Virtual calculations for analyzing the operation of air spring

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Abstract. The 3D-model of an air spring for road vehicles is presented. A virtual calculation of the air spring has been carried out. Calculation results have been analyzed for adequacy by investigating grid deformation and checking pressure inside the rubber part of the air spring. The most dangerous places of the air spring are shown. Possibilities of LS-Dyna software package for engineering analysis are demonstrated. The influence of computer-aided design systems on modern engineering solutions is considered. **Key words:** solidworks, ls-dyna, virtual calculation, anaerobic materials, road vehicles, air suspension, impregnating compounds.

1 Introduction

Air suspensions are widespread in the design of road vehicles, trailers and semi-trailers nowadays. Compared to the traditional mechanical suspension, air suspension has a number of advantages which make vehicle manufacturers use this type of suspension in their vehicles [1-3]. The air suspension uses a large number of non-metallic elements which impose certain restrictions on the operating conditions. One of the main elements of this suspension is an air spring, which has a rubber part. The air-spring places restrictions on the temperature at which the air-spring can be safely operated. Tests have shown that operation at temperatures of -50°C is not possible [3].

At present, polymeric materials are widely used to improve the properties of non-metallic elements at negative temperatures [4-7], for which special theoretical and experimental methods have been developed to assess their performance under given operating conditions [8-12]. On the basis of tests carried out earlier it was established that the use of impregnating materials allows to obtain properties of rubber at -50 °C, similar to the characteristics of this material at -30 °C [1]. These results meet the requirements of standards and standards, which regulate the use of rubber products in the automotive industry in negative temperature conditions.

In the modern world, computer-aided design, manufacturing and engineering analysis programmes have become increasingly widespread. These computational programmes reduce the time required to carry out real tests and to prepare for them.

The aim of this work is to develop a mathematical calculation model of an air spring and to evaluate the adequacy of the calculation results. This is necessary to ensure that by obtaining the results of experiments with materials of the non-metallic part of the air spring,

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it would be possible to apply them in the final mathematical model and consider the behaviour of this material in the composition of the product. The aim of this work is to develop a mathematical calculation model of an air spring and to evaluate the adequacy of the calculation results. This is necessary to ensure that by obtaining the results of experiments with materials of the non-metallic part of the air spring, it would be possible to apply them in the final mathematical model and consider the behaviour of this material in the composition of the product.

2 Research methods and results

Airtech air spring is the subject of this study. Air springs of this company are installed on many trucks of different manufacturers (MAN, Volvo, Mercedes, Scania, etc.). Depending on the vehicle brand, the air springs vary in their mounting points on the longitudinal member and lever, but the design and material of the non-metallic part of the air spring remain unchanged.

SolidWorks software was used to create a volume model of the air spring. In the automotive industry, this software package is considered to be the leader in solid state and surface modelling capabilities. Using surface modelling tools, the 3D-model of Airtech air spring was created (Figure 1).

Fig. 1. 3D-model section of air-spring.

This software package also has a calculation module, but it is suitable for simple tasks using metal in the structure. In this case, the main test object is the rubber part of the pneumatic cushion. Therefore, LS-Dyna software was chosen for the virtual calculation, which enables the solution of complex computational problems with non-metallic materials.

The first step in preparing the 3D-model for virtual calculation is to build the grid. LS-PrePost is both a preprocessor and a postprocessor and allows the user to prepare the 3D-model for calculation and to check the results after calculation. It has the ability to build a grid and adjust it depending on the task and the geometry of the part. This subprogram has been used to build a grid for the considered air spring (Figure 2).

