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Methodology of prediction of dilatation gap between aluminum segments of vulcanization molds based on thermal-stress analysis

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1. Introduction

The paper presents the application of numerical methods in order to improve tire production. The study of the possibility of minimizing finishing by manual trimming of excess material was carried out. A computational methodology is proposed to simulate the prediction of the dilatation gap between vulcanization mold segments with the aim of minimizing the flow of rubber from the mold when heated to 165°C.

The solution of the problem is important especially from the point of view of increasing the mentioned production efficiency. The analysis was carried out on finite element models of the Al segment, its carrier and the tightening ring. Based on the obtained results, a methodology was developed to predict the dilatation gap needed to zero the gap between the Al segment and its support at 165°C [2].

2. Determination of radial displacement and dilatation gap

The finite-element models of segment carriers and tightening rings were created for four types of containers - K1 to K4 (Fig. 1) [1, 3]. Individual members of the analyzed system were connected to a state that corresponds to the system in the pre-heating state. The calculation has been done using the FE method and using the ANSYS and MATLAB [4, 5].

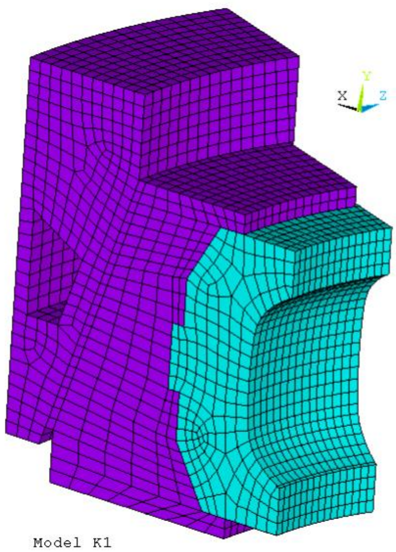

Fig. 1 Computational model of Al segment, carrier and tightening ring (K1 container)

The difficulty of analyzes has been simplified by the possibility of prescribing symmetry conditions. The boundary conditions are prescribed on the surfaces and correspond to the state when the container is closed but not compressed to the operating state.

Places on the surfaces that come into contact with the upper or lower plate of a given container type have been designed to evaluate radial displacements. The values at eight points were analyzed. This method was chosen primarily because the radial displacements of the monitored areas did not have a constant value. Analyzes were processed for realized prescribed dilatation gaps of half of one segment, i.e. for 0.1 and 0.5 mm. The resulting radial displacements for the individual containers at the prescribed tangential displacement of the Al segment are shown in Figs. 2 and 3.

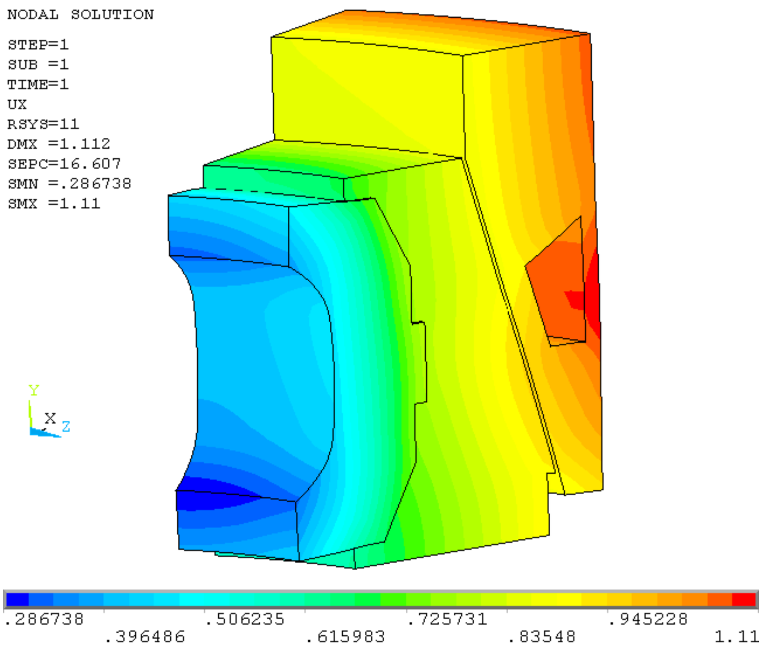

Fig. 2 Radial displacement of K1 container segment for prescribed displacements of 0.1 mm

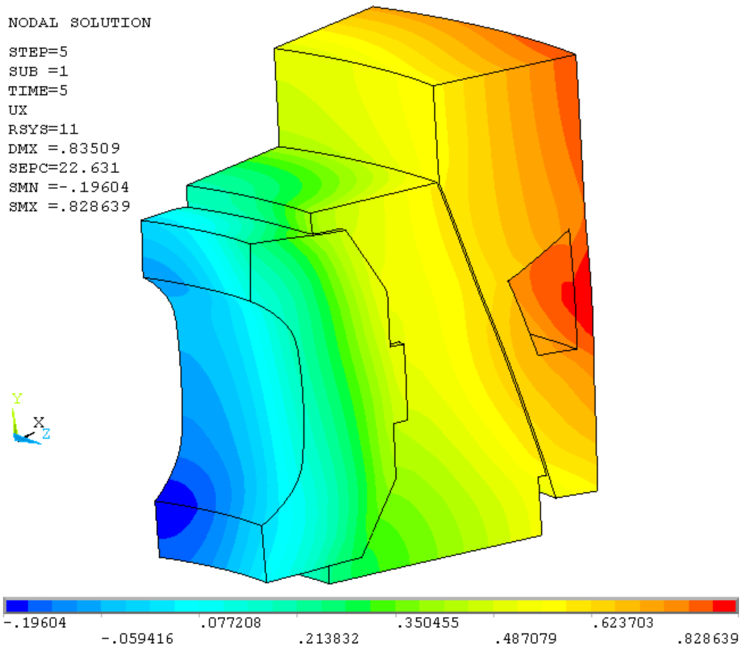

Fig. 3 Radial displacement of K1 container segment for prescribed displacements of 0.5 mm

To determine the expansion gap, it was also necessary to calculate the radial displacements of the upper and lower plates for the individual containers as they come into contact with the Al segment surface. The boundary conditions correspond to the storage in a closed container. The finite element models (Fig. 4) were generated for the purpose of calculations in the ANSYS program package and the radial displacements were subsequently analyzed.

