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STATIC NUMERICAL ANALYSIS OF A HYDRAULIC CURING PRESS

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Abstract: *This paper introduces static numerical analysis of a whole hydraulic curing press. The analysis is done using finite element method in Marc Mentat software. Individual parts of the curing press are identified in the paper and the setting of the computational model is described. There are suggestions for design optimization with respect to the material savings and lowering of stress peaks. This computational model can be used as a guide for analysis of curing presses with similar designs.*

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

1. Introduction

The tire curing press is a machine which is used for the final stage of tire production. Semi-finished tires are inserted into the mould of the curing press and by treatment with a defined pressure and temperature they obtain their final shape and final mechanical properties. (The chemical reaction that occurs in the curing press is called vulcanization.) FEM analyses are used for this type of machine to achieve the required parameters, for the tire to be made to required quality. These computations can find significant material savings for the producer of the press and efficiently raise the machine's parameters. Static analyses of strength are usually done for these presses. Further analyses include the computation of the temperature field of the vulcanization chamber's outer surface which is crucial to the heat loss (Hynek, 2013) and thermal influences of the press frame (Jirasko, 2016). The distribution of the temperature inside the mould is also considered for the right technology of tire vulcanization (Hynek, 2011).

The static analyses of the whole press is summarized in this article for the purpose of identifying critical points of the design and finding possibilities of material savings while maintaining the machine's required parameters. The calculation is done using finite element method (FEM) in Marc Mentat.

Discovering oversized parts which are not justified with respect to the strength can lead to significant weight savings and lowering of the design demands of certain parts without decreasing the press functionality. These aspects are considered in this curing press design variant which is often used by Asian press producers. It is a design in which the crossbeam moves upwards (vertically) when the press opens and the slide table with the lower part of the mould moves horizontally to the position where the tire is removed by the crane. Hydraulic cylinders (positioned under the lower chamber) are used to impart the closing force. The crossbeam is fixed by four pins to the rods in its working and idle position. The press parts are shown in Fig. 1.

Lightening of the design also brings other economic benefits for the machine's producer besides lowering the price of the production. These benefits include: faster opening, lower operating energy requirements, lower price of the drives, etc.

The tire mould tightness is required for the sake of the tire's final quality. Peripheral clearance in the mould's dividing plane should be minimal, ideally none at all. If the pressure chamber is in use the

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heating medium should not be able to leave the chamber and thus put the press staff in danger. Considering the not negligible displacements of the pressure chamber and subsequent parts of the press, it is necessary to use adequate sealing for the chamber in its peripheral groove. (Therefore we included pictures of the contact status in the area of the seal groove in the results of the analyses of individual variants of the press.) An analysis of the overlaps (or clearance) of the mould and the chamber is usually required for the ideal setting of every new machine design. This topic is more thoroughly described in the article (Keckstein, 2016), where the analyses algorithm for ideal setting is presented. In this press analysis only the optimal setting variant results are presented. Compression of the sealing as a consequence of the press closing must be sufficient to cover the size of the cover displacements.

