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CRIMPING PROFILE OPTIMIZATION ON THE AIR SPRING USING FINITE ELEMENT METHOD

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Abstract: *Due to the fact that the requirements of the industry aim to improve the dynamics, the safety and the comfort during the use of the vehicles, it is recommended to use the finite element method for component quality optimization. The purpose of this paper is to provide an overview of the current state of analysis through the finite element method of the crimping process used to assemble air springs produced in the automotive industry. Starting from the prototype of an air spring, the researches are focused on the study of the assembly of the piston with the bellow and the crimping ring through the crimping process. After analysis with the finite element method and static tests, improvements were made to the piston, the results of the tests revealing an improvement as opposed the original variant of the piston.*

Key words: Air Spring, Finite Element Method, Crimping, Automotive Industry.

1. Introduction

The industry requirements aim to improve safety, dynamics and comfort while using the vehicles. At the same time, in order to meet these requirements, more and more manufacturers are starting to use finite element analysis to optimize the quality and to reduce the costs of the components.

Over the years, the cars were fitted by car manufacturers with mechanisms to improve comfort and roadholding. One of these mechanisms is the suspension which during the last years had an evolution influenced by the technology of the time, as well as the production price. The suspension of the car is designed to ensure passengers comfort and to protect the load and component parts against shocks, as well as harmful oscillations caused by the road irregularities [3]. Another role of the suspension is to ensure the elastic connection between chassis, body and bridges or directly with the wheels of the car. The isolation from vibrations ensures driver comfort and health and prevents the appearance of damages to the components caused by inertial forces. If the suspension system meets all these requirements, another objective to be achieved is that the vehicle can be driven at higher speeds and have vibrations equal or less than a vehicle without suspension [1].

Air springs have been used primarily for commercial vehicles and luxury cars because they are quite expensive. Unlike conventional suspensions, they have several advantages. The air spring offers greater comfort and improved handling performance as it has a relatively low rigidity and allows for optimal wheel alignment. In addition, air springs can protect the car body better on rough roads and ease luggage loading in the boot of the vehicles because the suspension height can be adjusted by loading and unloading air from the suspension through the pneumatic circuit [2].

2. Experimental research

Air springs used in small vehicles are developed with U-shaped bellows with a reduced diameter and a modified fit. Small bending radius with small outer diameters of up to 200 mm are used when designing the bellow and a quality elastomeric material is required. Air spring is assembled into small vehicles together with the shock absorber in a single module or they can be used as separate components. The excellent features offered by the air spring to small vehicles have their own price. Obviously, the vehicles equipped with air spring are much more expensive than those equipped with helical spring suspension. The additional charge is a very important point of discussion when adding an air spring to a small vehicle.

The figure below shows the prototype of an air spring made using the design software Catia V5. The main components of the air spring are: the cover, the piston, the shock absorber and the bellow. In this case the diameter is about 150 mm and has a total length of about 670 mm. The most important requirements are the capacity and installation space of the air spring. For small vehicles, a natural frequency of about 1 Hz is considered.

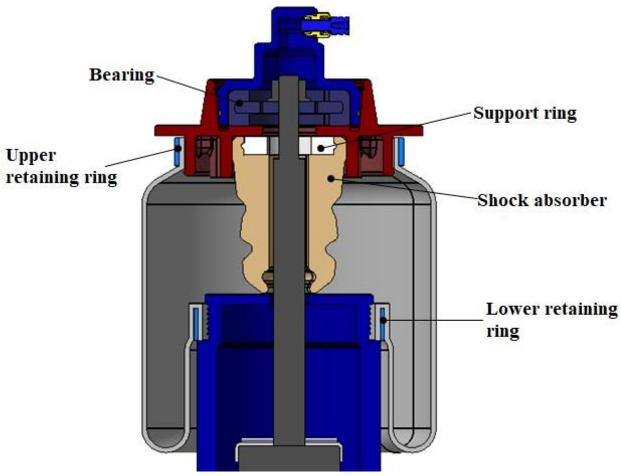


Figure 1: Section through prototype air spring

The researches are focused on the study of the assembly of the piston with the bellow and the crimping ring through the crimping process. This process represents the technology of fastening a bellow between a base and a pressing part. The crimping base, regardless of material an properties, can not reach plastic deformation area. The base must have the neccesary geometry in order to fulfill the conditions of:

- Sealing (necessary for the inner volume to be hermetically sealed);
- Fastening (necessary for the bellow to be locked);
- Connection (which is the attachment of various parts through the bellow).

