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MILL ROLLS THERMAL STRESS ANALYSIS USING FINITE ELEMENT METHOD

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ABSTRACT

The paper presents the analysis of thermal stress field distribution that occurs in the mill rolls, using finite element method. The finite elements method or the analysis with finite elements is based on the concept of building complicated object out of simpler ones, or dividing complicated objects into simpler ones, for which known schemes of calculation can be applied. The main idea in the method of finite element is to find the solution of a complicated problem by replacing in with a simpler one.
The analysis of the thermal strains in rolling cylinders, using finite elements method, has been carried out on Adamit-type cylinders, cast of hypereutectoid steel and used in rolling profile I on the middle profile rolling train of S.C. Siderurgica S.A. Hunedoara.
The industrial experimental data (rolling temperature, cooling water temperature, material characteristics etc.) are the basics for simulation program..

KEY WORDS:
mill rolls, simulation, thermal stress

1. INTRODUCTION

A particularly actual problem for the steel making companies is the low exploitation endurance of the rolling cylinders, as they are the most stressed parts in the rolling train.

By taking into consideration thermal strains we could carry out a complete study, very close to the real conditions of rolling cylinder exploitation, as the thermal influences constitute one of the basic causes leading, even under favorable exploitation conditions, to thermal fatigue fissures, that reduce the use of cylinders in rolling sessions [1].

2. EXPERIMENTAL

The analysis of the thermal strains in rolling cylinders has been carried out on Adamit-type cylinders, cast of hypereutectoid steel and used in rolling profile I on the middle profile rolling train of S.C. Siderurgica S.A. Hunedoara.

The method of the finite element implies the generation of a discretizing lattice on the surfaces previously defined, taking into consideration the fact that all the knots and elements of the lattice are numbered [2], [3]. We mention that, on discretizing, we obtained a total number of 253613 elements and 49768 knots.

The plane discretizing of the rolling cylinders and of the rolled profile are given in fig. 1.

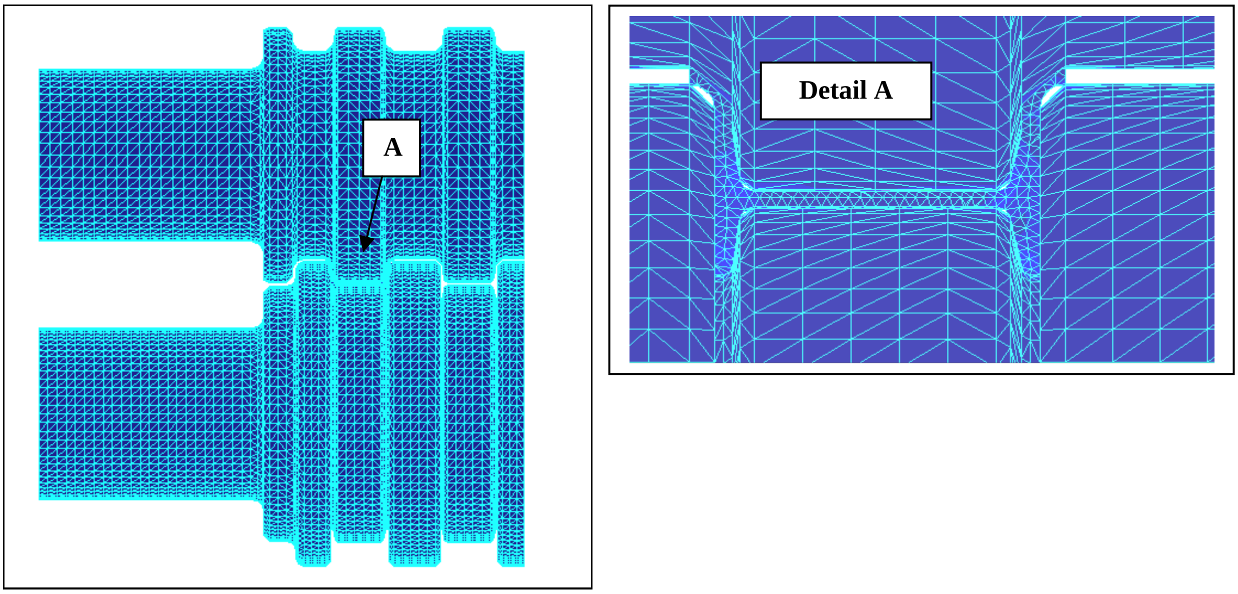


Figure 1. Diagram of the plane modeling of the rolling cylinders and the rolled profile I.

