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COMPUTATIONAL MODEL FOR HEAT TRANSFER IN A TYRE CURING PRESS

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Abstract: *This paper provides an introduction to the issue of heat transfer in curing presses. It deals with a validation model for the heat transfer coefficients and transfer of boundary conditions to the newly designed variants. The article also deals with the description of materials used, links between individual components and setting of the boundary conditions for this type of task. A brief assessment of the benefits of the newly proposed variants is made in the conclusion.*

Keywords: Heat transfer, Curing press, Finite element method, Mechanical engineering.

1. Introduction

The aim of this calculation is to determine the surface temperature of two new variants of a curing press (type VL75) when the temperature of the inner surface of the pressure chamber is 145 °C. We can solve heat transmission as a stationary task (steady state) thanks to these arguments: the main interest is to find out the highest possible surface temperature that could arise; there is no significant cooling between the production cycles of the curing press (Hynek, 2011, 2013). The calculation is done using finite element method (FEM) in Abaqus 6.11. The computational model is validated by comparison of the calculated temperature field with the temperature field of a real curing press (VL95). A thermal field was obtained using a thermal imager. The validation model is modified to have the same material properties and structure as the real VL95 curing press.

2. Computational model

The curing press has one plane of symmetry so the model is only one half of the press. Individual parts of the press are meshed according to the following geometry: 3D elements with 8 nodes, shell elements with four nodes and beam elements with two nodes. The entire press is divided into several sub-units which are tied together. Figure 1 shows the entire assembly. Shell and beam elements are rendered with their thickness (section). Each unit is meshed as a single piece, which means that all real connections within a single unit are linked. Some sub-units are meshed so that it is possible to define various material properties of different machine parts elements. This allows modelling more machine parts at once without having to define additional links. The difference between the variants is shown in Figure 2. Variant 1 unlike Variant 2 has: top cover connected to the upper pressure chamber; bottom cover extended to the shoulder of the lower chamber; and there is a gap between the protective belt and the top cover. The protective belt is connected with the top part of the chamber in all models. The upper cover is connected with the chamber only for model validation. Connections are meshed using beam elements with 2 nodes. Connections distribution can be seen in the results in Figure 4. Regions where the connections occur have a higher temperature (the angle between connections is 30 °).

Material properties are listed in Table 1 (Bejan, 2003, Bonollo, 1996, Lattimer 2012). All models use insulation material S4000® for insulation boards. The S 4000® is a laminate based on glass-fibres bound with a high-temperature polymer. Foam glass insulation is used to validate the model instead of two-component hard polyisocyanurate (PIR) foam.

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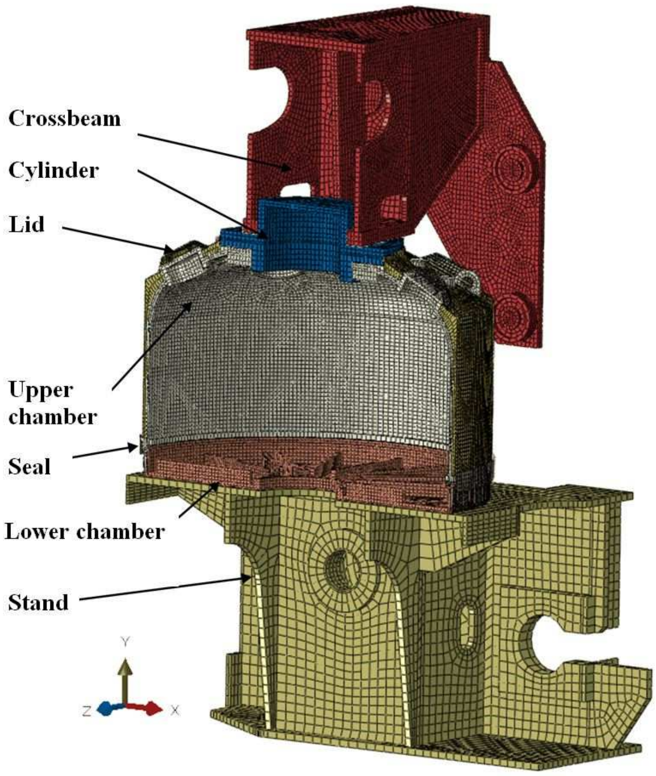


Fig. 1: Whole computational model of the curing press.