A sealing is an element or elements or even a device that performs certain functions: separation of spaces with different pressures, separation of different technological environments, protection against foreign body penetration in certain spaces, protection against loss of lubricants, closure of a space as hermetically as possible containing a pressurized medium, etc. The operating, constructive, technological and ecological factors acts on the function capacities of the sealings. The most important are: the properties of the working environment, the working regime, the characteristics of the joining and sealing materials, the allowable limits of the losses, the running time, etc [4]. In the case of air springs there is a static seal. The assembly of piston, bellow and ring is performed within crimping process.

The bellow must be able to withstand the internal pressure of air spring and the extension, compression and torsional movements. In addition, the bellow is designed to withstand very different environments: from -40°C to 80°C, abrasions and different size dust particles.

The crimping ring can be welded or from a single monobloc, and it is not required to be made out of a good steel. The quality of the ring surfaces should be very good and it should lack sharp edges and the radius must be higher than 0.3 mm.

The crimping process takes place in a special machine with radial tanks that can be operated mechanically or hydraulically. The process takes place in 4 stages:

- Elastic deformation of the crimping ring;
- Plastic deformation until contact between the bellow-base-ring:
- The deformation continues until the required crimping force (Fx) is reached;
- Opening the tanks until the contact is interrupted.

The simulation of the crimping process is done with the help of ABAQUS finite element analysis program, by performing an axisimetric analysis, thus reducing the processing time significantly. The modeling of the assembly is done using deformable parts: piston, bellow, crimping ring; while the tanks are used as a rigid analytical piece because the tensions in the tool present no interest. In this analysis a piston made of A6082, a S235 crimping ring and a NBR bellow (a hyperelastic material) were used. The meshing of the parts is done using CAX4R elements (a 4 node, reduced-integration, axisymetric solid element), CAX4H hybrid (4 node, hybrid with constant pressure) is used for the bellow only because this part is made out of a hyperelastic material. The piston has 2856 elements with the approximate size of 0.8 mm.The bellow has 880 elements with the maximum size of 0.7 mm and the minimum size of 0.14 mm. In order to achieve a finer mesh in the crimped area of the bellow, the "bias" method was used. The ring has 146 elements. The total number of elements of the assembly is 3882 and the total number of nodes is 4377.