In order to determine the material thermal-physical properties, we took into account the fact that the steel that the rolling cylinders are cast from is an Adamit-type, hypereutectoid steel, grade OT- A3, having the chemical structure given in tab.1. The steel to be rolled is an all purpose steel (OL 37), having the chemical structure given in tab.2.[4].

Table 1. The chemical structure of the Adamit-type, hypereutectoid steel (I.T.E.770-89)

Steel grade	Chemical structure, %									
	C	Si	Mn	P_{max}	S_{max}	Cr	Ni_{max}	Mo	Cu_{max}	Ti_{max}
OTA3	1,8-2,0	0,6-0,8	0,7-0,9	0,04	0,02	1,0-1,2	1,6-2,0	0,3-0,5	0,2	0,06

Table 2. The chemical structure of the steel to be rolled

Steel grade	Chemical structure, [%]				
	C	Mn	Si	P_{max}	S_{max}
OL 37 (STAS 500/1,2 - 80)	max. 0,20	max. 0,80	max. 0,07	0,06	0,06

The thermal-physical and material properties of the Adamit-type, hypereutectoid steel that the rolling cylinders are cast from are [4]:

- the coefficient of linear expansion: $\alpha = 13 \cdot 10^{-6} \frac{1}{K}$;

- thermal conductivity: $\lambda = 31 \frac{W}{m \cdot K}$;
- specific heat: $c_p = 620 \frac{J}{kg \cdot K}$;
- initial temperature: $T_{initial} = 20^oC$.

The thermal-physical and material properties of the steel to be rolled, i.e. (OL37), respectively of profile I, are [4]:

- the coefficient of linear expansion:

$$\alpha_{100^o C} = 12{,}2 \cdot 10^{-6} grdC^{-1}; \alpha_{700^o C} = 14{,}9 \cdot 10^{-6} grdC^{-1};$$

- thermal conductivity: $\lambda_{20^o C} = 50 \frac{W}{m \cdot K}$; $\lambda_{800^o C} = 25 \frac{W}{m \cdot K}$
- specific heat: $c_{P20^o C} = 452 \frac{J}{kg \cdot K}; c_{P600^o C} = 753{,}3 \frac{J}{kg \cdot K}; c_{P800^o C} = 933{,}3 \frac{J}{kg \cdot K}$;
- initial (rolling) temperature: $T_{rolling} = 800^oC$.

3. DETERMINATION OF THE STRAIN STATE IN CASE OF APPLYING THE COOLING WATER ON TWO SURFACES

In case of calculating the thermal strains at 800^oC, the rolling cylinders being cooled on two surfaces, we took into consideration the fact that the strains in the neck areas are not relevant because movements were null here ("expansion blocked"), as the bearing clearance was ignored. The diagram of the water cooled surfaces with respect to the position of the rolled section is given in fig. 2.

