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RESEARCH ABOUT THERMIC SHOCKS IN WARM ROLLING CYLINDERS

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

ABSTRACT
Thermic shocks in rolling cylinders are usually produced in the beginning of the rolling process, when some compulsory conditions are subdued, especially when the rolling cylinders are not correctly warmed up and the initial temperature in the production plants during the cold season are low – such conditions are meant for a correct use of the stands.
This paper work refers to some research that has been done about the thermic shock produced inside the warm rolling cylinders due to the instantaneous variation of temperature, caused by repeated warming and cooling off of the rolling cylinders. On one hand, these get warm in case of almost 1100° C, due to their contact with the incandescent half-manufactured product, and on the other hand, they cool off into water.
Keywords: thermic, shock, rolling

1. INTRODUCTION
Thermic shocks in rolling cylinders are usually produced in the beginning of the rolling process, when some compulsory conditions are subdued, especially when the rolling cylinders are not correctly warmed up and the initial temperature in the production plants during the cold season are low – such conditions are meant for a correct use of the stands.
This paper work refers to some research that has been done about the thermic shock produced inside the warm rolling cylinders due to the instantaneous variation of temperature, caused by repeated warming and cooling off of the rolling cylinders. On one hand, these get warm in case of almost 1100° C, due to their contact with the incandescent half-manufactured product, and on the other hand, they cool off into water.
During that process all thermic pressure is determined according to the variation in temperature within the rolling cylinders meant for the study of their thermic usage, as well as the parameters of the thermic shock for all the rolling cylinders made of different type of steel or cast iron; the conditions and factors that influence the producing of the thermic shock are also established during such process.
For the research of the hot rolling cylinders, the Laboratory of Technological Equipment from the framework Faculty of Engineering Hunedoara disposes of an experimental rolling mill with the diameter of ϕ 220 mm, presenting the advantage were a scaled-down copy (1:5) of the industrial rolling mill ϕ 1300 mm. This rolling mill represents a complex equipment which corresponds all the parameters of roughing rolling mills incorporate in the technological process of industrial production.

2. SPECIFIC FEATURES OF A THERMIC SHOCK
Thermic shocks are particular to any thermic pressure/tension produced in case of warm rolling cylinders. Such tensions are in fact compressions and reach excessively high values in the maximum value of the diameters of the calibration cables.

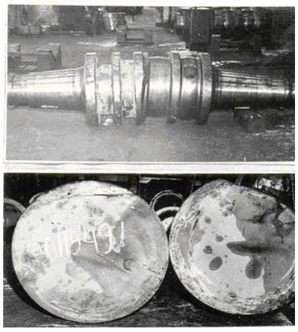

Figure 1. Breaking through shearing of the calibration cable of a rolling cylinder, caused by a thermic shock

These tensions exceed the breaking tension of the materials – steel or cast iron – are used for making up the cylinders. The shearing is produced as following - fig. 1

The thermic shock of a rolling cylinder is possible only if the cylinder is changing its temperature almost instantaneously, according to the source of warmth introduced inside the cylinder through the deformation point and by the blocking out of the transfer of temperature inside the calibration cable towards the outside. We should mention that some circular plane plates (with specific size) could be attached to some segments of the sections of the rolling cylinder near the calibration cables. They are used for measuring the thermic shock

3. DETERMINING THE THERMIC TENSION ACCORDING TO TEMPERATURE

Any variation of temperature on the surface of the rolling cylinders has been determined based on the study of the thermic usage of the cylinders, according to the temperature of the half-finished product meant for rolling, its weight, the weight of the cylinders, and the rolling speed. fig. 2 describes the oscillogram of the variation of temperature fields of a warm rolling cylinders' rotation.

