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THE RESEARCHES AND EXPERIMENTS REGARDING THE THERMAL AND THE EQUIVALENT TENSION FROM THE HOT ROLLING MILLS CYLINDERS, IN AVOIDING THE GROWING THERMAL FATIGUE RESISTENCE AND THE INCREASE OF SERVICE LIFE

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ABSTRACT
These work for researches regarding the thermal and equivalent tensions from the hot rolling mills cylinders, in avoiding thermal shocks and the increase of durability in exploitation is a technical novelty, both theoretically and experimentally, and tries to give answers to most current problems related to this domain of activity. The exponential curve type according to the rotation angle of the cylinders is established, following a thorough analysis of the hot rolling process. The temperature variation curves on the surface and the radial section of the rolls are determined experimentally, and particularly, the superficial layer of the calibres is studied. Using original mathematic equations established for the numerical calculus of the symmetrical and asymmetrical field of temperature, with experimental data that allow the study of evolution of these tensions and determining the conditions in which the thermal fatigue specific cracks appear. Applying the deformation energy theory, the equivalent tensions are determined, for which, initially, the resulting main tensions acting in the element of the rolls material, in three-dimensional coordinates, are calculated.
Keywords: tension, equivalent, stresses

1.INTRODUCTION
The researches upon thermal and equivalent tensions from the hot rolling mill cylinders represent an important scientific, theoretical, experimental and economical issue.
Hot rolling mill cylinders are the parts most subjected to wear in the rolling trains because the incandescent rolled material is plastically deformed between the water-cooled rolls.
In order to compete on international level, many of the cylinder producing companies had to constantly develop the research areas, the laboratories to verify quality. The thermal tensions are variable, complex, with extremely marked influences. Therefore, to intensify the rolling processes we need to observe the durability limits, with thermal tensions produced in symmetrical and asymmetrical temperature fields, at a large number of stress cycles. To this purpose it is necessary to know as accurately as possible the type of stress, the materials, and a detailed characterises evaluation, to determine exploitation timing and to compare with previously established values.
The thermal fatigue specific fissures in the form of cracks are produced under the action of thermal tensions resulting from the variation of symmetrical and asymmetrical thermal fields, which appear during the exploitation process of rolling cylinders, tensions, that largely depend on the following factors: rolling temperature; rolling speed, respectively the number of rotations and cylinder diameter; length of the cylinders; pause duration during the rolling process, the mass of the laminate compared with the mass of the rolling cylinders.
The study and research of tensions that action in the rolling cylinders is impetuously necessary not only to diminish the fissures caused by thermal fatigue, to increase the exploitation duration, but also

to avoid thermal shocks, which are very dangerous in the exploitation process and produced by large variations, temperature snapshot that lead to shearing of caliber beads in cylinders.

2.THE ANALYCAL AND NUMERICAL CALCULUS

Separating the temperature fields in radial symmetrical and asymmetrical fields allows the separate study not only of temperature fields but also of the produced thermal tensions. The research upon the equivalent and thermal tensions in hot rolling mill cylinders is to be put into practice in three-dimensional coordinates, as presented in figure 1, [1].

σ_{rr} – radial normal tension, appearing in radical direction, perpendicularly on quadrangle abb_1a_1 and cc_1dd_1; σ_{zz} – axial normal tension, appearing in OZ axe, perpendicularly on quadrangle bb_1cc_1 and aa_1dd_1; $\sigma_{\varphi\varphi}$ – circumferential normal tension, appearing perpendicularly on quadrangle abcd and $a_1b_1c_1d_1$; τ_{zr} – tangential tension, appearing in radical direction in quadrangle bb_1cc_1 and aa_1dd_1; τ_{rz} – tangential tension, appearing parallel with OZ axe, in quadrangle $abb_1\ a_1$ and cc_1dd_1;τ_{φ} – tangential tension, appearing in radical direction in quadrangle abcd and $a_1b_1c_1d_1$; $\tau_{r\varphi}$ – tangential tension, appearing in quadrangle abb_1a_1 and cc_1dd_1;$\tau_{\varphi z}$ – tangential tension, appearing parallel with OY axe, in quadrangle abcd and $a_1b_1c_1d_1$; $\tau_{z\varphi}$ – tangntial tension, appearing in quadrangle bb_1cc_1 and aa_1dd_1;