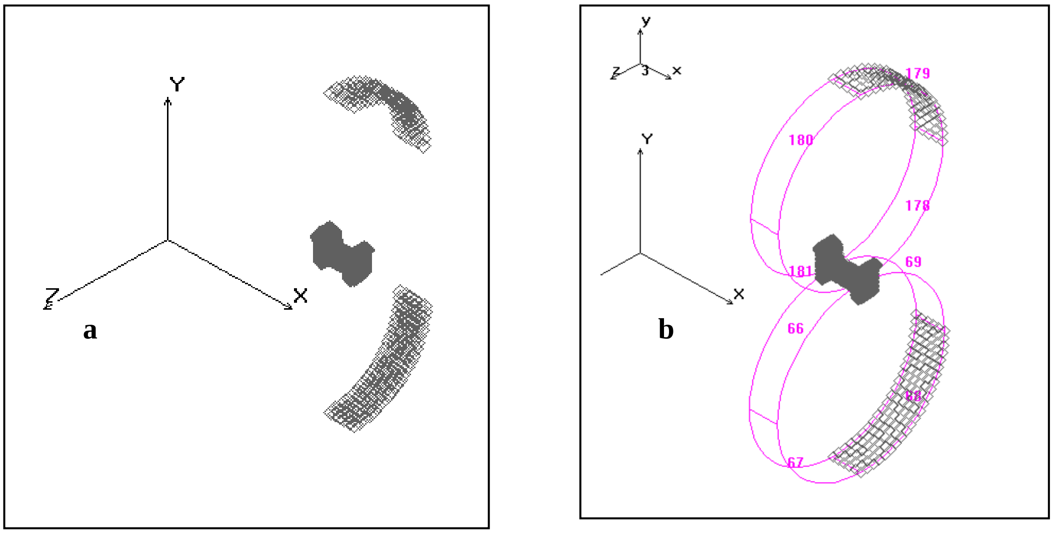
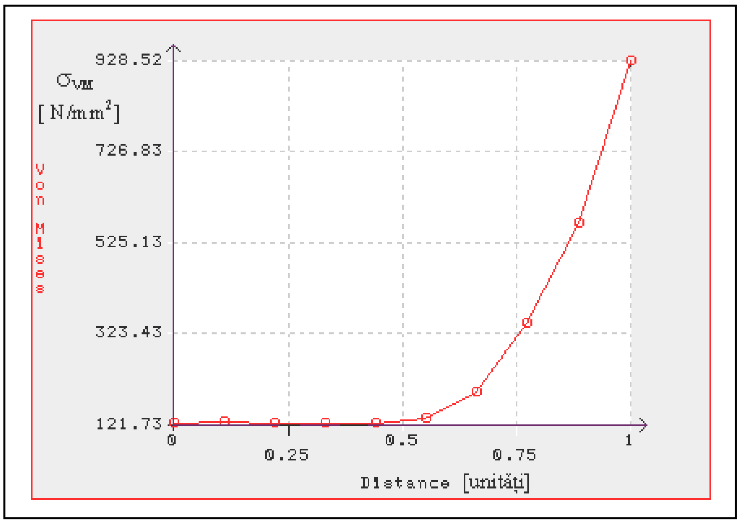


Figure 2. The rolling cylinder cooling diagram, without displaying the surfaces the cooling water is applied on (fig a) and displaying them (surfaces 68 and 179) (fig.b).

In order to draw the diagrams corresponding to the thermal strains in the knots placed on the critical rolling areas of the cylinder circumference, it is necessary to place the knots on the circumference of the groove pass. In order to draw the diagrams corresponding to the thermal strains in the knots placed on the critical rolling areas of the cylinder circumference, it is necessary to place the knots on the circumference of the groove pass.

In fig. 3 we gave the ensemble of the cylinder cross-section, as well as the magnitudes of the Von Mises strains for the following knots (schematically pointed out on the surface of the upper cylinder): 35215, 35218, 35221, 35224, 35227, 35230, 35233, 35236, 35239, 35242. In the plan given in fig.3, one can notice an increase in the thermal strains towards the rolling area (the profile). Thus, for knot 35215 Von Mises strain is 121,73 N/mm^2 and for knot 35242, of 928,52 N/mm^2. The distance between the first and the last knot under study represents, in fact, the length of the bisecant, respectively 167,8894 mm (in the graph given in the figure, it is considered to be equal to the unit).



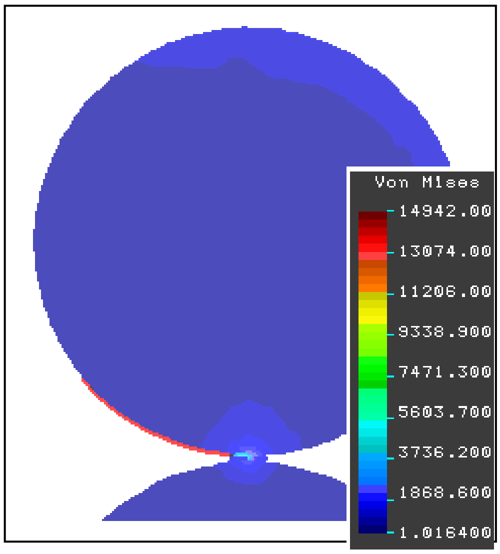


Figure 3. Variation of the Sigma Von Mises strains.

In fig. 4 we gave the ensemble of the cylinder cross section, as well as the magnitudes of the Von Mises strains for the following knots (schematically pointed out on the surface of the upper cylinder): 35126, 35129, 35132, 35135, 35138, 35141, 35144, 35147, 35150, 35153, 35156. The diagram shows a decrease in the thermal strains away from the rolling area, knot 35126 having a Von Mises strain of 930,77N/mm^2 and knot 35156 of about 246 N/mm^2. In this case, the calculated length of the bisecant is 185,1947mm.

