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DURABILITY IMPROVEMENT OF A WISHBONE BUSH FOR A PASSENGER VEHICLE

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ABSTRACT

In this study an elastomer wishbone bush was designed and developed to fulfil a specific durability test requirement. A number of design alternatives was analysed and developed using a finite element technique. During the design iterations it is aimed to reduce the maximum strain values and internal friction forces to enhance the durability performance of the elastomer bush (Results of final iteration was shown in this study). After the design phase, a number of prototypes was produced and tested according to the durability test requirement which was set by the end customer. According to the durability test results, it was seen that the elastomer bush survived approximately 1,1 million cycles (target is 1 million cycles) in the durability test. Considering the former bush design could only reach approximately 100K cycles, the new design is a complete success.

Keywords: Elastomer bush, finite element technique, durability, wishbone

BİNEK ARAÇLARDA KULLANILAN BİR SALINCAK BURCUNUN DAYANIMININ İYİLEŞTİRİLMESİ

ÖZET

Bu çalışmada, kauçuktan imal edilmiş bir salıncak burcunun belirli dayanım testi şartlarını sağlaması için tasarımı ve geliştirmesi yapılmıştır. Sonlu elemanlar metodu kullanılarak belirli bir sayıda tasarım alternatifi analiz edilip geliştirilmiştir. Tasarım denemelerinde, burcun dayanım performansının iyileştirilmesi için, dahili sürtünme kuvvetlerinin ve uzamaların azaltılması hedeflenmiştir. (Çalışmada sadece son tasarım denemesinin sonuçları rapor edilmiştir). Tasarım fazından sonra, prototipler üretilmiş ve müşteri tarafından belirtilen şartlara göre dayanım testine tabi tutulmuştur. Dayanım testi sonuçlarına göre, burç yaklaşık 1,1 milyon çevrim boyunca zarar görmemiştir (Hedef 1 milyon çevrimdir). Burcun bir önceki tasarımının, aynı test koşullarına yaklaşık 100K çevrim dayanabildiği düşünüldüğünde, yeni tasarım başarılı olmuştur.

Anahtar Kelimeler: Kauçuk burçlar, sonlu elemanlar metodu, dayanım, salıncak

1. Introduction

Elastomer bushes used in the axle and suspension systems of vehicles are very important components because they have a very high degree of influence on the drive dynamics and handling performance of vehicles. Elastomer bushes have to also survive at least until the end of guarantee period of vehicle by withstanding all the extreme loading and environmental conditions during their life-spans.

A wishbone bush is expected to let translational and angular displacements with certain static and dynamic mechanical properties. The most important properties can be listed as static and dynamic rigidities, phase angle in the degrees of freedom at interest. If an elastomer bush is loaded with a constant static load in a degree of freedom, one can also add creep rate property to this list. These properties define the driving dynamics and handling performance of the vehicle. These properties are set by the car maker during the design of complete axle and suspension systems should be kept within the allowed tolerances during the complete life-span of elastomer bush.

During operation, a wishbone bush is exposed to a wide range static and dynamic loads exited by the road and partially the powertrain. Therefore, elastomer bushes are expected to have both the defined static and dynamic behaviour and high durability to bear with extreme loading conditions.

In this study, a wishbone bush, which doesn't fulfil the specified durability requirement, was analysed and its design was developed to enhance its durability performance. Analyses were carried out by a FEM software called MSC Marc.

Durability tests are carried out using two different types of test machines, one test machine has an electro-mechanic excitation system while the other has servo-electric excitation system.

2. Former design of the elastomer bush

The wishbone bush has three main components as shown in Figure 1. It has a steel inner component of a spherical shape, an outer steel tube and a rubber body made of a natural rubber compound. This wishbone bushing is exposed to a very high tilting (cardianic) displacements during normal operation. Therefore, it is designed such that it behaves similar to a spherical ball joint. The outer diameter of bush is 55,3 mm and the length of the inner bush is 48,9 mm.