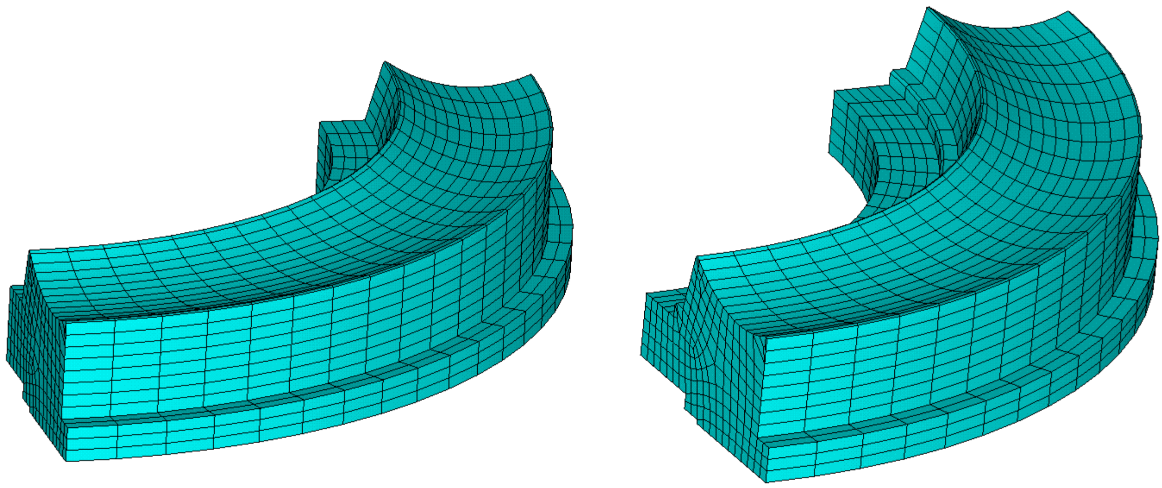

Fig. 4 Finite element mesh on upper (left) and lower (right) plate models of the K1 container

The resulting average values of the radial displacement of the upper and lower plates of the monitored contact surface are shown in Table 1.

Table 1 The radial displacements of the upper and lower pressure plate

Container type	**Average value of the radial displacement (upper plate) [mm]**	**Average value of the radial displacement (lower plate) [mm]**	**Used average radial displacement of plates [mm]**
K1	0.39432	0.39925	0.3968
K2	0.44828	0.44876	0.4485
K3	0.49672	0.49690	0.4968
K4	0.49661	0.49660	0.4966

The main idea of the methodology for determining the dilatation gap between Al segments was based on a series of simulations to determine the value of the prescribed tangential displacement of the Al segment so that the resulting radial displacements of the Al segment contact surface and the upper (or lower) plate are equal when heated to 165°C. This modeled the state where gaps in contact between individual system members should be zero.

Proposal of the methodology for determining the dilatation gap:

- analysis of the resulting radial displacements of Al segments (due to a temperature gradient of 145°C),
- analysis of radial displacements of the upper and lower plates (due to a temperature gradient of 145°C),
- analysis of dependence of radial displacements of Al segments on prescribed dilatation gap defined in the range of 0.1 to 0.5 mm in half of the segment (corresponded to the total prescribed gap in the range of 1.6 mm to 8 mm),

- linear extrapolation of the observed functional dependence to a point with the same radial displacement value as in the case of a plate (resets the gap between the Al segment and the plate),
- determination of the resulting dilatation gaps for individual types of containers.

When calculating the resulting dilatation gap, the average values of the investigated variables on the monitored areas were considered. By extrapolating the functional dependence of the radial displacement of the Al segment to the size of the dilatation gap, the size of the dilatation gap per half of the segment was determined. By multiplying the obtained value by 16, the resulting value of the dilatation gap required to zeroing the radial gap between the Al segments and the upper or lower plate when heated to 165°C was obtained (Table 2).

Table 2 The resulting value of the dilatation gap

Container type	**Average radial displacement of horizontal plates [mm]**	**Extrapolated average value of radial displacement of Al segment [mm]**	**Resulting extrapolated value of the dilatation gap between Al segments [mm]**
K1	0.3968	0.3968	16 x 0.0852 = **1.36**
K2	0.4485	0.4485	16 x 0.1151 = **1.84**
K3	0.4968	0.4968	16 x 0.1739 = **2.58**
K4	0.4966	0.4966	16 x 0.1225 = **1.96**

3. Conclusion

The presented contribution is of great application importance and its aim is to present the methodology and possibilities of using a series of suitably controlled calculations using the FEM for computer prediction of the dilatation gap between Al segments of the vulcanization mold with the aim of zeroing at 165°C.

The obtained results have the character of an initial study. In order to obtain reliable results, it is necessary to describe the technological process more precisely, control measurements to refine the input data and modify the model, to define more precisely the thermal interaction between individual system members and to carry out subsequent verification under real conditions.

Acknowledgements

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