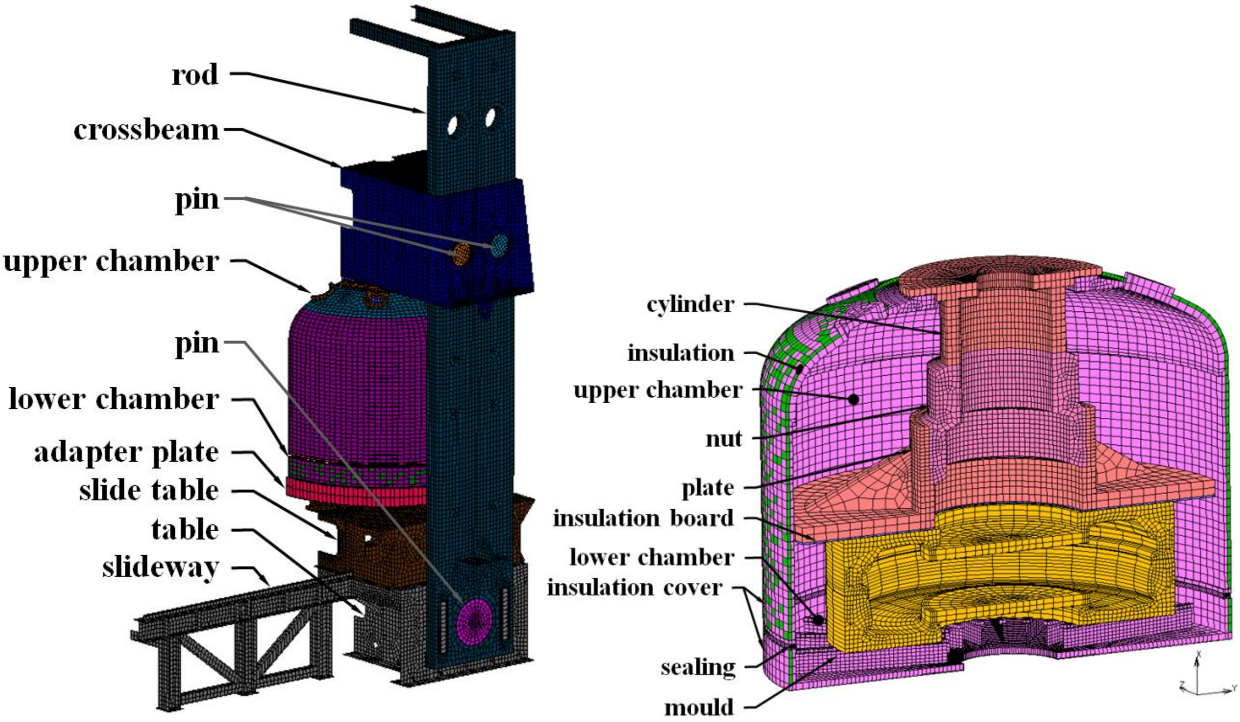

Fig. 1: Whole computational model of the press and the detail of the chamber.

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 (hex8), shell elements (quad4). The main examined machine components are connected by touching contacts. The material properties of the metal parts are listed in Tab. 1, rubber sealing properties (Mooney) are listed in Tab. 2.

Tab. 1: Mechanical properties of metal parts.

Part	**Material**	**Density** ρ [kg·m^{-3}]	**Young's modulus** **E** [GPa]	**Poisson's ratio** ν [-]	**Yield strength** R_e/R_{p02}[MPa]	**Tensile strength** R_m [MPa]
stand, crossbeam, rod	S355	7800	210	0.27	300	500
pressure chamber	P265GH	7800	210	0.27	255	410
mould	GE 200	7850	170	0.30	200	450
plate, hang cylinder	GX7CrNiMo12-1	7850	210	0.30	440	590
nut	CuAl9Ni5Fe1Mn1	7800	110	0.34	295	590
cover insulation	foam glass	140	0.1	0.2	-	-

Tab. 2: Mechanical properties of the rubber sealing.

	Density [kg·m^{-3}]	C_{10} [Pa]	C_{01} [Pa]
sealing - 95 shore	1070	3000000	1400000

3. Boundary conditions

All degrees of freedom were removed from the press table base and an appropriate boundary condition was applied in the press symmetry plane. The analysis was divided into 3 steps. Every step was divided into 10 increments due to the higher number of contacts in the computational model:

Step 1: During this phase the lower part of the chamber with the mould is moved by 0.6 mm towards the upper part and thus both mould halves tightly press against each other while the peripheral chamber sealing is simultaneously deformed in the seal groove.

Step 2: Press closing force 4500 kN is imparted by the hydraulic cylinders. The boundary condition from the first step is deactivated in this step.

Step 3: A pressure of 2.4 MPa is applied to the inner surfaces of the mould and a pressure of 0.8 MPa is applied to all the inner surfaces in the chamber.

