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THERMAL ANALYSIS OF TYRE CURING PROCESS

M. Hynek*, P. Votapek*

Abstract: *The manufacturing of tyres requires mastering the control of curing process which has a significant effect of the thermal and mechanical behavior of the formed part. Basically, curing analysis can be considered as thermal-mechanical coupled phenomena with heat consuming character and significant dependence of physical properties on temperature. Quite a number of papers deal with chemical aspects of rubber curing, compare numerous cure reaction kinetic models, discuss various mathematical models for the simulation of the vulcanization and demonstrate the interaction between temperature distribution fields and curing degree fields (Bafrnec, 2007). The mail goal of this paper is to focus on the understanding of the heat transfer in a cure press with respect to the used heating procedure and the designs of the cure mold. Moreover, a comparison between the effectiveness of steam dome and heating plate cure presses is made. The findings can be used for the optimization of curing cycles and thus for increasing the quality of the final product as well as for the potential energy consumption reduction.*

Keywords: ***Cure press, mold heating, energy consumption reduction.***

1. Introduction

There are currently used two concepts of building a cure press – steam dome and heating plates (see Fig. 1). Although the steam dome concept is more energy consuming it is still preferred in the production of large tyres as a more uniform temperature distribution in the curing mold is achieved (Ghoreishy, 2005). This argument can be confirmed by thermovision measurement of the curing mold (Honner, 2002). However, the effect of the mold heating concept on the time history in thick parts of the cured tyre is not significant (especially, if additional heating channels are exploited) as shown later in this paper.

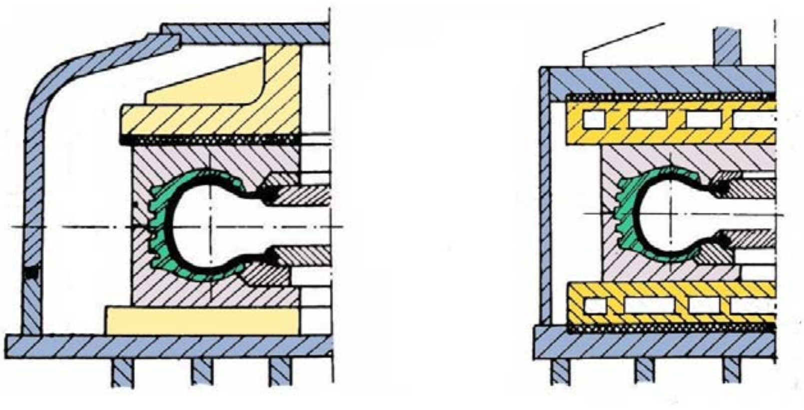

Fig. 1: EM 2011 logo Tyre curing press concepts – steam dome (left), heating plates (right).

2. CAD and FEM Model

Although a 3D CAD model of a real tractor tyre (see Fig. 2) was created it was decided to analyze the problem as axisymmetric.

* assoc. prof. Ing. Martin Hynek, Ph.D. and Ing. Petr Votapek: Department of Machine Design, Faculty of Mechanical Engineering, University of West Bohemia, Univerzitni 22; 306 14, Pilsen; CZ, e-mails: hynek@kks.zcu.cz, pvotapek@kks.zcu.cz

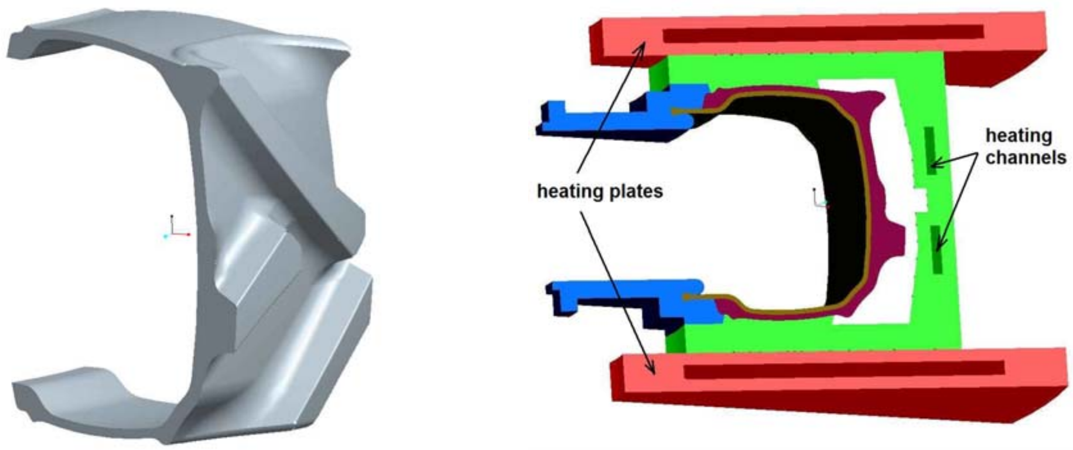

Fig. 2: CAD model – tyre segment (left), mold segment (right).