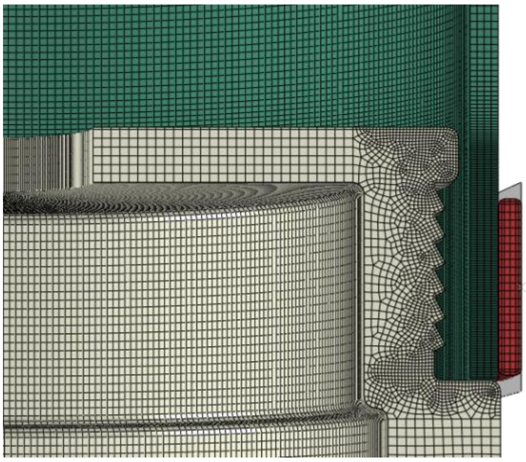
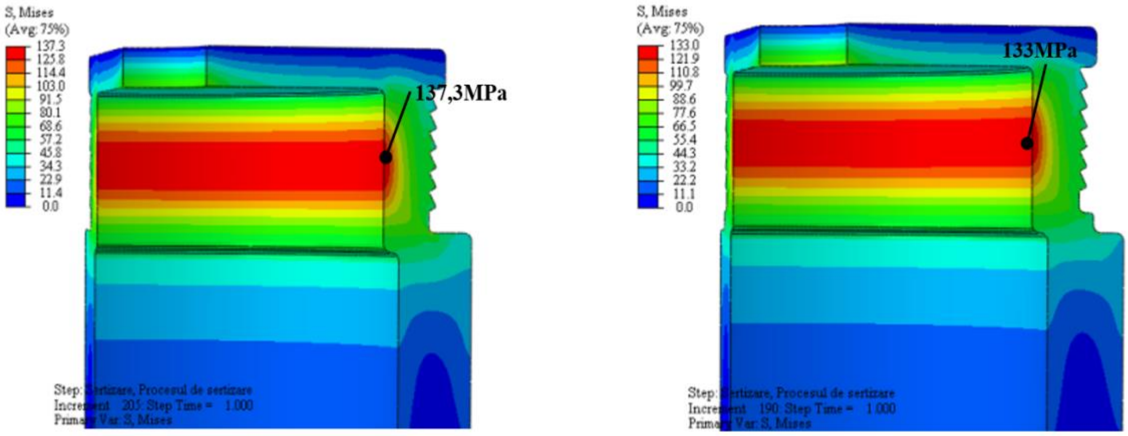


Figure 2: The meshed assembly

When defining body interactions, friction coefficients of 0.15 are used when both parts are made of metal and 0.3 for contact between an elastic material and a metal. The created contacts are of "Surface-to-surface" type and are created between: tank-ring, ring-bellow, piston-ring, piston-bellow.

Following analysis through the finite element method and static test, where a pressure is applied inside the air spring in order to check the sealing and bellow fixation, excessive bellow compression at the bottom of the ring was observed and that the bellow was not well locked between the other two components of the analized assembly. To avoid excessive compression, after researches it has come to the conclusion that using a recess in the area of the piston shoulder will fix the bellow better.

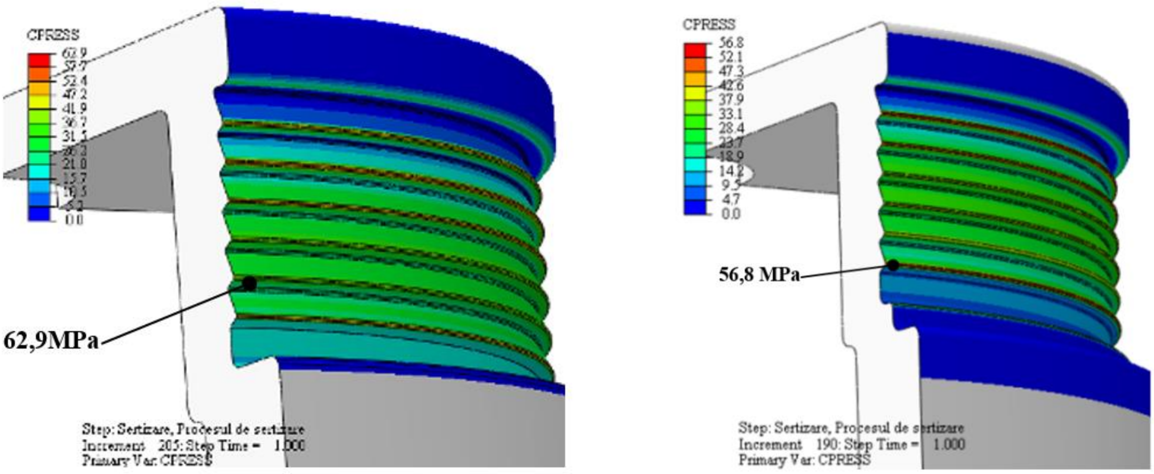
By comparing the results of the two analyzes through the finite element method made for the original and the optimized piston, significant improvements are observed. Since the material used for the piston is an aluminum, among the results extracted from the two simulations there is von Mises equivalent stress which in the crimping step has for the initial variant the value of 137,3MPa and for the optimized version the value of 133MPa.



