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THERMAL LOAD IMPACT ON STEAM PARAMETERS FOR COOLING THE SHAFT FURNACE

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Abstract: *In the current cooling system of Trepça Shaft Furnace, water for cooling is with temperature of low level with limited capability to utilize heat. Scheme proposed by cooling system with evaporation, provides the favorable opportunities to utilize heat. In this paper is analyzed the impact of thermal loads, thermal physical parameters of steam-water mixture, then the geometric and hydromechanics parameters of outline circulation communication in circulation consumption (G_0), in circulation speed (ω_0) and mass content of steam consumption (x_D) during the cooling process of shaft furnace by evaporation.*

Key words: *Furnace, cooling, heat, speed, consumption.*

1. INTRODUCTION

The cooling system by evaporation based on the level of the temperature and the amount of heat released out of process. The proposed outline for the furnace cooling as shown in Fig. 1, consist of part of manifolds (TL1, TL2), from the part pipelines composite of the lower cooling (FP), medium (FM) and on top (FS), from exonerative pipes (TSH1, TSH2) and steam cylinder-separator (CS). In outline are including connection pipes (TLDH1, TLDH2) and collectors (KO1, KO2). Manifolds, connection and exonerative of outline are the diameter, length, height and certain number (d_{L1}, d_{L2}, d_1, d_2, d_{SH1}, d_{SH2}, L_{L1}, L_{L2}, L_1, L_2, L_{SH1}, L_{SH2}, H_{L1}, H_{L2}, H_N, H_{FP}, H_{FM}, H_{FS}, H_{SH1}, H_{SH2}, H_{KTH}, n_{L1}, n_{L2}, n_1, n_2, n_{SH1}, n_{SH2}) as well as the corresponding coefficient of hydraulic resistance (ξ_{HL1}, ξ_1, ξ_2, ξ_{DL1}, λ_{L1}, ξ_{HL2}, ξ_3, ξ_4, ξ_{V1}, ξ_{DL2}, λ_{L2}, ξ_{HL2}, ξ_3, ξ_4, ξ_{V1}, ξ_{DL2}, λ_{L2}, ξ_{HP}, ξ_{DP}, λ_N, ξ_{H1}, ξ_4, ξ_5, ξ_{D1}, λ_1, ξ_{HM}, ξ_{DM}, ξ_{HL2}, ξ_6, ξ_7, ξ_{D2}, λ_N, λ_2, ξ_{HS}, ξ_{DS}, λ_N, ξ_{HSH1}, ξ_8, ξ_{V2}, ξ_{DSH1}, λ_{SH}, ξ_{HSH21}, ξ_9, ξ_{DSH2}, λ_{SH2}).The impact of thermal loads, thermal-physical parameters (p, T_N, $\rho´$, $\rho´´$, ρ, $h´$, $h´´$, h, c_p, ν, β, μ, a, σ, λ, P_r, $\Delta h´/\Delta p$) of steam-water mixture, then geometric parameters and hydro mechanical of communications of outlines circular in consumptions circular (G_0), in speed (ω_0) and the circulation mass content of steam consumption (x_D) is in interest to assess the cooling system by evaporation in Trepça shaft furnace.

2. THERMAL LOAD IMPACT, ON DYPHASIC BRINGING OF OUTLINE

For practical calculations of heat transmission between gas and cooling medium in the furnace coolant (FP, FM, FS), should be designate the amount of heat per unit surface area according to the formula (Michael & Howard, 2004) as the following:

$$q_P = \frac{t_{GP} - t_{AU}}{1/\alpha_{GP} + \delta_{GAP}/\lambda_{GAP} + \delta_{MP}/\lambda_{MP} + \delta_{KP}/\lambda_{KP} + 1/\alpha_{AUP}} \quad (1)$$

Where α_G, α_{AU} - are coefficients of gas heat transmission (Gordon, 1993) and steam- water composite (Sacadura, 1993) Who are determined by the following equation:

$$\alpha_G = e^{0,31T_G^{0,39}} \quad (2)$$

$$\alpha_{AU} = 1.25 c_p^{1/2}\, h^{-1/6}\, T_N^{-1/2} \left(p \rho´ a/\sigma\right)^{1/3} q_p^{2/3} \quad (3)$$

Whereas t_G, t_{AU} – is gases temperature in the lower coolant level, and temperature of steam –water composite, °C ;$_{GA}$,δ_M, δ_K then λ_{GA}, λ_M λ_M – thickness and heat conductivity coefficients for protective layer, coolant wall and calcium carbonates layer in level of FP, FM and FS. Amount of heat transmitted to the unit surfaces area of FP, FM and FS is determined according to equation:

$$Q_F = Q_{FP} + Q_{FM} + Q_{FS} = q_P A_P + q_M A_M + q_S A_S \quad (4)$$

Where are: A_P, A_M, A_S - overall coolant surfaces of the lower, medium and of the top level, m^2.