In the first stage, four variants of cure press were analyzed (see Tab. 1) and temperature histories in four locations (see Fig. 3) were compared.

Tab. 1: Solved variants.

Variant name	***Brief specification***
plates + channel	plates and heating channels (hot steam), membrane (hot water), aluminum insert
only plates	plates (hot steam), no channels, membrane (hot water), aluminum insert
steam dome	steam dome (hot steam), membrane (hot water), aluminum insert
steam dome, steel	steam dome (hot steam), membrane (hot water), complete mold made of steel

Boundary conditions for steam dome variants were defined in accordance with thermocouple measurements by definition of time histories of heat transfer coefficients and temperatures measured on the real steam dome cure press. The ambient temperature close to the press was 120°C, the temperature of the heating water in the membrane reached 170°C and steam temperature in the steam dome reached 165°C.

The boundary conditions for the heating plate variant without heating channels were adopted from measurements conducted on a similar cure press with heating plates. Steam temperature in the heating plates and heating channels reached again up to 165°C.

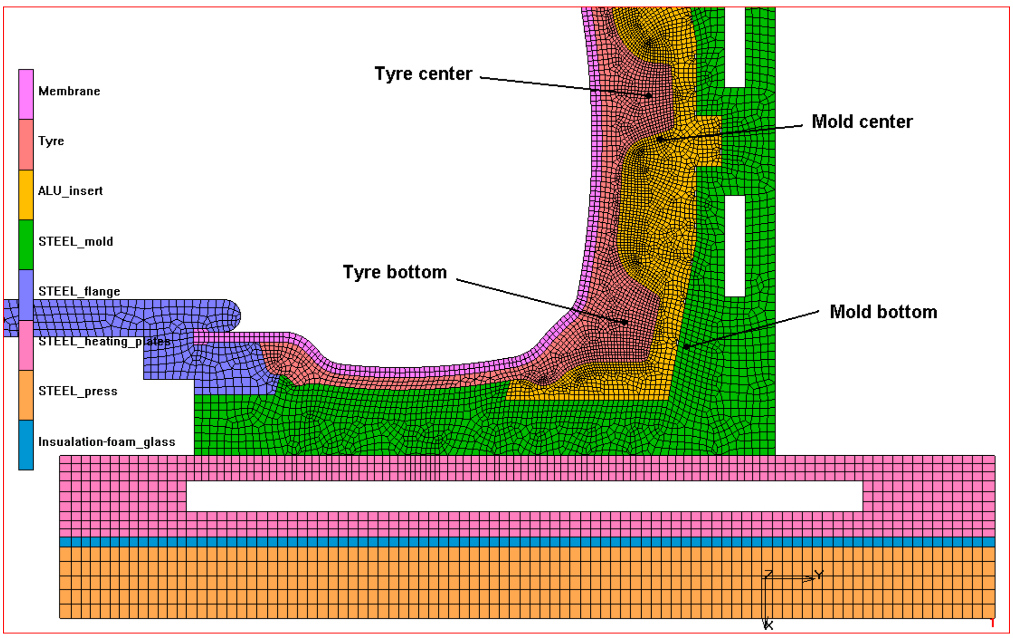

Fig. 3: Mesh of the axisymmetric FEM model with four locations for temperature history comparison.

3. Results

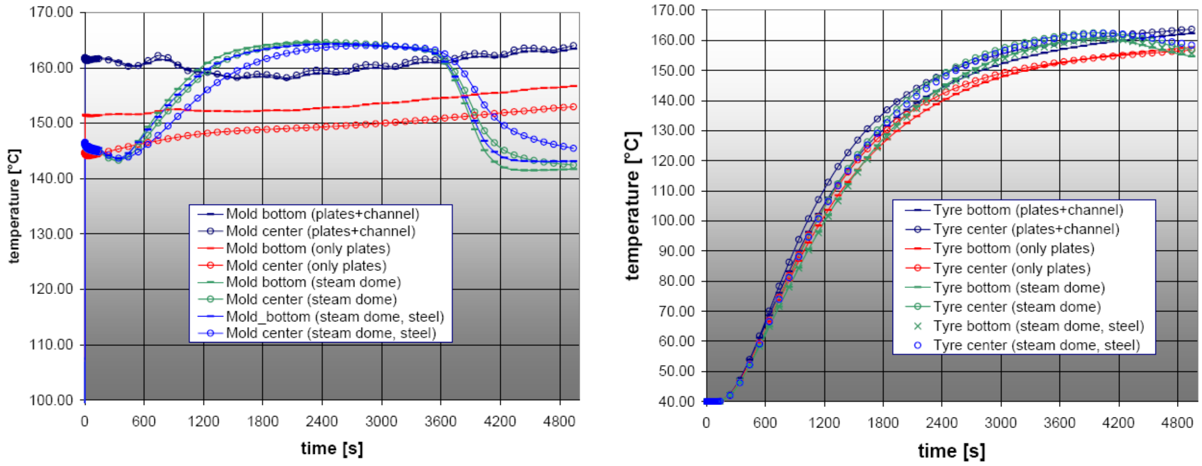

Fig. 4: Temperature histories in mold (left) and tyre (right) for all four variants.