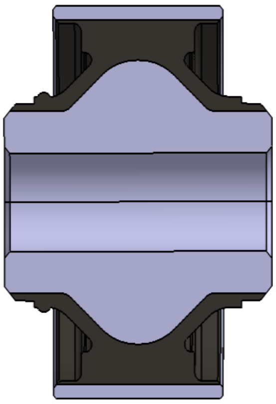

Figure 1: Existing Design.

3. Durability test and pass criteria

During the durability test the bush is subjected to a cardianic displacement of ±15° about an axis which is perpendicular to the central normal vector of the cross-section given in Figure 1 at a frequency of 2 Hz.

The pass criteria of durability test are to have no physical deformation or formation of cracks on the rubber surface after 1 million cycles. During the durability test if outer and inner metals have any contact, it is said that the wishbone bush fails the test.

4. Durability results of the former design

A picture of the failure part is given in Figure 2. This picture was taken after 100K cycles of the durability test. It is obviously seen that the part has physical damages, cracks and even some elastomer particles tore off the main body.

Figure 2: Failed part.

To see the internal structure of the failed part, it is cross-cut and the view of its cross section is given in Figure 3.

Figure 3: Cross-section of failed part.

According to this cross section it can be said that the physical damage started at the bulge surface or a place near the bulge surface of the elastomer body and penetrated inwards.

5. Fem results of former design

In order to enhance the durability performance of bushings and to relief the stresses caused by shrinkage effects, elastomer bushes are calibrated to a smaller diameter after the vulcanization process. This operation is sometimes called swaging. The most important reason of this calibration operation is to prevent tensile loadings in the elastomer body during normal operation.

In this application, the ends of the outer busing is cold formed 90° to its symmetry axis to increase the axial stiffness of the elastomer bush.

These two operations create permanent residual stresses in the outer tube and elastomer body. Therefore, they have to be included in the finite element calculations before subjecting the bush a cardianic displacement.

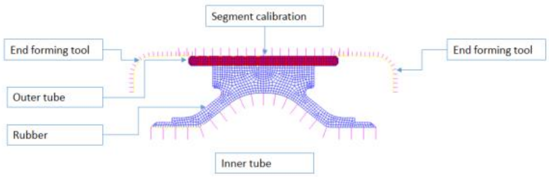

Figure 4: Fem model of former design.

Figure 4 shows the fem model of former design. In this model, there are 1080 4-noded quad elements used. Elastomer material was modelled as a hyper-elastic material of Mooney-2 Terms. Outer material was modelled by both elastic and plastic behaviours.

After the swaging and end-forming operations, the resulting deformation state and shear strain distributions are given in Figure 5 and Figure 6, respectively.

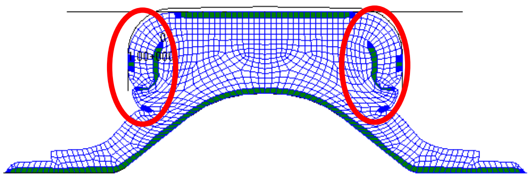

Figure 5: Deformation state of former design after swaging and end-forming operations.

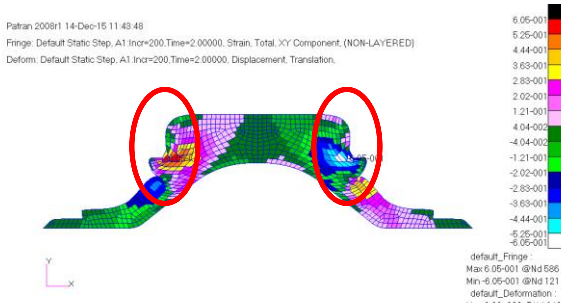

Figure 6: Shear strain distribution of former design in elastomer body after swaging and end-forming operations.

According to above figures, it can be said that there is excessive deformation at the places shown by red circles. The rubber is folded inwards and the outer metal tube is tending to penetrate towards the rubber body.