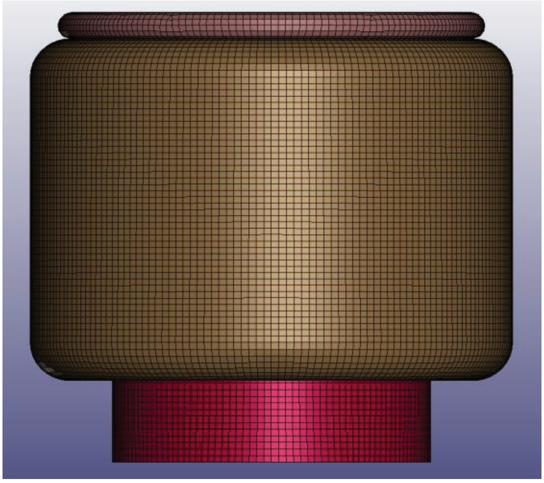


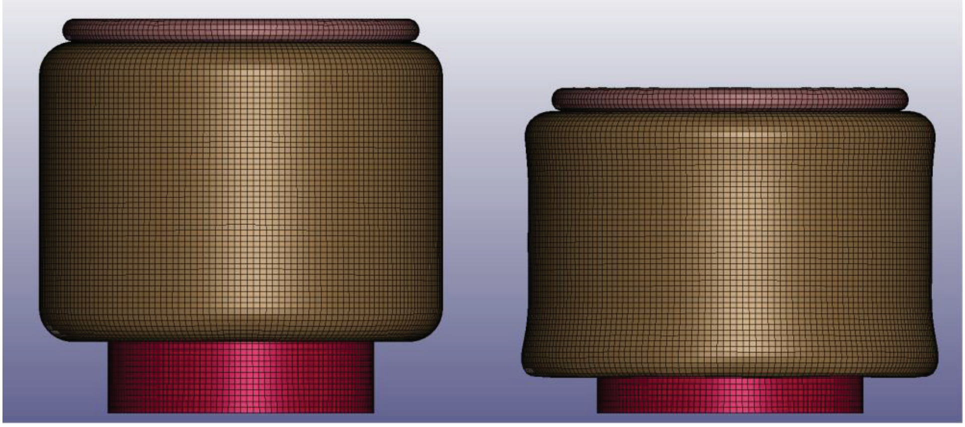
Fig. 2. Grid result for an air spring 3D-model.

In this case a grid for 2D-elements was used, as the model was made with a shell. The size of the elements was chosen based on the geometry of the model and task.

After constructing the grid, the calculation conditions can be set. In this case, the lower metal part of the air spring has been rigidly fixed and the upper metal part moves to the middle of the total length of the air bellows.

A pressure of 5-6 atm has been set inside the rubber part of the air spring, which corresponds to the real values in the pneumatic system of trucks, trailers and semi-trailers. This was done using the airbag function, which allows the airflow function to be set as a function of time.

After preparing the 3D-model, a virtual calculation was performed. The results show the deformation in the rubber part of the air-spring (Figure 3).



a) b)

Fig. 3. Comparison of initial (a) and final (b) position of the air spring after calculation.

A major factor in verifying the adequacy of the results obtained is the examination of the grid after calculation. The grid should deform uniformly in all parts of the 3D-model, without the so-called "hourglass effect" (Figure 4). In complex 3D-models this effect is more likely to occur in a local zone with a large number of strongly deformed elements, such zones can be easily observed when examining the deformed 3D-model. In this 3D-model, as it can be seen, this effect is not observed, thus giving reason to be confident in the adequacy of the obtained results.

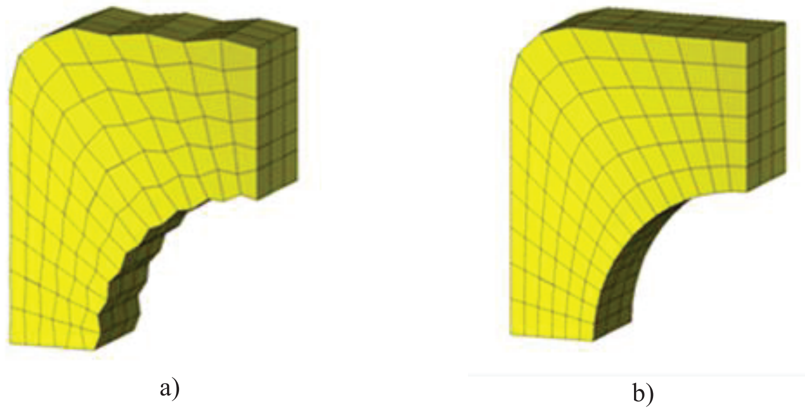


Fig. 4. Example of a grid with (a) and without (b) an hourglass effect.

After verifying the adequacy of the grid, the dependence of the pressure variation within the cushion must be evaluated to ensure that the pressure is consistent with the real parameters (Figure 5).