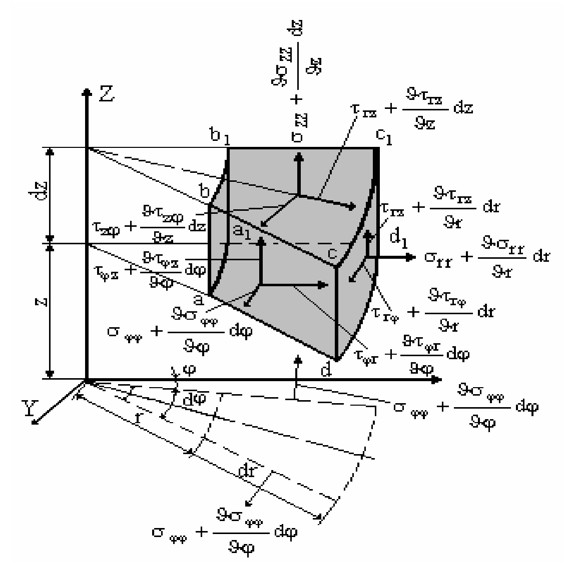

Figure 1. Vectorial representation of the normal and tangential tensions, which appear in an elementary volume of cylinders

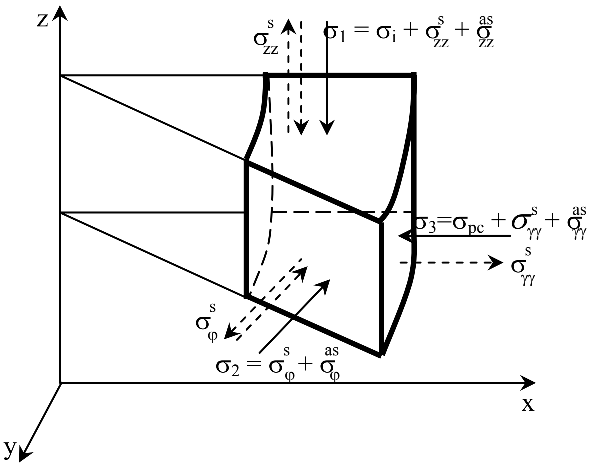

Figure 2. The action scheme of the component tension to determine the resulting main tension

The numeric calculus and evolution of these tensions is to be performed after mathematical equations noting that for tensions produced by radial symmetric temperature fields are noted with “s” and for asymmetrical temperature fields the notation is “as”.

There are established the relationships for the numerical calculus of tensions produced by symmetrical, respectively asymmetrical temperature fields, that are expressed with formula 1,2,3 – for symmetrical temperature fields and 4,5,6,7 – for tensions produced by asymmetrical temperature fields, [2].

$$\sigma^{s}_{rr}(\rho,\tau) = \frac{E\alpha}{1-\upsilon}\left[\int_0^1 \bar{t}(\rho,\tau)\rho d\rho - \frac{1}{\rho^2}\int_0^\rho \bar{t}(\rho,\tau)\rho d\rho\right] \qquad (1)$$

$$\sigma^{s}_{\varphi\varphi}(\rho,\tau) = \frac{E\alpha}{1-\mu}\left[\int_0^1 \bar{t}(\rho,\tau)\rho d\rho + \frac{1}{\rho^2}\int_0^\rho \bar{t}(\rho,\tau)\rho d\rho - \bar{t}(\rho,\tau)\right] \qquad (2)$$

$$\sigma^{as}_{rr} = -\frac{E\alpha}{2(1-\upsilon)}\frac{\rho}{R}\left[\frac{1}{\rho^2} - 1\right]\left[t(1,\varphi) - \bar{t}\right] \qquad (3)$$

