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THE INFLUENCE OF THE SYMMETRICAL THERMAL TENSIONS WHEN PRODUCING THERMAL FATIGUE INSIDE THE WARM ROLLING CYLINDERS

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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: warm, test, values, fields

1. INTRODUCTION

The rolling cylinders are due to variable and complete stress caused by the thermic tensions, which are caused by the temperature fields produced by the specific temperature variations specific to a rolling process. Specialized literature [1] has revealed that the division of the temperature fields into symmetrical and asymmetrical radial fields allows us to study the temperature fields, as well as the thermic tensions produced amongst them one at the time.

Our work study determines the symmetrical thermic tensions due to some Mathematical relations, and use the data determined due to laboratory experimental rolling process. Due to the values we have calculated, we are able to analyze the influence of such tensions when producing the temperature fields inside the warm rolling cylinders.

2. THEORY ELEMENTS

The variation of the symmetrical radial temperature fields and of the $\bar{t}$ average temperature variation produce variable tensions inside the rolling cylinders, each stage of the rolling process, and some specific values of the warm rolling process.

In the work – Basis of Thermic-Resilience, by Kovalenko A.D. [3], paragraph 4.6 – thermic tensions inside the cylinder and disk items through plane, symmetrical axial temperature fields -, the author analyzes the thermic tensions inside an empty cylinder, whose radial section represents a cylinder ring and whose outside radius is r_2 and inside radius is r_1. Analogically speaking, this situation has helped us determine the mathematical relations for calculating the symmetrical thermic tensions – they are presented in detail, in [1], [2].

Thermic tensions produced by the radial symmetrical temperature must be numerically calculated for each isochrone temperature diagram, as a result of the process of temperature diagrams registered in case of experimental rolling process.

The variation of the radial symmetrical temperature, as well as the $\bar{t}$ average temperature variations, produce some variable tensions inside the rolling cylinders to each working stage, and their values are specific to the warm rolling cycle.
Thermic tensions caused by the radial symmetrical temperature fields inside the warm rolling cylinders are determined due to the relations (1), (2) and (3).
These relations: $\bar{t}(\rho, \tau)$ - average temperature, and the integral function who describes the temperature fields variation, represented by the exponential curves of the temperature diagrams; ρ - specific radius of the cylinder radial section; $\rho = \frac{r}{R}$; α- line dilatation value; E- longitudinal resilience module; ν - transversal contraction module; $\bar{t}$ - average temperature.
We have used the following constant values for our calculations:
a. The values of the tensions caused by the symmetrical temperature fields have been determined after we had solved out the numerical relations: (1), (2), (3), and we have obtained the values of the integrals in such relations using the Simpson formula, relation (4).
b. For calculation relations (1), (2), (3), the initial temperature for warming up the rolling cylinders is also important, when time is τ = 0, and considering the l'Hospital rule, we have come to the following calculated value (5).
Where: T- average temperature at certain levels of the radial section of the rolling cylinder; $T = \bar{t}$; T_0 – initial temperature for warming up the rolling cylinders.

3. TENSION CALCULATION

For performing the calculations, we have considered that the initial warming up temperature is of 50^o C.

Table No. 1: Values of radial tensions, σ_{rr}^{s}, produced by symmetrical temperature fields

The depth Δr [mm]	The radius in the rsdial section $\rho = \frac{r}{R}$	$\int_0^1 \bar{t}_{(\rho,F_0)}\rho d\rho$	$\frac{1}{\rho^2}\int_0^\rho \bar{t}_{(\rho,F_0)}\rho d\rho$	Symmetrical radial tensions $\sigma_{rr}^{s}[daN/mm^2]$
The symmetrical temperature fields produced in the hot rolling mill cylinders with n = 65,2rot/min				
0	1	25,823582	25,823582	0
1,5	0,9846938		24,68527	0,406377
3,0	0,9693877		24,203865	0,5782389
6,0	0,9387755		23,66766	0,769664
98	0		23,05914	0,986905
$\lim_{\rho\to 0}\frac{1}{\rho^2}\int_0^\rho(\bar{t}-t_0)\rho d\rho = \frac{1}{2}(\bar{t}-50^0C)_{\rho=0}$				
The symmetrical temperature fields produced in the hot rolling mill cylinders with n=150,7rot/min				
0	1	23,397734	23,397734	0
1,5	0,9846938		22,320742	0,384486
3,0	0,9693877		21,31516	0,743478
6,0	0,9387755		21,34882	0,7314622
98	0		17,60275	2,068809
$\lim_{\rho\to 0}\frac{1}{\rho^2}\int_0^\rho(\bar{t}-t_0)\rho d\rho = \frac{1}{2}(\bar{t}-50^0C)_{\rho=0}$				

Inside all calibres of the rolling cylinders, we have determined the thermical tensions produced by the symmetrical temperature fields for Δr in depth, underneath the calibre surface from the radial section of the rolling cylinders.