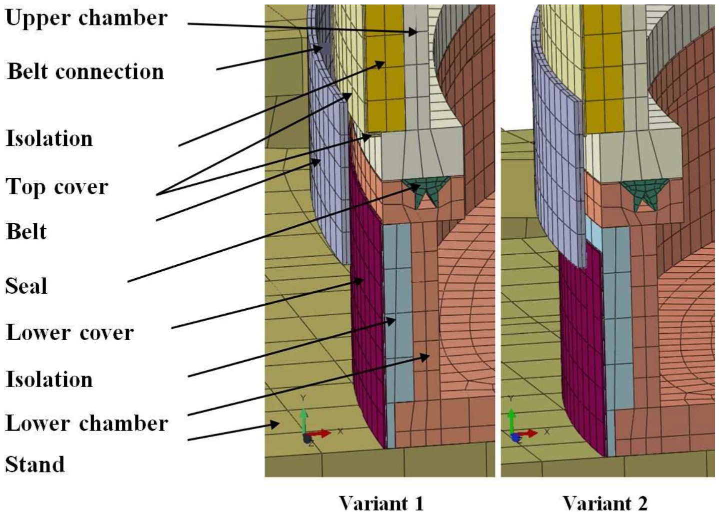
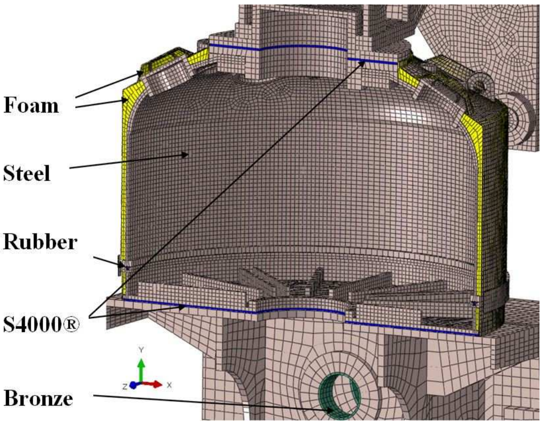


Fig. 2: Detail of the dividing plane with the seal.

Tab. 1: Material properties.

Material	Density [kg·m^{-3}]	Specific heat [J/kg·K]	Thermal conductivity [W/m·K]	Materials
Rubber	1000	450	0.14	
Steel	7800	470	53.40	
Foam glass	140	840	0.04	
PIR foam	42	1400	0.04	
S4000®	2000	900	0.12	
Bronze	8940	384	386.00	

2.1 Boundary conditions

Heat transmission is solved as stationary. A constant temperature of 145 °C is set on the inner surface of the pressure chamber. The heat transfer coefficient $\alpha = 4\ \mathrm{Wm^{-2}K^{-1}}$ is set for all external surfaces of the press. The condition of air is set as still with temperature of 36°C. The protective belt is an exception and the ambient air temperature is set to 50 °C.

2.2 Validation of the model

The temperature field on the surface of the press is validated by comparing the model results with the image made by the thermal imager. The image from the imager is available for press VL95. Due to the different design of VL75 variant 1 and VL95 the following changes had to be made:

- PIR foam is replaced with foam glass.
- Pressure chamber assembly holes - insulating covers are not used.
- Connections of top cover with the upper chamber is added.

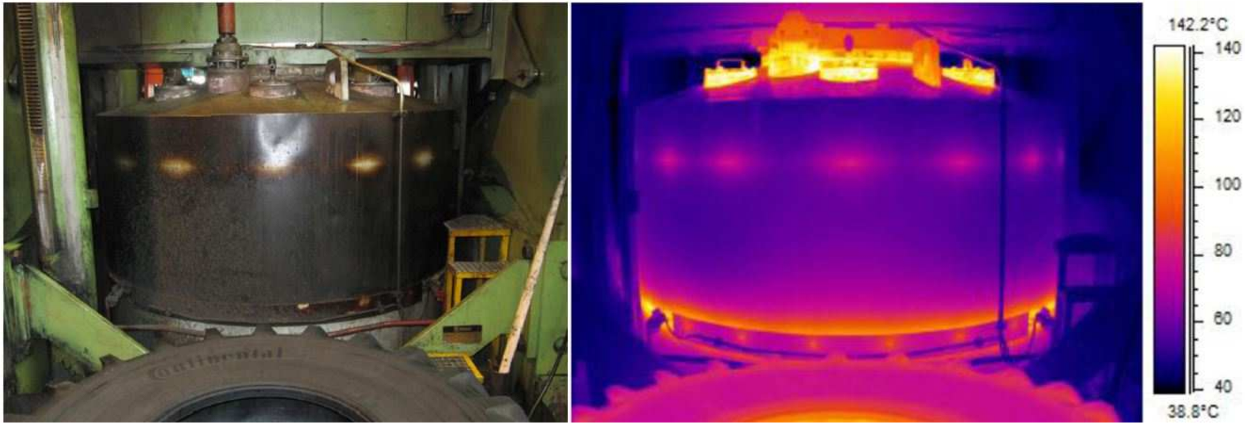


Fig. 3: The photo of the curing press and the thermal image.

The real view of the VL95 press and corresponding image from the thermal imager is shown in Figure 3. The temperature field from the validation model is shown in Figure 4. It is clear that comparison of Figure 3 and Figure 4 provides some consensuses. The differences are evident in the connection points of the upper cover and the protective belt. This difference is probably caused by the idealization of these connections into rods with a circular cross section and also there is a perfect distribution of insulation foam around the connections in the model.

