12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology
TMT 2008, Istanbul, Turkey, 26 – 30 august, 2008

DETERMINING THE COMPOSITE TENSION INSIDE THE WARM ROLLING CYLINDERS

Camelia B. Pinca
Gelu O. Tirian
University "POLITEHNICA" of Timişoara, Romania
331128 Hunedoara, Revoluției street no.5, Hunedoara

ABSTRACT

The warm rolling cylinders are under stress – composite tension – caused by the mechanical tensions, on one hand and tensions produced by the temperature fields, on the other hand. Such tensions vary and are complicated. They also have excessively high values which are caused by the impact of the cylinders with the incandescent rolling product.

Our paper work is going to describe how, during laboratory tests, the composite tensions harm the rolling cylinders of a rolling mill. These tests are actually some original concepts made according to the principle of symilar that allows us to extrapolate the results we have obtained in case of the industrial rolling mills.

Keywords: tension, composite, warm

1. INTRODUCTION

The warm rolling cylinders are under stress – composite tension – caused by the mechanical tensions, on one hand and tensions produced by the temperature fields, on the other hand. Such tensions vary and are complicated. They also have excessively high values which are caused by the impact of the cylinders with the incandescent rolling product.

Our paper work is going to describe how, during laboratory tests, the composite tensions harm the rolling cylinders of a rolling mill. These tests are actually some original concepts made according to the principle of symilar that allows us to extrapolate the results we have obtained in case of the industrial rolling mills.

2. THEORETICAL ELEMENTS FOR CALCULUS

The resulting tensions, following the complicated stress that the rolling cylinders are subject to, have been determined according to the theorem of overlapped effects [1]. This theorem admits that tensions should be calculated as an algebric sum of the tensions produced during the mechanical-thermic stress. Total values on the main axis of a material-element cut off from a warm rolling cylinder is the result of the algebra sum amongst bending, twisting, contact pressure tensions and tensions produced by the symmetrical and asymmetrical temperature fields, according to picture from fig. 1.

These main tensions refer to each stage of the rolling cycle of the half-manufactured, considering all the stress tensions. If we use the theory of deformation energy, we can determine equivalent tensions for certain levels of the radial section of the rolling cylinder calibres. The equivalent tensions have been calculated according to the relation (1).

$$\sigma_{ech} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\nu\left[\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_1\sigma_3\right]} \qquad (1)$$

In relation (1) σ_1, σ_2, σ_3 – resulting main tensions;

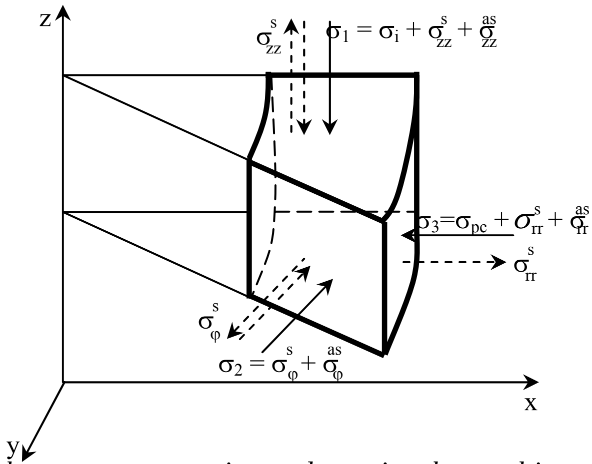

Figure1. The action scheme of the component tension to determine the resulting main tension

σ_1 – tension as a result of the cylinder axis - z;

σ_2 – tension as result of the circumference –

σ_3 – resulting radial tension

$$\sigma_1 = \sigma_i + \sigma^s_{zz} + \sigma^{as}_{zz}\ ;\ \sigma_2 = \sigma^s_{\varphi\varphi} + \sigma^{as}_{\varphi\varphi} ; \sigma_3 = \sigma_{pc} + \sigma^s_{rr} + \sigma^{as}_{rr} ;$$

υ = 0,3; σ_i - stress of flexion; σ_{pc} - stress of contact pressure.; σ^s_{zz}, $\sigma^s_{\varphi\varphi}$, σ^s_{rr} - thermal tensions produced by symmetrical temperature fields ; σ^{as}_{zz} , $\sigma^{as}_{\varphi\varphi}$, σ^{as}_{rr} - thermal tensions produced by symmetrical temperature fields .

3. DETERMINING BOTH EQUIVALENT AND RESULTING MAIN TENSIONS

Due to the extended number of calculations and because of the reduced work space, we shall describe some simplified results, referring to one single revolution of the warm rolling cylinders, such as: n = 35,7 rot/min, where thermic tensions are higher.

As far as the mechanical tensions are concerned, they have been determined according to the following guidelines:

- bending and twisting tensions of the rolling cylinder calibres have been determined precisely and without any difficulty, according to specialized literature [1].
- pressure contact tensions between the rolling product and the cylinders, within the deformation area, could be determined by mathematical relations and average values of the parameters obtained during the rolling process.