a. **Initial variant** b. **Optimized variant**

Figure 3: von Mises equivalent stress

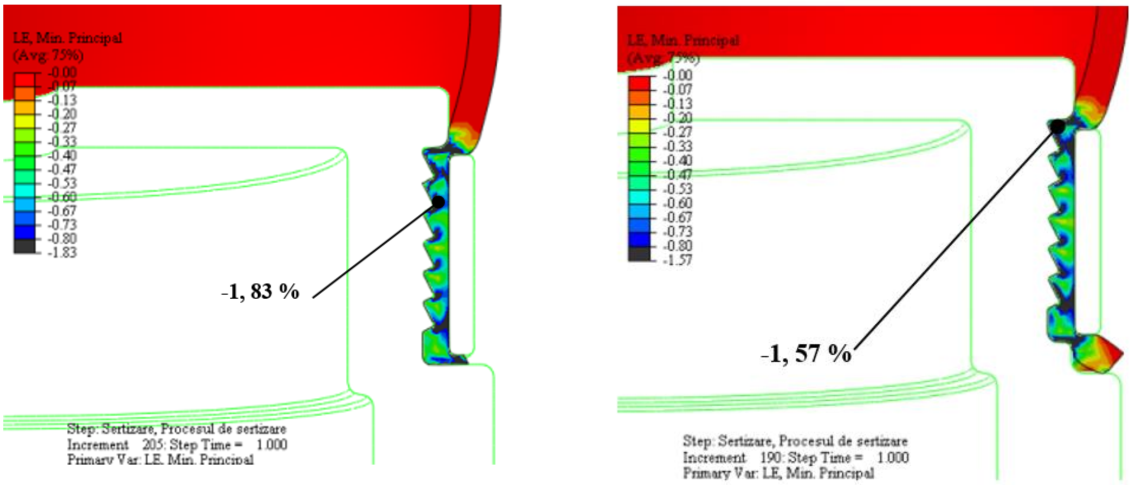
In Figure 4 it is observed that the maximum values reached by the contact pressure in both steps are at the tip of the teeth which creates the crimping contour, that area being the first to come in contact with the bellow. Contact pressure is a normal stress distribution on the contact surface of the two parts. For the initial variant we get a maximum contact pressure of 62.9MPa and for the optimized variant the maximum value drops to 56.8MPa.



a. **Initial variant** b. **Optimized variant**

Figure 4: Contact pressure distribution on the piston

From the values of the logarithmic strain results an improvement is observed in the case of the optimized variant, reaching a value of -1.57% which is less than the value of -1.83% obtained for the initial variant.



a. Initial variant **b. Optimized variant**

Figure 5: Logarithmic strain

From the results of the finite element analysis performed on the optimized piston, an improvement is observed unlike the original variant of the piston. In the case of the optimized piston, a better sealing than the first variant of the piston has been observed and the bellow is better locked by the recess on the piston's shoulder.

3. Conclusion

The analysis through the finite element method plays a very important role in the development of any product due to time reduction, cost savings and because it can optimize the product early in the development process.

To solve the problem of fixing the bellow, the piston of the air spring has been optimized by providing a recess in the area of the pistons' shoulder that allows the bellow to penetrate into that area and to be better secured. Following the analysis we can conclude that there is an improvement in the results for the optimized variant of the piston as opposed to the results of the initial variant, as presented in the table below:

Table 1: The differences obtained after analysis of the initial and optimized variant of the piston

	Initial variant of the piston	**Optimized variant of the piston**
	von Mises equivalent stress	
Crimping	137,3MPa	133MPa
Decrimping	98,9MPa	95,3MPa
	Radial displacement	
Crimping	-0,014mm	-0,00138mm
Decrimping	-0,01mm	-0,00098mm
	Contact pressure	
Crimping	24,53MPa	19,72MPa
Decrimping	17,44MPa	13,86MPa
	Logarithmic strain	
Crimping	-1,83%	-1,57%
Decrimping	-1,99%	-1,47%

4. References

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