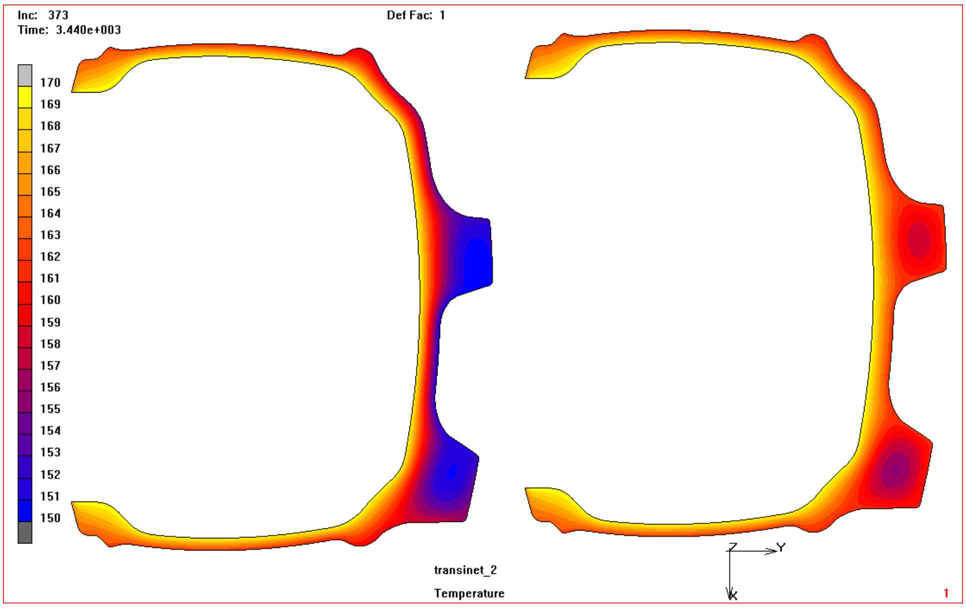

Fig. 5: Thermal field [°C] in tyre in time 57min20s – "only plates"(left), "plates+channel" (right).

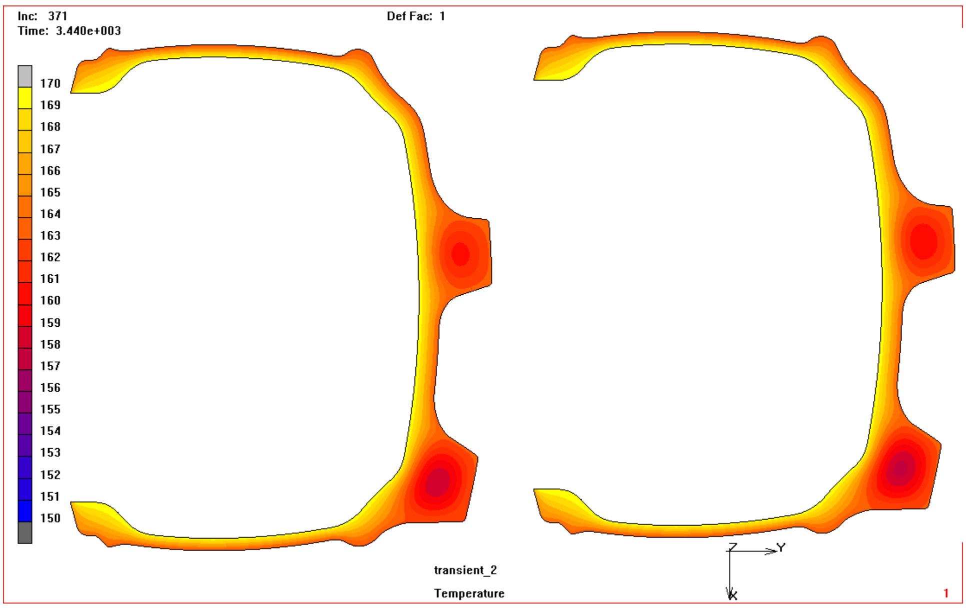

Fig. 6: Thermal field [°C] in tyre in time 57min20s – "steam dome"(left), "steam dome, steel" (right).

