	0.03575	0.02689	0.02521	0.0254	0.02405	0.025	0.02404
Min. Stress (MPa)	0.0125	0.0119	0.0083	0.0084	0.0084	0.008	0.0084	0.008
Fatigue Life (Cycles)	8912000	8912000	2162000	2162000	1000000	1000000	6495200	6495200

5. CONCLUSION

From Table No. 1, it can be concluded that the deformation of all four-rubber sample is depends on their material composition. When compared to Neoprene rubber, SBR rubber, and Silicon rubber, the maximum deformation of HNBR rubber is found to be 99.61%, 80.49%, and 90.32% less, respectively. It is observed that the percentage decrement in maximum stress of HNBR rubber as compared to Neoprene, SBR, and Silicon Rubber is about 33.4%, 7.02% and 1 .57% respectively. The fatigue life of HNBR rubber is more as compare to SBR, and Silicon rubber. It is also observed that there is no effect of increase of rubber thickness from 6.5 mm to 8 mm on fatigue life of all four-rubber bush. It is concluded that on basis of fatigue life as well as deformation criteria, Hydrogenated Nitrile Butadiene Rubber is best suited for rubber bush application.

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