The numerical calculations of these bending and twisting tensions have been made in case of the fibres inside the cylinder sections – corresponding to a certain - r – radius; we determine the thermic tensions for that radius and we are able to compare the values of these tensions and evaluate their influence while overlapping the other types of calculated tensions.

In case of plastic deformation inside the core, we should consider that the pressure contact tensions on the surface of the cylinder calibres are equivalent to the deformation tensions. Therefore, in case of the warm rolling, contact pressure tensions could not be determined by Hertz relation, who refers to elastic stress, but by Exelud relation [1], using the experimental results obtained for certain rolling parameters. The synthesis of the values of mechanical tensions determined by experiments is contained in table 1.

As far as the thermic tensions are concerned, there are two categories, such as:

- those produced by symmetrical temperature fields are called symmetrical thermic tensions;
- those produced by asymmetrical temperature fields are called asymmetrical thermic tensions.

Table 1. The synthesis of the mechanical tensions determined through experiments

No.	**F_m [kN]**	**Bending tensions σ_i [N/mm^2] determined at the depth of Δr [mm];**						**Twisting tensions τ_r [N/mm^2] determined at the depth of Δr [mm]**						**σ_{pc} [N/mm^2]**
		0	1,5	3	6	9	15	0	1,5	3	6	9	15	
1.	8527	50,9	50,8	50,7	50,4	50,2	49,7	18,0	18,0	18,0	18,0	17,8	17,6	42,6
2.	11021	65,7	65,7	65,5	65,2	64,9	64,2	19,9	19,8	19,8	19,7	19,6	19,4	64,6
3.	8555	51,9	51,9	51,8	51,6	51,3	50,8	17,7	17,6	17,6	17,5	17,4	17,3	52,3
4.	10905	66,1	66,1	65,9	65,6	65,3	64,7	20,9	20,8	20,8	20,7	20,6	20,4	70,4
5.	11010	66,4	66,4	66,3	66,0	65,6	65,0	19,9	19,8	19,8	19,7	19,6	19,4	72,4
6.	10260	61,7	61,7	61,5	61,2	60,9	60,3	18,5	18,4	18,5	18,3	18,2	18,1	65,1
7.	9582	85,3	85,3	85,1	84,7	84,2	83,4	24,0	23,9	24,0	23,8	23,7	23,4	76,8
8.	9999	85,3	85,3	85,1	84,7	84,2	83,4	22,9	22,8	22,8	22,7	22,5	22,3	82,5
9.	65534	40,5	40,5	40,4	40,2	40,0	39,6	13,8	13,8	13,8	13,7	13,6	13,5	47,6
10.	7621	44,8	44,8	44,7	44,5	44,2	43,8	11,9	11,8	11,8	11,8	17,6	11,6	73,6
11.	8410	58,9	58,9	58,8	58,5	58,2	57,6	19,2	19,1	19,1	19,0	18,9	18,7	93,0
12.	8682	60,7	60,7	60,5	60,2	59,9	59,3	16,4	16,4	16,4	16,3	16,2	16,0	108,8
13.	6927	57,8	57,8	57,7	57,4	57,1	56,5	14,7	14,6	14,6	14,5	14,4	14,3	79,4

The calculations and the ways of determination have been described in detail in paper work [2]. In the following, we refer to the synthesis of the results obtained as graphical descriptions. Fig. 2 presents the tensions variations produced by the symmetrical temperature fields, σ^{s}_{rr}, $\sigma^{s}_{\varphi\varphi}, \sigma^{s}_{zz}$, in the radial section of the rolling cylinder of the experimental installation, and the number of cylinder rotations is n = 35,7 rot/min. In order to determine the asymmetrical thermic tensions $\sigma^{as}_{rr}, \sigma^{as}_{\varphi\varphi}, \sigma^{as}_{zz}, \sigma^{as}_{r\varphi}$, we have used written calculus software Microsoft Acces, who allowed us to solve the tension equations. The results of the calculations representing the values of the tensions produced by the asymmetrical temperature fields inside the rolling cylinders have the number of cylinders' rotations of n = 35,7 rot/min; the number of the cylinders' rotation of n = 35,7 rot/min is represented in fig. 3.

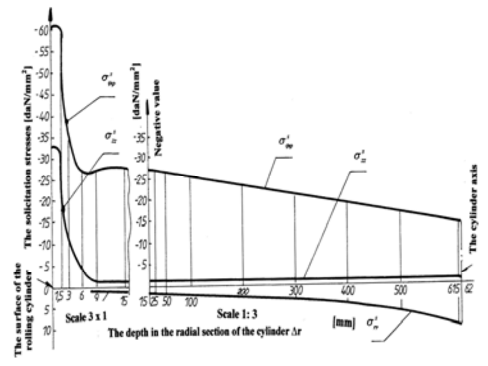

Figure 2. Representing the variation of tensions produced by the symmetrical tension inside the warm rolling cylinders

