

## STUDIES REGARDING THE COOLING OF THE ROLLED PIECES WITH ATOMIZING WATER

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### ABSTRACT

*The diversity of metallurgical materials and processes imposes a large scale of cooling speeds. The classical cooling mediums restrict the scale of the cooling speeds, reason for which nonconventional alternatives were necessary to be studied. In this respect, the atomizing mater ensures a large scale of cooling speeds which can cover the requirements in the metallurgical processes. In this article it is present the cooling speed of some rolled products in atomizing water in comparison with the classical conditions.*

KEYWORDS: rolled, atomizing water, ultrasounds.

### 1. The water atomizing process with ultrasounds

The acoustic cavitation represents the main effect of the ultrasonic energy in liquids, which is the basis of the liquids atomization. The atomization process can be explained by means of the ultrasonic dispersion phenomenon, namely when the activated system is under the form of liquid-gas, then at the separation between the two mediums, a thick and thin fog is created. It is know that the capillary waves can be excited on the free surface of a low viscosity liquid by means of an ultrasonic transmitter placed exactly under the surface of the liquid.

If the amplitude of the oscillation beyond a certain limit value, the waves become instable and project thin particles of liquid to the gas, under the form of fog. According to R. Pohlmann and K. Stamm laws, in the case of a liquid with free surface in a gas or vacuum, the following relations that define the phenomenon can be taken into consideration:

$$\lambda = \frac{2\eta}{\rho} \left( \frac{\rho}{\pi\sigma f} \right)^{1/3} \quad (1)$$

$$d_m = \frac{1}{2} \left( \frac{\sigma\pi}{\rho f^2} \right)^{1/3} \quad (2)$$

Where:  $\lambda, f$  are the wave length and the ultrasonic wave frequency [m], [Hz];  $\rho$  - liquid density [ $\text{kg/m}^3$ ];  $\sigma$  - surface stress [N/m];  $\eta$  - liquid viscosity [ $\text{Ns/m}^2$ ].

From here it results that the particles' size and fog density can be prestablished according to necessities.

The ultrasonic dispersion of the liquids in gases is produced when the intensity of the ultrasonic radiation gets sufficiently high values in order to the phenomena that generate the dispersion process.

### 2. The cooling process of some rolled products with atomizing water

Among the methods of liquids dispersion, it is worth mentioning the pneumatic pulverization by means of with a high speed liquid-gas can be obtained. In the pneumatic pulverization devices, the jet or liquid film is introduced in the gas flow and on the gas-liquid separation surface, instability waves appear which bring about the liquid jet dispersion (or the flow) in drops.

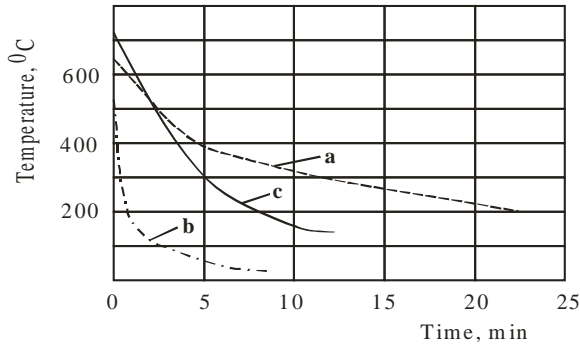
The gas, having the form of jet, can be brought under an angle at the liquid flow, fact that determines additional deformations of the separation surface.

The liquid flow dispersion represents a complex physical process which depends on many exterior and interior causes. Generally, the process is determined by aerodynamic forces which the superficial tension forces hinder the dispersion process.

The medium created, obtained through pneumatic pulverization of water (a combination gas-liquid) was named atomizing water and has applications in the laminated products cooling process.

From the speciality references [1,2] it results that the efficiency of rolled products cooling process in gas-liquid flow is obtained at a higher impact speed of the biphasic jet with the heated metal of 10 mm/s at water/air mass rate, in limits from 1/2 to 1/10.