These depths relate to those levels we have determined them for, and for whom we have measured the temperature variations inside the rolling cylinders. These levels are: $\Delta r = 0$; 1,5; 3; 6; R – the radius of the experimental rolling cylinders [mm]. The action of the symmetrical temperature fields produced only main tensions, such as: σ^s_{rr} - radial tensions; $\sigma^s_{\varphi\varphi}$ - circumferential tensions; σ^s_{zz} - axial tensions; and all the other tensions and the tangential tensions are equal to 0.
Using the relations (1), (4) and (5), we establish the radial tensions σ^s_{rr} , and the results are contained in Table No. 1. According to the relation (2), (4) and (5), we are able to determine the circumferential tensions - $\sigma^s_{\varphi\varphi}$ - and the results are contained in Table No. 2. The relations (3), (4) and (5) determine the axial tensions σ^s_{zz} , and the results are contained in Table No. 3.

Table 2: Values of radial tensions $\sigma^s_{\varphi\varphi}$, produced by symmetrical temperature fields

The depth Δr [mm]	**The radius in the rsdial section** $\rho = \frac{r}{R}$	$\int_0^1 \bar{t}_{(\rho,F_0)}\rho d\rho$	$\frac{1}{\rho^2}\int_0^\rho \bar{t}_{(\rho,F_0)}\rho d\rho$	$\bar{t}_{(\rho,F_0)}$	**Symmetrical radial tensions** $\sigma^s_{\varphi\varphi}[daN/mm^2]$
The symmetrical temperature fields produced in the hot rolling mill cylinders with n=65,2rot/min					
0	1	25,823582	25,823582	254,63496	-90,9046
1,5	0,9846938		24,68527	184,52471	-65,46894
3,0	0,9693877		24,203865	152,67694	-53,92742
6,0	0,9387755		23,66766	117,71828	-41,25576
98	0		23,05914	117,71828	-41,03852
$\lim_{\rho\to 0}\frac{1}{\rho^2}\int_0^\rho(\bar{t}-t_0)\rho d\rho = \frac{1}{2}(\bar{t}-50^0C)_{\rho=0}$					
The symmetrical temperature fields produced in the hot rolling mill cylinders with n=150,7rot/min					
0	1	23,397734	23,397734	246,664	-88,05904
1,5	0,9846938		22,320742	179,63125	-63,74387
3,0	0,9693877		21,31516	118,30046	-41,48978
6,0	0,9387755		21,34882	105,2055	-36,826902
98	0		17,60275	105,2055	-35,48955
$\lim_{\rho\to 0}\frac{1}{\rho^2}\int_0^\rho(\bar{t}-t_0)\rho d\rho = \frac{1}{2}(\bar{t}-50^0C)_{\rho=0}$					

According to the analysis of the calculation contained in table 1, we are able to see the radial tensions - σ^s_{rr} , at the surface of the cylinder are equal to 0, and the superficial layer has sub-unit values. Such tensions have positive values and cause some stretching, in case of all rolling cylinders' turns, and they increase onto the symmetrical axis of the cylinder.
According to the analysis of the results, the calculations contained in table 2, circumferential tensions - $\sigma^s_{\varphi\varphi}$ - are only negative; they produce compression and decrease on the surface of the cylinder onto the symmetry axis. These tensions are associated with axial tensions produced by the asymmetrical temperature fields, helping to producing and developing longitudinal fissures on the surface of the rolling cylinder.
Axial tensions - σ^s_{zz} - reach their highest values on the surface of the cylinders, their values are negative and decrease down to absolute value inside the cylinder.

Table 3: Values of radial tensions, σ_{zz}^{s} produced by symmetrical temperature fields

The depth Δr [mm]	The radius in the rsdial section $\rho = \frac{r}{R}$	$\int_0^1 \bar{t}_{(\rho,F_0)} \rho d\rho$	$\bar{t}_{(\rho,F_0)}$	Symmetrical radial tensions $\sigma_{zz}^{s} [daN/mm^2]$
The symmetrical temperature fields produced in the hot rolling mill cylinders with n = 65,2rot/min				
0	1	25,823582	254,63496	-72,46664
1,5	0,9846938		184,52471	-47,43728
3,0	0,9693877		152,67694	-36,06763
6,0	0,9387755		117,71828	-23,58738
98	0		117,71828	-23,58738
The symmetrical temperature fields produced in the hot rolling mill cylinders with n=150,7rot/min				
0	1	23,397734	246,664	-71,35306
1,5	0,9846938		179,63125	-47,42237
3,0	0,9693877		118,30046	-25,52728
6,0	0,9387755		105,2055	-20,85238
98	0		105,2055	-20,85238

4. CONCLUSIONS

Amongst the three elements of the asymmetrical thermic tensions, the circumferential tensions - $\sigma_{\varphi\varphi}^{s}$ - are the most important when producing the component of the resulting main tensions - σ_2. These main tensions - σ_2 – produce longitudinal fissures on the surface of the rolling cylinder, and which are parallel to the generating axis of the cylinder – at its pane – and make up a „connection" to the net. These fissures are very little in the beginning, then they develop gradually and reach 1…2 mm in length, and 8 …10 mm in depth. These tensions are causing the thermic fatigue of the warm rolling cylinders.

5. REFERENCES

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