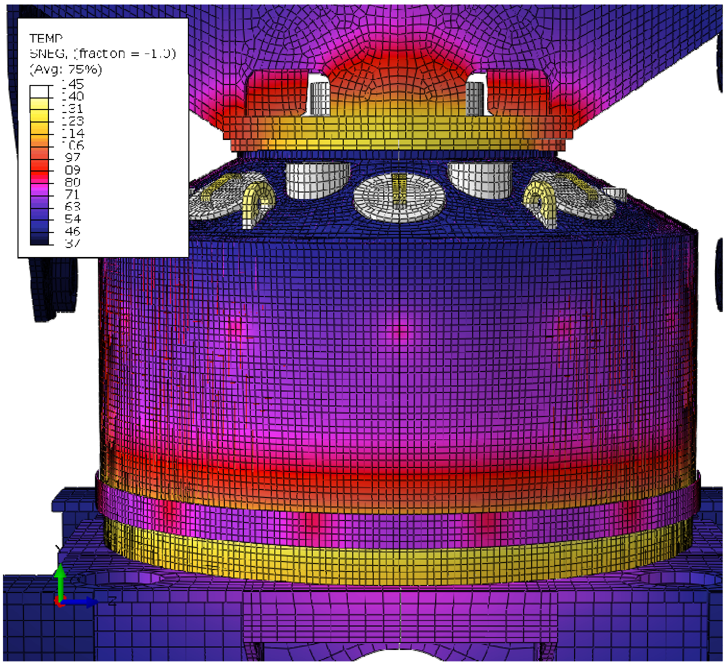


Fig. 4 Temperature field of the validation model.

3. Results

An overall view of the first variant's temperature field is shown in Figure 5 on the left. Heat bridges greatly increase the surface temperature of the press and associated heat loss. The temperature field of the second variant is on the right of Figure 5. It is obvious that in comparison with the first variant the temperature of the top cover is reduced. The temperature value above the upper edge of the protective belt is 76°C (Variant 1 has 110°C). The temperature on the bottom cover is also reduced but not so much. The reason for this is that the foam insulation is thinner than in the upper cover.

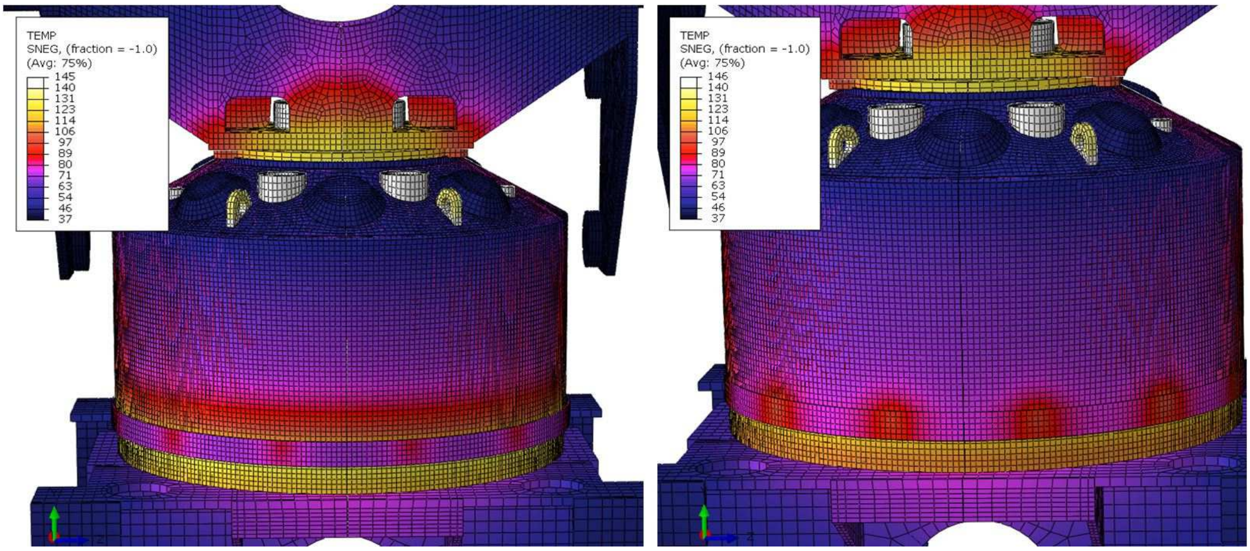


Fig. 5 Temperature fields of Variant 1 and Variant 2.

4. Conclusions

This paper describes a possible method for solving calculations for heat transmission in curing presses. The validation method and calculation setting of the model is discussed in the article. Calculations with the newly designed variants were performed based on the validated computational model.

A comparison of the validation model and Variant 1 shows a reduction in the surface temperature of the top cover connection points. Furthermore, it is obvious that if lid covers are used, the temperature in the area of the lid covers is only 53°C, so the heat loss is reduced in comparison with the VL95 press. Variant 2 compared to Variant 1 proves the reduction in temperature at the surface of the area around a plane dividing the upper and lower cover. The reduction of temperature in the area of the lower cover is not as good as on the top cover. Due to the higher temperature in the lower cover, it is appropriate to increase the thickness of the insulation in this area. The critical point in terms of heat loss and temperatures remains the connection of the pressure chamber with the crossbeam.

Acknowledgement

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