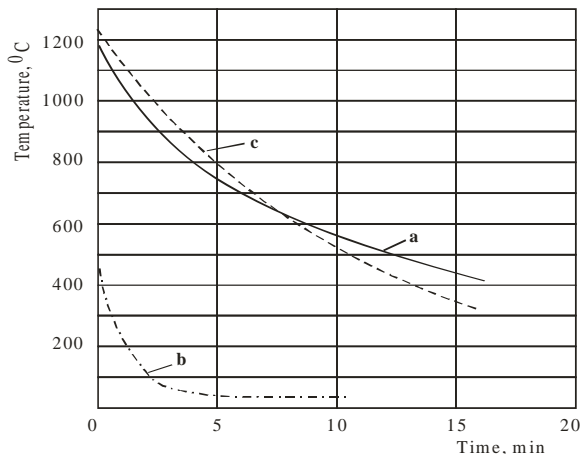
Precise data are to be presented in this material concerning the behaviour during the cooling in atomizing water process, in comparison with classical mediums for three rolled products: plate, pipe and billet.



**Fig.1.** The curves of the rolled tables cooling process: a. cooling with aerosols ( $v = 15$  m/s); b. cooling with aerosols ( $v = 70$  m/s); c. diving in water.

In figure 1 data regarding the cooling speeds of the rolled table surface for different cooling methods.

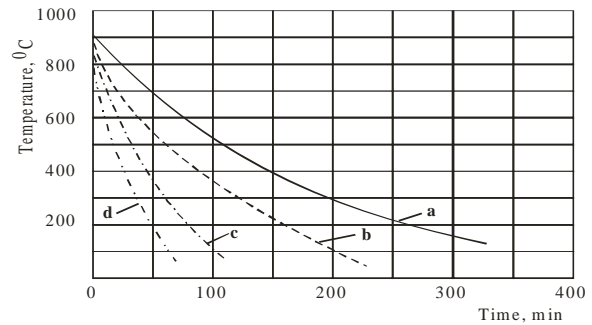
The a and b curves characterises the intensity of the cooling process during the atomizing water blasting operation of the table surface in air current at speeds of 15 and 70 m/s. to make a comparison we are presenting the cooling speed of the tables during water diving process [1].



**Fig.2.** The pipes cooling curves: a. cooling with aerosols ( $v = 15$  m/s); b. cooling with aerosols ( $v = 70$  m/s); c. diving in water.

In figure 2 the cooling speeds of pipes surface with a diameter of 80 m are presented, during their blasting with water aerosols having speeds of 15 m/s

(curve "a") and 70 m/s (curve "b") [1]. Curve "c" represents the cooling speed of the pipes during water diving.



**Fig.3.** The curves of semi finished  $\Phi 127$  mm cooling process: a. air cooling; b. cooling by pass through a cooling chamber; c. cooling by air blasting; d. cooling by aerosols blasting.

In figure 3 the cooling speeds curves of the square semi finished products with section 127x127 mm [2] are presented, where "a" curve characterizes the cooling in still air, "b" curve the billets cooling transported with rotation through a cooling chamber, "c" curve the cooling through jet air blasting and semi finished rotation and curve "d" the cooling of the semi finished product with aerosols (air-water) and with the rotation of the semi finished products.

The graphics analysis from figures 1, 2, 3 shows that for different rolled product types, the cooling process with aerosol jet (water-air) reduces considerably the cooling time of the rolled product in comparison with the cooling process in conventional mediums (water-air).

The cooling water-air jets of great speed must have a great level of dispersion, this ensuring at small liquid volumes a maximum possible cooling speed.

The main factors that influence the cooling speed of the rolled products with an aerosol jet are the following:

- the mass ratio of liquid-gas volumes;
- the distribution in the transversal section of jet.
- the finesses degree (dimension) of the liquid particles in aerosol jet;
- the speed and impact angle of the aerosols jet with the cooling surface of the dispersed jet.