Similarly, in fig. 5 we gave the ensemble of the cylinder cross section, as well as the magnitudes of the Von Mises strains for the following knots (schematically pointed out on the surface of the upper cylinder): 4277, 4281, 4285, 4289, 4293, 4297, 4301, 4305, 4309, 4313, 4317, 4321. In the plan given in fig. 5 one can notice a decrease in the thermal strain away from the rolling area. Thus, for knot 4277 Von Mises strain is of 902,51N/mm^2 and for knot 4321 of 173,26N/mm^2 (in this case, the calculated length of the bisecant is 185,1947 mm). In fig. 6 we gave the ensemble of the cylinder cross section, as well as the magnitudes of the Von Mises strains for the following knots (schematically pointed out on the surface of the upper cylinder): 4423, 4427, 4431, 4435, 4439, 4443, 4447, 4451, 4455, 4459, 4463, 4467. Fig. 6 shows that for knot 4467 Von Mises strain is of 822,58 N/mm^2 and for knot 4423 of 99,203 N/mm^2 (the calculated length of the bisecant is 185,1947mm).

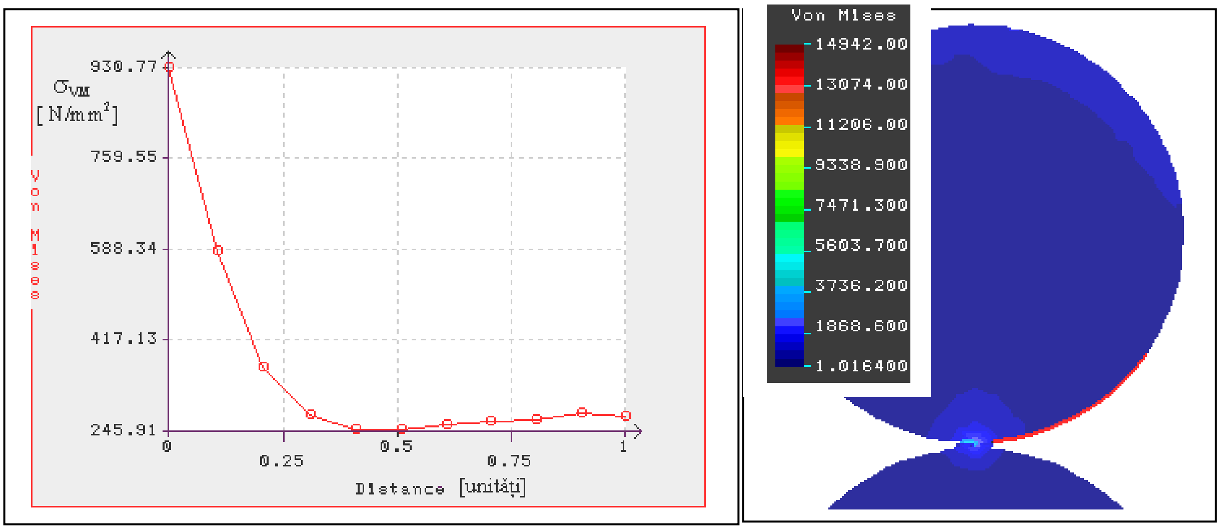


Figure 4. The variation of Sigma Von Mises strains.

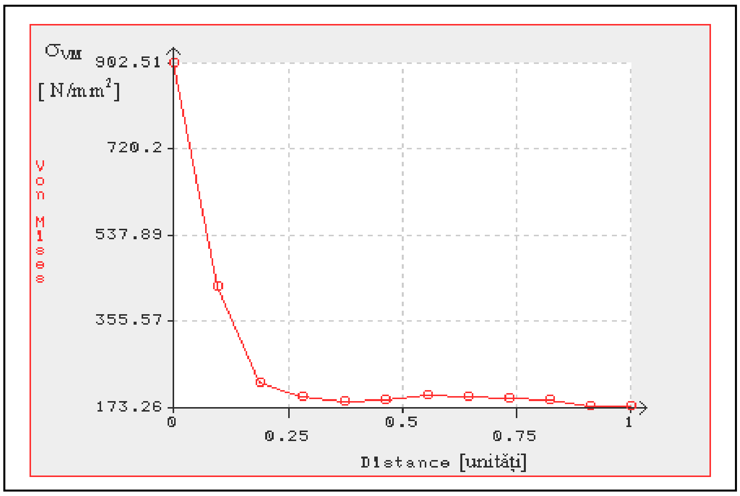
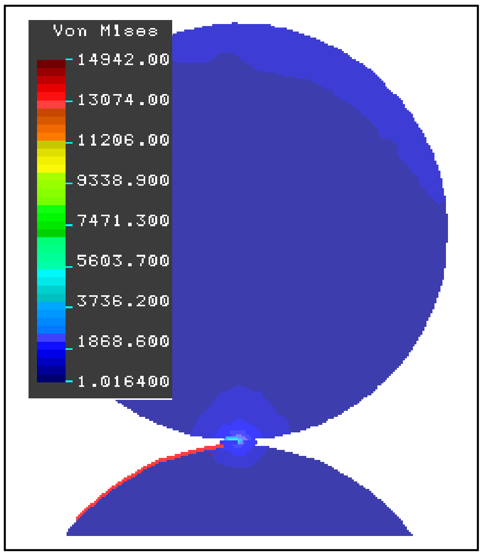