Figure 7 shows the strain distribution after a cardianic displacement of 9° after the former manufacturing operations (swaging and end-forming) are completed. It can be clearly seen that the outer metal penetrates through the rubber body even at an angle of 9°. The situation will be worse at an angle of 15°. [1]

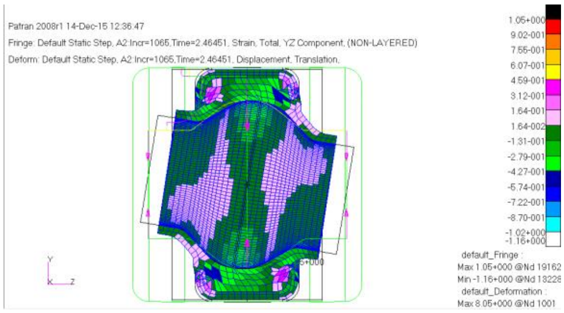

Figure 7: Shear strain distribution of the former design after a cardianic displacement of 9°.

FEM results shown on figures 5, 6 and 7 are in full agreement with the physical failures shown in figures 2 and 3. The hot spots determined by the FEM analyses are actually the same places where the elastomer bushes fail.

Maximum and minimum shear strain values and the contact normal force between the outer metal and rubber are the most important properties to control and reduce to enhance the durability performance of this elastomer bush.

According to the FEM results without any cardianic displacement, the maximum and minimum shear strain values were determined to be +0,6/-0,6 mm/mm. The maximum contact normal force was determined as 1300 N. These two values will be compared to the same values of new design proposal to quantify the improvement achieved in this study.

6. New design proposal of the elastomer bush

Cross-section of the proposed design is given in Figure 8. There are two important design changes exist in this proposal.

1. The outer diameter of former bush was 56 mm before the swaging operation. In other words, the bush was to be calibrated by 0,7 mm after the vulcanization operation. The outer diameter of design proposal is 57,6 mm. This means that the elastomer bush is to be calibrated by 2,3 mm inwards. The reason of this is to achieve higher permanent compressive strain level within the elastomer body, thus, the tensile strain states are eliminated or minimized during durability test. Another result of this change is to eliminate to have any stress relaxation state within the elastomer body to enhance

durability performance of the elastomer bush. [1], [2]

2. The distance between the rubber surface and end surface of outer metal tube was increased from 5 mm to 7,2 mm. This change was done to reduce the contact normal forces between the outer metal tube and rubber surface after swaging and end-forming operations.

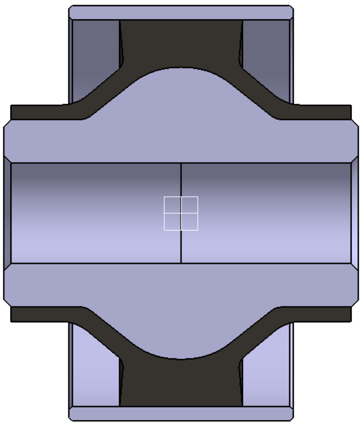

Figure 8: Design proposal.

7. FEM results of the design proposal

Figure 9 shows the fem model of design proposal. In this model, there are 1072 4-noded quad elements used. Elastomer material was modelled as a hyper-elastic material of Mooney-2 Terms. Outer material was modelled by both elastic and plastic behaviours. The swaging and end-forming operations are included in these analyses, as well.

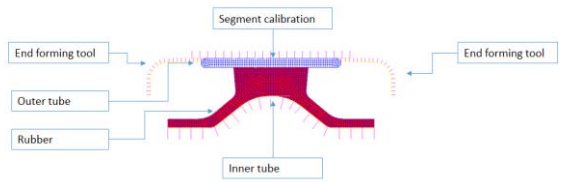

Figure 9: FEM model of the design proposal.

After the swaging and end-forming operations, the resulting deformation state and shear strain distributions are given in Figure 10 and Figure 11, respectively.