### 3. Theoretical aspects of the cooling speed

The cooling time is one of the main variables which characterize the cooling process [5].

For the cooling time calculus and that of the cooling curves at some pieces surfaces one can use the heat exchange equation:

$$t_r = \frac{m \cdot C_p}{\alpha \cdot A} \cdot \ln \frac{T_0 - T_m}{T_r - T_m} \quad (3)$$

Where:  $T_0$  is the initial temperature is equivalent with the final temperature of the heating process [K];  $T_m$  – the temperature of the cooling mediums [K];  $T_r$  – the temperature up to when the cooling process is done during  $t_r$ ;  $m$  – the piece mass [kg];  $\alpha$  – the total superficial exchange coefficient of heating [ $W/m^2K$ ];  $A$  – the contact surface between the cooling medium and piece [ $m^2$ ];  $C_p$  – the medium specific heat of the metallic material from which the piece is made [ $J/kgK$ ].

For the gas quenching of a piece from the initial temperature  $T_1$  to the final temperature of the charge  $T_2$ , the relation becomes:

$$t_r = \frac{m \cdot c_p}{\alpha \cdot A_s} \cdot \ln \frac{T_1 - T_f}{T_2 - T_f} \quad (4)$$

Where:  $T_f$  – the temperature of the recirculates gas;  $\alpha$  – the total coefficient of heat exchange:

$$\alpha = \frac{1}{\frac{1}{h} + \frac{D}{2k_p}} \quad [W/m^2K] \quad (5)$$

$A_s$  – area of charge surface [ $m^2$ ];  $m$  – the charge mass [kg];  $c_p$  – the specific heat of the charge [ $J/kgK$ ];  $h$  – the heat exchange coefficient of the gaseous phase [ $W/m^2K$ ];  $D$  – the specific dimension of the piece;  $k_p$  – the thermal conductivity of the piece [ $W/mK$ ].

Analysing the equations [4] and [5] we draw the conclusion that for a maximum cooling process we can act on the "U" variable and implicitly on "h" one.

For a turbulent flow parallel to the surface:

$$\frac{h \cdot D}{K} = 0.23 [Re]_{\text{gas}}^{0.8} \cdot [Pr]_{\text{gas}}^{0.3} \quad (6)$$

and for a turbulent flow perpendicular to the surface:

$$\frac{h \cdot D}{K} = 0.3 + \frac{0.62 [Re]^{0.5} \div [Pr]^{0.333}}{\left[1 + \left(\frac{0.4}{Pr}\right)^{0.667}\right]^{0.75}} \cdot \left[1 + \left(\frac{Re}{282}\right)^{0.625}\right]^{0.8} \quad (7)$$

Where:  $Re = \frac{Dv \cdot \rho}{\eta}$ ;  $Pr = \frac{c_p \cdot \eta}{k}$ ;  $h$  – the heat

exchange coefficient of the gaseous phase at the ambient temperature [ $W/m^2K$ ];  $k$  – the thermal conductivity of the gas at the ambient temperature [ $W/mK$ ];  $v$  – the gas speed at the surface [ $m/s$ ];  $\rho$  – the gas density at the ambient surface temperature [ $kg/m^3$ ];  $\eta$  – the gas viscosity at the ambient temperature [ $Ns/m^2$ ].

For the particular case of the nitrogen, at speeds of 60 cm/s over a roll with a diameter of 10 mm,  $h = 112 W/m^2K$ , in parallel current, and in perpendicular current,  $h = 350 W/m^2K$ .

The gas pressure is associated with the gas speed. Their combination shows the mass flow capacity, and its growth produces the increase of the heat exchange speed.

The combination among the physical features of the two phases: liquid, gas shows the value of the heat exchange coefficient at a certain temperature.

## 4. Conclusion

Obtaining some cooling mediums with controlled speeds but different from the conventional ones is a necessity for the metallurgical industry. The biphasic air-water medium obtained through atomizing water with ultrasonic generators can solve a large range of cooling speeds with certain applications in metallurgy.

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