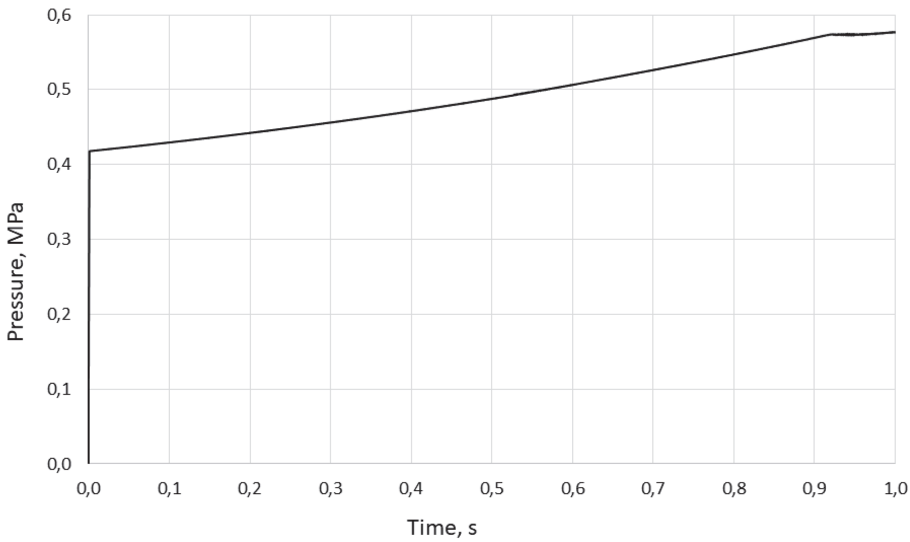


Fig. 5. Dependence of air pressure inside an air spring on time.

The graph shows that during the calculation the internal pressure rises smoothly from 4 atm to 6 atm at the end of the calculation, which corresponds exactly to the actual conditions. The pressure in the cushion is not a constant value and may vary due to different load conditions. However, it always remains within the specified limits. Therefore, it can also be concluded from this figure that the results are correct.

After an initial check of the adequacy of the results obtained, you can move on to viewing the distribution of stresses, displacements and resulting pressures within the cushion.

First of all, it is necessary to observe the stress distribution pattern and the places where these stresses are concentrated. Figure 6 (a) shows the general distribution of stresses. Based

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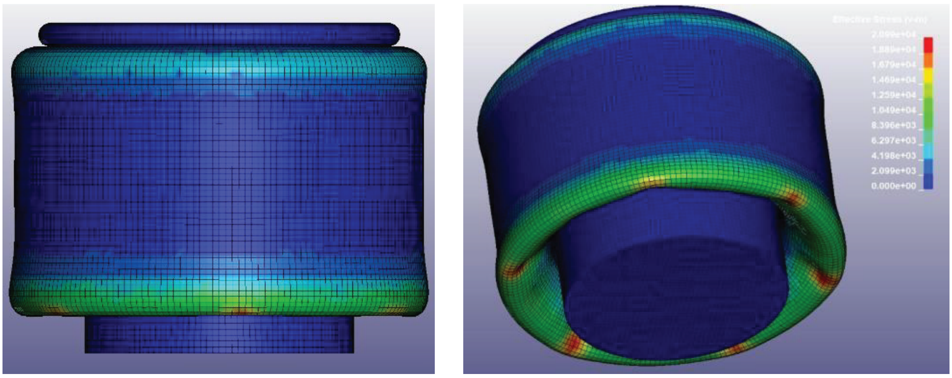
on a literature review and a set of previous studies [1-3, 13, 14], it is established that the most dangerous places of an air spring: contact areas of the rubber part with the upper and lower parts of the air spring.



a) b)

Fig. 6. General image of stress distribution in the air spring (a) and in its most loaded lower part (b).

The calculation carried out in this paper confirms this; the highest stresses are recorded at the lower and upper parts of the air spring. Figure 6 (b) clearly shows how the lower part of the air spring rubber arm deforms. It can be seen that characteristic breaks appear in the lower part where the highest stresses occur. At normal operating temperatures these will not be a problem. However, as the temperature drops and the rubber stiffens, these breaks can lead to cracks under cyclic loading conditions and the tightness will be compromised.

3 Conclusion

Modern engineering software packages provide results for calculations of structures and physical situations of varying degrees of complexity. In this calculation, the LS-Dyna software package was used, which is one of the leaders in solving complex problems, using different materials. In this work, a mathematical calculation model was prepared in order to analyze the application of different compositions of the rubber part, as well as to evaluate the influence of impregnation compounds. In the future, using the test results of real samples, it is necessary to make changes only in the rubber part material and evaluate the changes. This will significantly reduce the time and cost of preparing and carrying out complex tests.

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