Figure 5. The variation of Sigma



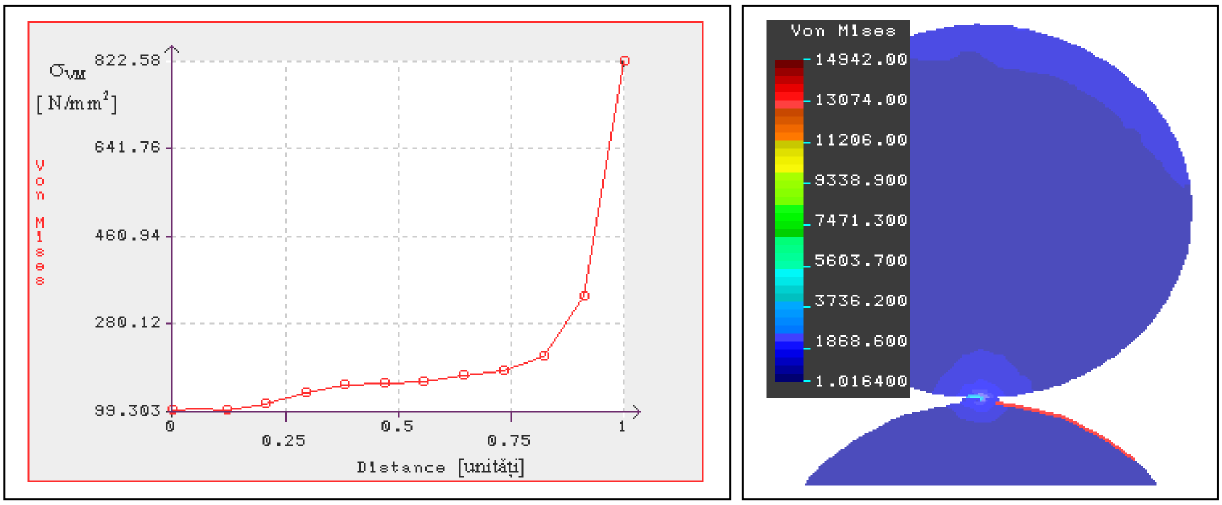


Figure 6. The variation of Sigma Von Mises strains.

4. CONCLUSIONS

As a result of simulating the rolling process by means of the finite element method in view of quantitatively and qualitatively determining thermal strains, we came to the following conclusions:

- thermal strains are the basic cause of fissuring the rolling surface of cylinders as a result of thermal fatigue, caused by the high values in the areas neighboring the contact area with the incandescent semi-finished part; the graphs show that the values of the thermal strains in the area under consideration rank within 121,73 and 930,77 N/mm^2 for the upper cylinder and 99,303 and 902,51 N/mm^2 for the lower cylinder;
- thermal strains have significantly higher values as compared to the mechanical ones and act at relatively short intervals of time (within fractions of a second);
- the rolling cylinders break during the rolling process because of thermal fatigue;
- a most precise knowledge of the character of the strains generated by the complex stresses the hot rolling cylinders undergo, allows the determination of the duration in exploitation under safe conditions, by their comparison to certain limit values imposed from the very beginning;
- strains in the rolling cylinders have a cyclical character and the strain state is mainly the result of the action of the fields of symmetrical and asymmetrical temperatures that cause thermal fatigue on their surface and superficial layer.

5. REFERENCES

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