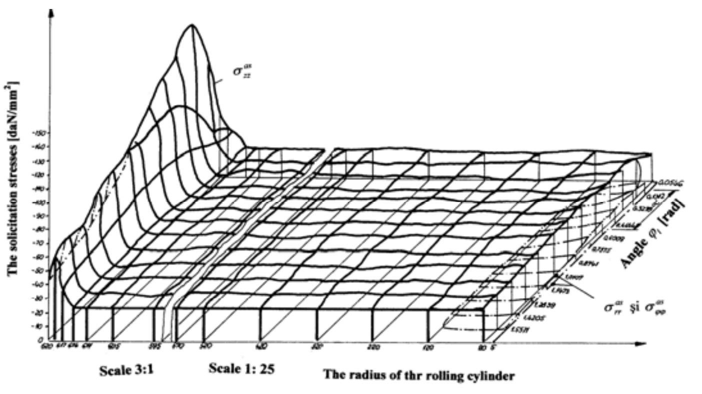

Figure 3. Representing the variation of tensions produced by the asymmetrical tension inside the warm rolling cylinders

Due to the results contained in Table no. 1, to the graphics from figure no. 2 and 3, and using the relations (2), (3) and (4), we have determined the main tensions σ_1 , σ_2, σ_3. Based on relation (1), these relations have helped us determine the equivalent tensions at the surface of the rolling cylinder, where Δr = 0; and in the radial section, at Δr = 1,5; 3; 6 and 15 mm in depth. The synthesis of the results is contained in table 2.

Table 2.The calcululs of the resulting main tensions $\sigma_1, \sigma_2, \sigma_3$ and equivalent σ_{ech} for the experimental rolling with n =35,7 rot/min

The simbol of the tensions	*The values of the resulting main tensions $\sigma_1, \sigma_2, \sigma_3$ and quivalent tension σ_{ech}*					
	The depth in the cylinder section Δr [mm]					
	0	**1,5**	**3**	**6**	**9**	**15**
σ_1	-1693	-1052	- 615	-274	-273	-273
σ_2	-603	- 612	- 405	-271	-274	-274
σ_3	-70	1,2	4,3	8	10,8	12
σ_{ech}	1590	1048	628	326,7	330	329,9

4. RESULTS

According to the analysis of the bending, twisting, and contact pressure, rotation tensions are calculated and contained in table 1, the result is that: - the lowest bending tensions in the superficial layer go down to 3...6 mm in depth, under the surface of the calibre, but have insignificant values; they are at the surface - σ_i = 85,5 N/mm^2, and they get lower inside the cylinder;- the twisting tensions produced during rolling have very low values. The highest tension we could calculate is of τ_r = 24 N/mm^2 at the surface of the calibre. This is backed up by practical experiments; - stress tensions in case of contact pressure influence the surface of the calibres within the deformation core area; we calculated and their highest value is of σ_{pc}= 108,8 N/mm^2.

Circumferential tensions $\sigma^{s}_{\varphi\varphi}$ reach their highest values at the surface of the cylinder and decrease as far as they go deeper. Circumferential tensions $\sigma^{as}_{\varphi\varphi}$ are null at the surface of the calibres and at the extreme points of the liniary segments who represent the abscissa of the asymmetrical temperature field. Axial tensions σ^{as}_{zz}, produced by the asymmetrical temperature values, have important values at the surface of the cylinder and the superficial layer.Tangential thermic tensions σ^{as}_{rr} , produced by asymmetrical temperature tensions, reach values below 1 at the surface of the cylinder and in the superficial layer. The main resulting tensions σ_1 and σ_2 reach only negative values and cause compression. Main tensions σ_3 are negative at the surface and in the superficial layers, and they go down to Δr = 1,5 mm in depth. They become positive once they go down and increase as they get closer to the axis of the cylinder. The main radial tensions σ_3 at the surface of the cylinders have relatively low values compared to tensions σ_1 and σ_2, and those are the most important values in case of equivalent tensions. The values of the equivalent tensions σ_{ech} are influenced mainly by tensions σ_1 and σ_2 , whose highest values are reached in case of slow rotations of the warm rolling cylinders.

5. CONCLUSIONS

All classical resisting tensions that are used for calculating the rolling cylinders have insignificant values, but such calculation is not appropriate in case of real working conditions. Asymmetrical thermic tensions go in cycles, they repeat after each rotation of the cylinders, and they are extremely dangerous because they cause the thermic fatigue of the rolling cylinders. The tension inside the rolling cylinders is the main result of the stress caused by the symmetrical and asymmetrical temperature fields that cause thermic fatigue at the surface and in the superficial layers of the warm rolling cylinders.

6. REFERENCES

[1] Toader Şt, Pinca C., Pleşa D.- Thermal fatigue of the hot rolling mill cylinders, Timişoara, ISBN 973-625-185-3, Romania, 2004

[2] Pinca C., - Researches and experiments regarding the thermal and the equivalent tensions from the hot rolling mills cylinders, in avoiding the growing thermal fatigue resistanc and the increase ofservice life, Grant No.58 GR/ 19.05.2006, Tema 3, Cod CNCSIS 45