$$\sigma_{r\varphi}^{as} = \frac{E\alpha}{2(1-\nu)}\frac{\rho}{R}\left[\frac{1}{\rho^2}-1\right]\frac{\vartheta\left[t(1,\varphi)-\bar{t}\right]}{\vartheta\varphi} \tag{4}$$

$$\sigma_{\varphi\varphi}^{as} = -\frac{E\alpha}{2(1-\nu)}\frac{\rho}{R}\left[3-\frac{1}{\rho^2}\right]\left[t(1,\varphi)-\bar{t}\right] \tag{5}$$

$$\sigma_{zz}^{as} = E\alpha\left\{\frac{\nu}{1-\nu}\frac{\rho}{R}\left(2-\frac{1}{\rho^2}\right)\left[t(1,\varphi)-\bar{t}\right]-t(\rho,\varphi)\right\} \tag{6}$$

It is important to remember that the sign (+) is used for the normal stresses which produced stretching and the sign (-) for the ones which produce compression.
T – temperature variation depending on ρ, having a period equal to 2π, which we are noting with t (ρ,φ); $\bar{t}$ - average temperature in cylindre`s cross section which represents the integral of the function t$(1,\varphi)$ which describes the temperature variation on the cylindre`s surface; G – modulus of elasticity in shear, $G\frac{E}{2(1+\mu)}$; E - modulus of elasticity in longitude; μ - transversal contraction coefficient.
The present work calculates numerically the evolution of tensions produced by symmetrical and asymmetrical temperature fields, both on the surface and in the radial section of the rolls. The work also calculates the tensions produced by mechanical strain, which combined with the thermal ones algebrically will define the resulting main tensions that act upon a material element of the cylinder.
he equivalent tensions are to be calculated applying the deformation energy theory after relation (7). The resultates are presented in table 1.

$$\sigma_{ech} = \sqrt{\sigma_1^2+\sigma_2^2+\sigma_3^2-2\nu\left[\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1\right]} \tag{7}$$

$\sigma_1, \sigma_2, \sigma_3$ - resulting main tensions;

In this relations: $\sigma_1 = \sigma_i + \sigma_{zz}^{s} + \sigma_{zz}^{as}$; $\sigma_2 = \sigma_{\varphi\varphi}^{s} + \sigma_{\varphi\varphi}^{as}$; $\sigma_3 = \sigma_{pc} + \sigma_{rr}^{s} + \sigma_{rr}^{as}$

σ_i - stress of flexion; σ_{pc} - stress of contact pressure.

Table 1.The calcululs of the resulting main tensions $\sigma_1, \sigma_2, \sigma_3$ and equivalent σ_{ech} to the passages 1, 2, 3, 4, 5, 6 for the isocronal diagram with n =35,7 rot/min

No. of passages Caliber R [mm]	**The simbol of the tensions**	***The values of the resulting main tensions $\sigma_1, \sigma_2, \sigma_3$ and equivalent tension σ_{ech} for the isocronal diagram with n =35,7 rot/* [daN/mm²]**					
		The depth in the cylinder section Δr [mm]					
		0	**1,5**	**3**	**6**	**9**	**15**
1,2 3,4 5,6 620	σ_i	- 6,9	- 6,5	- 6,5	- 6,5	- 6,4	– 6,42
	σ_{pc}	7,0	-	-	-	0	0
	σ_{rr}^{s}	0	0,12	0,43	0,80	1,08	1,2
	$\sigma_{\varphi\varphi}^{s}$	-60,0	-61,4	-40,7	-27,3	-27,6	-27,6
	σ_{zz}^{s}	- 31,8	- 32,9	- 12,15	0,53	0,53	0,53
	σ_{rr}^{as}	0	0	0	0	0	0
	$\sigma_{\varphi\varphi}^{as}$	2,0	0,20	0,20	0,20	0,19	0,19
	σ_{zz}^{as}	-130,6	-65,7	-42,4	-21,4	-21,4	-21,4
	σ_1	-169,3	-105,2	-61,5	-27,4	-27,3	-27,3
	σ_2	-60,3	-61,2	-40,5	-27.1	-27,4	-27,4
	σ_3	-7,0	0,12	0,43	0,8	1,08	1,2
	σ_{ech}	159,0	104,8	62,8	32,67	33,0	32,99