4. Results

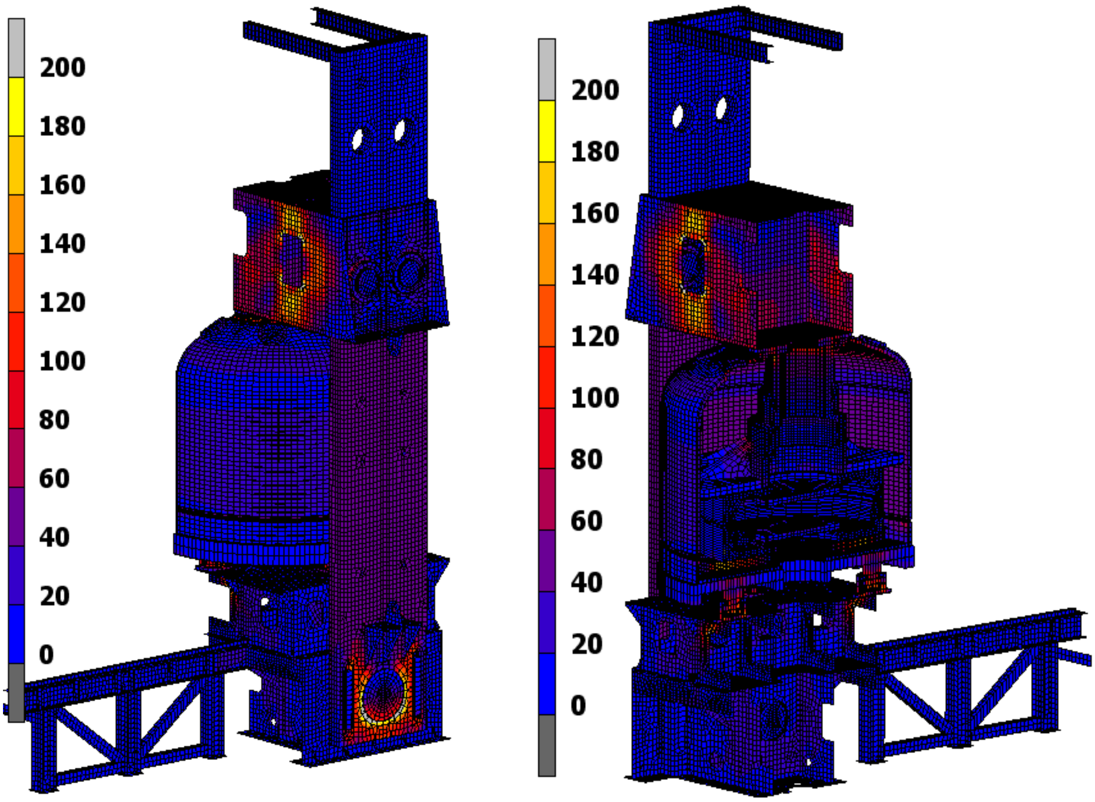

Fig. 2: Von Mises stress [MPa] in the press assembly (Step 3).

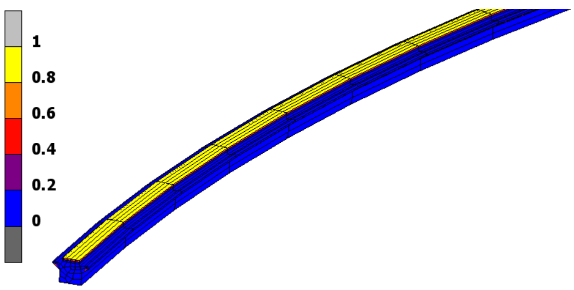

Fig. 3: Rubber sealing contact status- uninterrupted contact area.