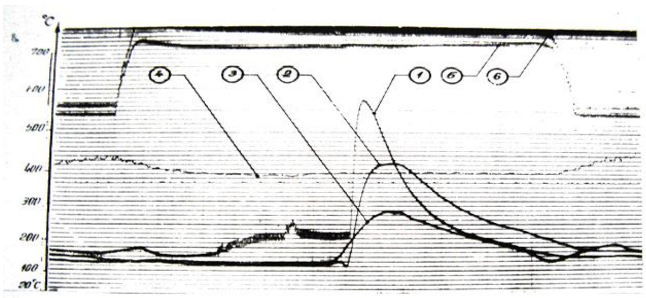

Figure 2. The oscillogram of the variation of temperature fields of a warm rolling cylinders' rotation

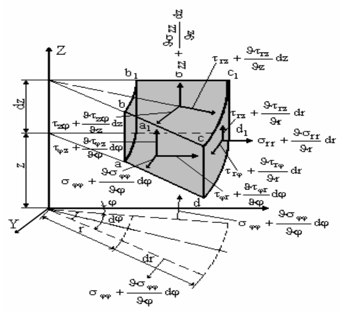

Figure 3. Material element cut from the rolling cylinder that is subdued to thermic tension

Thermal tension from the superficial layer of the rolling cylinders is directly correlated with the temperature variation and has been determined for the symmetrical and asymmetrical temperature fields inside the cylinders, on a type of material represented in fig.3. Thus, in case of symmetrical temperature fields, the thermic tension is determined by the relations (1), (2) and (3).

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

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

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

(3)

These relations contain:

$\bar{t}(\rho,\tau)$ - average temperature, the integral of the function who describes the variation of symmetrical temperature fields represented by the exponential curves of temperature variation, represented in fg. 3;ρ the specific radius in the radial section of the cylinders, $\rho = \frac{r}{R}$;

τ - the time that influences the temperature, which is important for the parameter, and indicates that for each stage of the rolling process (referring to the thermic tension), the average temperature is different.

The values of such tensions that influence the superficial layer of a rolling cylinder are described in Table 1.

Table 1. Values of thermal tensions produced by the temperature fields in the superficial layer of a rolling cylinder

E = 2,1 10[4] daN/mm[2] ; α = 11,9 10^{-6} 1/^{0}K; $E \cdot \alpha / 2(1-\upsilon)$ = 0,357			
The depth in the superficial layer Δr [mm]	Values of thermal tensions produced by the symmetrical temperature fields [N/mm^2]		
	σ_{rr}^{s}	$\sigma_{\varphi\varphi}^{s}$	σ_{zz}^{s}
0	0	- 605,1	- 318,4
1,5	1,29	- 614,4	- 329,0
3,0	4,33	- 407,3	- 125,0
6	8,06	- 273,2	5,4

Thus, in case of asymmetrical temperature fields, the thermic tension is determined by the relations (4), (5) (6) and (7).

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

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

$$\sigma_{\varphi\varphi}^{as} = -\frac{E\alpha}{2(1-\nu)}\frac{\rho}{R}\left[3-\frac{1}{\rho^2}\right]\left[t(1,\varphi)-\bar{t}\right] \quad (6)$$

$$\sigma_{zz}^{as} = E\alpha\left\{\frac{\nu}{1-\nu}\frac{\rho}{R}\left(2-\frac{1}{\rho^2}\right)\left[t(1,\varphi)-\bar{t}\right]-t(\rho,\varphi)\right\} \quad (7)$$

We have: t(ρ,φ) – variation of temperature of the cylinder section, according to the specific radius, ρ = r/R, and the angle of rotation; φ; $\bar{t}$ - the integral of the variation exponential curve of the temperature, according to the function t (1, φ) who describes the temperature on the surface of the cylinder; it represents a straight line we call average temperature; υ - the value of a transversal distortion; E – longitudinal resilience modulus; α - the value of liniar dilation.

Table 2 contains the values of asymmetrical thermical tension who influence only the superficial layer on a certain segment of the circumference of the rolling bore.