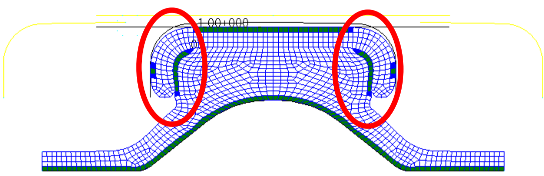

Figure 10: Deformation state of the design proposal after swaging and end-forming operations.

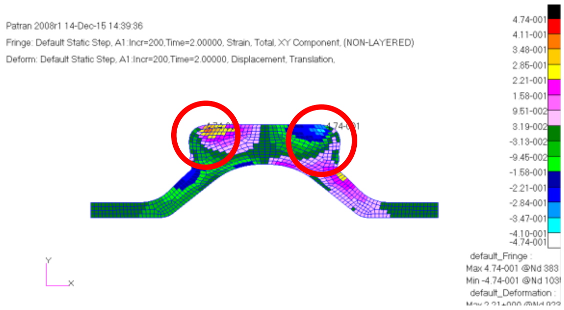

Figure 11: Shear strain distribution of the design proposal in elastomer body after swaging and end-forming operations.

According to above figures, it can be said that there is no excessive deformation at the places shown by red circles compared to the former design. The rubber is not folded inwards and the outer metal tube is not tending to penetrate towards the rubber body. The maximum and minimum shear stress values are reduced and moved to places (see the red circles in Figure 11) where there is no remarkable deformation in the cardianic displacement.

Figure 12 shows the strain distribution after a cardianic displacement of 9° after the former manufacturing operations (swaging and end-forming) are completed. It can be clearly seen that the outer metal doesn’t penetrate through the rubber body at an angle of 9°. The situation is expected to be also allowable at an angle of 15°.

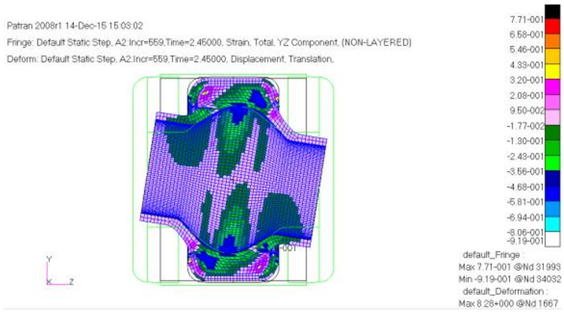

Figure 12: Shear strain distribution of the design proposal after a cardianic displacement of 9°.

FEM results shown on figures 10, 11 and 12 are implying that the hot spots determined for the former design of the wishbone bush do not exist anymore for the design proposal.

Considering the maximum and minimum shear strain values and maximum contact normal force, it can be seen that there are remarkable reductions.

According to the FEM results without any cardianic displacement, the maximum and minimum shear strain values were determined to be +0,285/-0,285 mm/mm. The maximum contact normal force was determined as 67,1 N. Comparing these two values with the values obtained for the former design, one can have the following table.

Table 1: Comparison between former and new designs.

Property	Former Design	New Design	Reduction (%)
Max/Min Shear strain (mm/mm)	±0,6	±0,285	-53%
Maximum contact normal force (N)	1300	67,1	-95%

8. Durability results of the design proposal

A number of prototypes was produced to perform the same durability test described in section 4 and three different samples are undergone through the durability test. It was seen that, the new design proposal survived even 1,1 million cycles without any unacceptable physical damage. The picture of a sample after the durability test can be seen in Figure 13.

Figure 13: Picture of the new design after 1,1 million cycles of durability test.

9. Conclusion

In this study a wishbone bush (an elastomer bush) designed and developed to fulfil a specific durability test requirement. Fem results were used to reduce the strain states, deformation states and internal contact normal forces (friction forces).

Maximum and minimum shear strain values were reduced by 53%, while the maximum contact normal forces were reduced by 95% compared to the former design. These reductions worked well and the durability of new design even 10% higher than required durability performance of the wishbone bush.

KAYNAKLAR

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