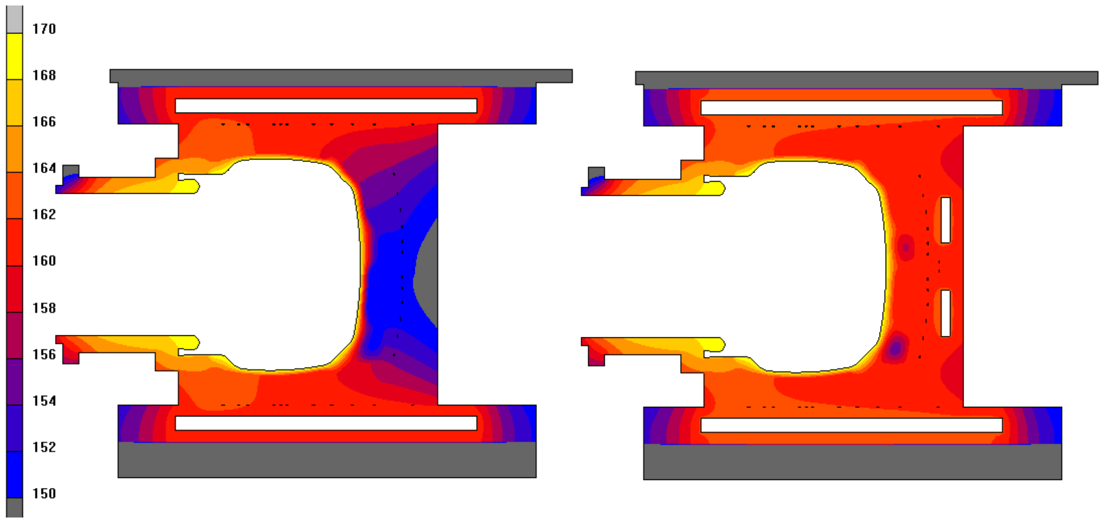

Fig. 7: Thermal field [°C] in mold in 57min20s – "only plates" (left), "plates+channel" (right).

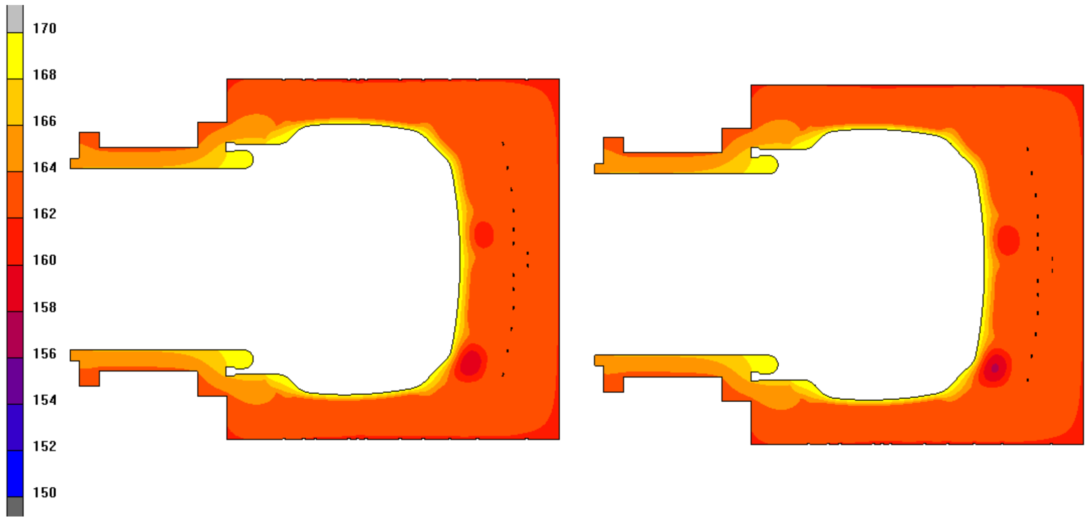

Fig. 8: Thermal field [°C] in mold in 57min20s – "steam dome" (left), "steam dome, steel" (right).

4. Conclusions

The effect of the mold heating concept (steam dome vs. heating plates) on the time history in thick parts of the cured tyre is significant despite the indisputable differences in thermal fields in molds heated with plates or steam. Heating plates in combination with properly designed heating channels (preferably with independent heating control) seem to a promising alternative to the steam dome concept. However, it should be pointed out that development of a new curing mold should be always accompanied by detailed thermal measurement with thermocouples placed in both mold and tyre to provide necessary setup data for FEM analyses.

From thermal point of view, the influence of insert material (aluminum or steel) on thermal fields in tyre and mold (and therefore on the cure process) is negligible and only manufacturing aspects can prevail.

References

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