The research on thermal tensions evolution is to be extended further on different brands of steels and irons used for the manufacturing of hot rolling mill cylinders, depending on the durability's up to the point of fissures and thermal fatigue cracks. Therefore, it is recommended to use the most rational and economical materials, as well as new, more performing materials to manufacture hot rolling mill cylinders.

3. CONCLUSIONS

The main resultant tensions σ_1 and σ_2 have only negative values and they turn out compresion with values excessively big on surface and in the shallow stratum of drums, until the depth of 6 ÷ 9 mm.

The main tensions σ_3 are negative on surface only in immediate approach of this until bigger depths of Δr = 1,5mm, next inwards become positive and grow them down to the cylinders axes where to small rotation speeds, e.g. when $n \leq 35,7$ rot/ min, and become over negative, while to bigger values, as e.g. $n \geq 43$ rot/min these tensions remain positive but with lower values.

The biggest absolute values of main tensions are one from the axial direction σ_1, they have maximum values to small turnovers of rolling drums, so to the passages 1, 2, 3, 4, 5, 6 effected with n = 35, 7 rot/ min, these tensions have the maximum value σ_1 = - 169,39 daN/mm^2.

The main tensions σ_1 which have the axial direction in cylinder have scared values, which on calibres surface surpass in frequent mode 150 daN/mm^2 and turn out circulars cracks under cracks form in the shallow stratus. These cracks are perpendicular on the main tensions direction σ_1. In the exploitation process, these cracks grow gradually, arriving at some cracks with the opening of over 3…5 mm, cracks what propagate deep until 20…30 mm. As it can observe from the table 1 main weight in the main axial tensions value σ_1, it have the tensions , the skewed fields products temperature, which whereas they are the accountable for circulars cracks production on the hot rolling cylinders calibres and they give the indicative aspect heat weariness.

The main tensions in direction circumferentiala σ_2 they are also negative, but on drums surface represents half from the axial main tensions value σ_1. If it analyses the table 1 observes as main component of tensions σ_2 they are the tensions, the regular fields products temperatures. These main tensions circumferential σ_2, i turn out on rolling drums surface cracks longitudinal, parallels with generators cylinders – journal to beads, forming a „link" to network. These cracks are silkier, it grows gradually and arrive at an opening of 1…2 mm with a depth of 8 …10 mm.

The radial main tensions σ_3 on cylinders surface have relative small values until 8…10 daN/mm^2 and have negative values, but immediate in the surface approach when $\Delta r < 1,5$ mm, become`s positive, but with small values, unimportant in comparison with the tensions $\sigma_{1\ \text{şi}}\ \sigma_2$, which have the decisive weight in the equivalent tensions value.

The equivalent tensions values sech they are influenced preponderent of the tensions $\sigma_{1\ \text{and}}\ \sigma_2$, which have maximum values to small rotation speeds of hot rolling cylinders n = 35, 7 rot/ min, so the maximum registered value (passage 9) is of σ_{ech} = 161,48 daN/mm^2 . It was remarking the fact as the rolling cylinders can put up with the main tensions $\sigma_{1\ \text{şi}}\ \sigma_2$, ever big in the shallow stratum of calibres, only for the fact as these tensions are of compresion, it acts a relative highly short time, of the tail-coatporder of second or to some passages the one much one or two seconds. In this situation, until the cracks appearance with cracks hues circumferential and longitudinal, the stuff puts up with tensions with values of three - four or bigger than the wreck tensions values.

So, can to conclude as the calls from the rolling drums have a cyclical character, they occur to each turnover of drums, while the tension state is in main skewed temperatures fields action result regular, what I turn out heat weariness on surface and in the shallow stratum of rolling drums warmly.

4. REFERENCES

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