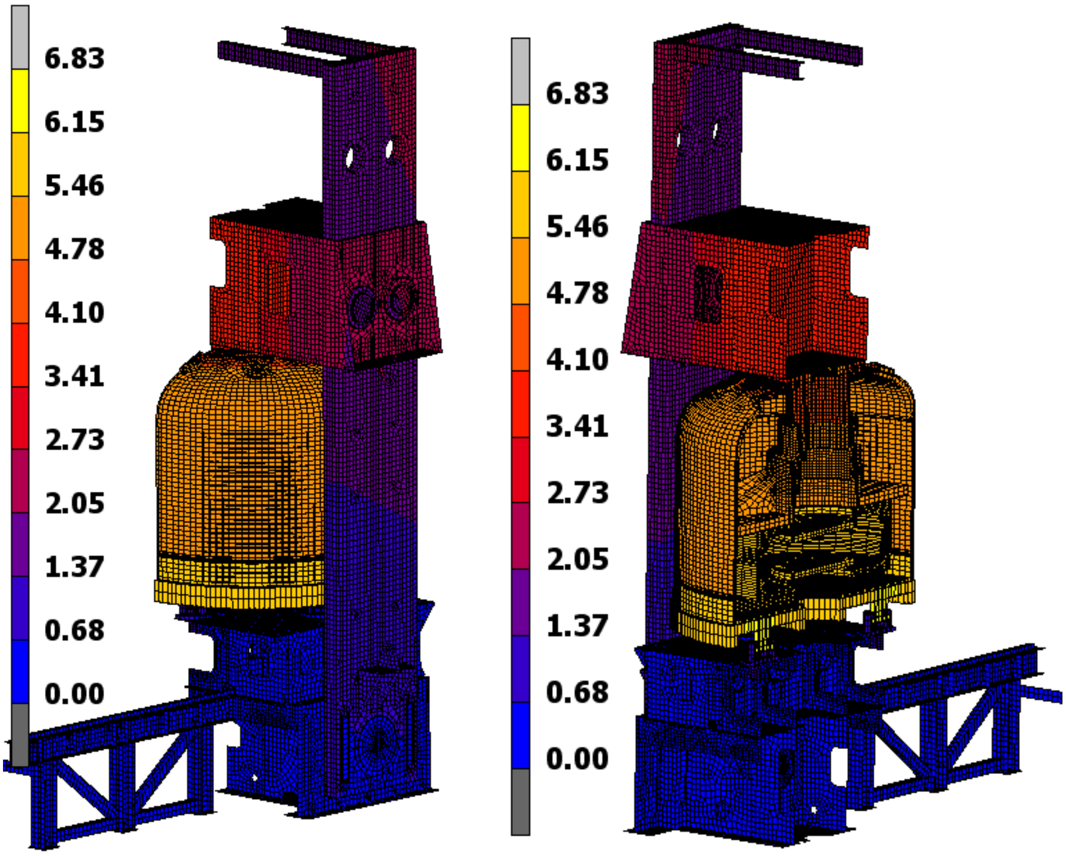

Fig. 4: Displacements [mm] in the press assembly (Step 3).

5. Conclusions

This paper describes a method for carrying out the static analysis of a curing press using Marc Mentat. A similar computational model can be used when analysing curing presses with a different type of design. The computational model and its settings and parameters are described here. The analysed design of the press is oversized in all weldments with the exception of the crossbeam and the area of the pin connection of the stand and the rod. Another area with a higher value of stress is the area of the lower chamber which is supported by the hydraulic cylinders. The chamber is deformed in a similar manner as in other press designs. This meets the demand for uninterrupted contact between the upper and the lower half of the chamber. In the area of the mould sealing edge (in the dividing plane) the contact is also uninterrupted. With respect to the quality of the final product and safety of operation safety the design of the press is sufficient.

Acknowledgement

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References

Hynek, M. and Votapek, P. (2013) Numerical analysis of thermal fields in the insulated cover of tire curing presses. 18th International Conference Engineering mechanics 2012.

Hynek, M. and Votapek, P. (2011) Thermal analysis of tyre curing process. In IM 2011. Praha: AVČR. pp. 223-226.

Jirasko, J. and Kottner, R. (2016) Computational model for heat transfer in a tyre curing press. 22nd International Conference Engineering mechanics 2016. pp. 262-265.

Keckstein, T., Jirasko, J. and Kottner, R. (2016) Finite Element Analysis of a Curing Press with Focus on Tightness of the Vulcanizing Chamber, Proceedings of the ASME 2016 International Mechanical Engineering Congress and Exposition.