Table 2: The values of asymmetrical thermal tension produced by the asymmetrical thermal fields in the superficial layers of a warm rolling cylinder

E = 2,1 10[4] daN/mm[2] ; α = 11,9 10^{-6} 1/^{0}K; $E \cdot \alpha / 2(1-\upsilon)$ = 0,1785 Angle of rolling circumference $\varphi_{\hat{i}} = 1{,}638 rad = 93{,}90^0$ and it has no. of division $\varphi_1 .... \varphi_{12}$					
Tension	No.of divisions φ_i	The depth in the superficial layer Δr [mm]			
		0	1,5	3,0	6,0
		The value of asymmetrical thermal tenssion [N/mm^2]			
σ_{rr}^{as}	φ_{1-12}	0	0	0	0
$\sigma_{\varphi\varphi}^{as}$	φ_{1-12}	0	0	0	0
σ_{zz}^{as}	φ_1	- 423	-349	- 324	- 202
	φ_{12}	- 423	-647	- 372	-232
$\sigma_{r\varphi}^{as}$	φ_1	- 11,5	- 11,4	- 11,4	- 11,3
	φ_{12}	0	0	0	0

Axial asymmetrical thermical tension has excessively high values and it is added with the values of symmetrical thermical tensions. They are caused by compression and transmitted to the region where the cables of the rolling cylinders are situated.

4. ESTABLISHING THE PARAMETERS OF THE THERMIC SHOCK

According to the research made so far, temperature variations are distributed all across the circular plate situated in the area of the bore cable where the rolling is produced. It is represented so that the tangent to the distribution curve should be situated in the middle of the cable and it should be horizontal and parallel to the axis of the cylinder. This is the *first limit condition for the thermic shock* because there is no temperature in the centre of that particular cable and of the symmetry axis of the plate; it follows the maximum radius during different moments in time. The *second limit condition for the thermic shock* requires that the inclination of the distribution curves of the temperature referring to the curve plate delimitated by the thickness of the bore cable should correspond to the value of thermic difusivity – which is equivalent only if it is tangential to the distribution curves.

The values of the parametres of the thermical shock for all rolling cylinders produced by different types of cast iron and steel is presented in Table 3.

Table 3. Values of the thermic tensions produced by the temperature fields in the superficial layer of a rolling cylinder

$E = 2{,}1\ 10^4$ daN/mm^2 ; $\alpha = 11{,}9\ 10^{-6}\ {}^0K$; $\mu = 0{,}3$; $\lambda = (45{,}4 \ldots 58{,}62)\ 10^3$ mm^{0}K			
Types of cast iron and steel	σ_R [N/mm^2]	The parametres of the thermical shock $\frac{\lambda \cdot \sigma_R}{E \cdot \alpha}$	Material criterion for the thermical shock $\frac{\sigma_R}{E \cdot \alpha}$
55 VMoCr12 90VMoCr15 65VMoCr15	Medium 830	$150{,}7\ 10^5$	$3{,}32\ 10^2$
OTA 3	720	$129{,}6\ 10^5$	$2{,}88\ 10^2$
FNS 2	600	$108{,}04\ 10^5$	$2{,}40\ 10^2$
FD 2	700	$126{,}05\ 10^5$	$2{,}80\ 10^2$

5. CONCLUSIONS

The production temperature of a thermic shock is directly proportional with the parameter of the thermic shock and with the material criterion. We should remember that all thermic tensions are caused by compression and they influence it during several cycles – in case of each rotation – who last very little (only few seconds), or in gravel filter stands, for one minute the most. For that reason, the working tensions must be four or five times higher than the breaking tension of a material in order to destroy the rolling cylinders by cutting off the cable next to the bore of the warm rolling cylinder. The best material is the cast iron FNS 2, while the worst is the iron allied with V, Cr and Mo.

The determining factor producing any thermic shock is not time, but the frequency of stress. The thermic shock is unavoidable in case of very high warming speeds.

6. REFERENCES

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