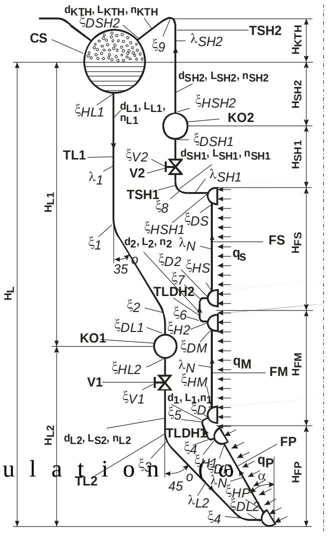

Fig.1. Outline circular scheme

To determine the height from which come of the movement effort, it is necessary to determinate the scission this begins the regime of steam (Kutepov, M. 1983). This scission determined by the length of the economizer part l_{EK} as follows:

$$h_{Z'} - h_{LSH} = \frac{q_{EK}\, \pi\, d\, l_{EK}}{\rho'\, \omega_0 \left(\pi\, d^2/4\right)} = \frac{4 q_{EK}\, l_{EK}}{\rho'\, \omega_0\, d} \quad (5)$$

Where are: h_{LSH} –water enthalpy incoming the manifolds, kJ/kg; q_p –heat density flux in the economizer scission, kW/m^2; d –Internal diameter of tube, m. Speed of circulation can be determined by the gradual approximation method (equation 8). The first designated the total coefficient of hydraulic resistance to water line under the equation:

$$z_{RLU} = z_{L1}\left(\omega_{0L1}/\omega_0\right)^2 + Z_{L2}\left(\omega_{0L2}/\omega_0\right)^2 + Z_{EK} \quad (6)$$

Where are: Z_{L1}, Z_{L2}, Z_{EK} – overall coefficient of hydraulic resistance in not heated manifolds with diameter dL1 and d_{L2} likewise in economizer part. The complex $\Sigma\Delta p_{ML}$ is determined by expression:

$$\Sigma\Delta p_{ML} = \Delta p_{PTF} + \Delta p_{TSH} + \Delta p_{LL} \quad (7)$$

Where are: Δp_{PTF}, Δp_{TSH}, Δp_{LL} – total loss of pressure in the herd of half-pipes in the ranks of furnace coolants in manifold and in the part of manifold (in up lift of composite above than free surfaces of liquid in cylinder).

$$\omega_0 = \sqrt{\frac{2g[\varphi_P H_{AP} + \varphi_M H_{AM} + \varphi_S H_{AS} + \varphi_{SH2}(h_{SH1} + h_{SH2})]}{z_{RLU} + \left(\Sigma\Delta p_{ML}/\left(\rho'\omega_0^2/2\right)\right)}\left(1 - \frac{\rho''}{\rho'}\right)} \quad (8)$$

Mass content of steam consumption at the exit of tubes herd of the furnaces coolants determined by the following equation:

$$x_D = G''/G' = \rho''\omega_{0SH2}/\rho'\omega_0 \quad (9)$$

3. CALCULATIONS AND RESULTS

Incoming data (Agolli, 1985) for calculation are: t_{GP}= 1200°C; t_{GM}=800°C; t_{GS}=400°C; t_{AU}=151.84°C; $\delta_{GAP} = \delta_{GAM} = \delta_{GAP}$ = 0.050m; $\delta_{MP} = \delta_{MM} = \delta_{MS}$ = 0.012m; $\delta_{KP} = \delta_{KM} = \delta_{KS}$ = 0.001m; $\lambda_{GAP} = \lambda_{GAM} = \lambda_{GAS}$ = 1 W/mK; $\lambda_{MP} = \lambda_{MM} = \lambda_{MS}$ = 45 W/mK; λ_{KP} = $\lambda_{KM} = \lambda_{KS}$=0.6W/mK; S_1=0.080m; H_{FP}=1.275m; H_{FM}=2.100m; H_{FS}=2.900m; n_{TP}=190; n_{TM}=194; n_{TS}=194; c_{PP}= 4417J/kgK; h=2109000J/kgK; T_N=151.84°C; p = 500000; ρ' = 915.164 kg/m³; a=17.27710⁻⁸ m²/s; σ = 4·10⁻⁴ N/m; S_p=0.080m; S_2= 0.030m; d_{L1}=0.080m; d_{L2}=0.050m; d_1=0.080m; d_2=0.080m; d_{SH1}=0.125m; d_{SH2}= 0.250m; d_{KTH}=0.200m; L_{L1}= 6.680m; L_{L2}=4.400m; L_1=0.300m; L_2=0.300m; L_{SH1}=2.400m; L_{SH2}= 4.840m; H_{L1}=5.400m; H_{L2}=3.800m; H_N=8,715m; H_{FP}=1.275m; H_{FM}=2.100m; H_{FS}=2.900 m; H_{SH1}=1.300m; H_{SH2}=2.140m; H_{KTH}=0.500m; n_{TP}=190; n_{TM}=194; n_{TS}=194; n_{L1}=8; n_{L2}=28; n_1=56; n_2=56; n_{SH1}=28; n_{SH2} = 8; ξ_{HL1} = 0.50; ξ_1 = 0.05; ξ_2=0.05; ξ_{DL1} = 1.10; ξ_{HL2} = 1.10; ξ_3 = 0.10; ξ_4 = 1.20; ξ_{V1} = 0.38; ξ_{DL2}=1.10; ξ_{HP} = 1.00; ξ_{DP} = 1.10; ξ_{H1} = 1.00; ξ_{H2} = 1.00; ξ_5 = 1.20; ξ_{D1}=1.10; ξ_{HM} = 1.10; ξ_{DM} = 1.10; ξ_6 = 1.20; ξ_7 = 1.20; ξ_{BS} = 1.10; ξ_{HS}=1.00; ξ_{DS} = 1.10; ξ_{HSH1} = 1.00; ξ_8 = 1.20; ξ_{V2} = 0,38; ξ_{DSH1}=1.10; ξ_{HSH2} = 1.00; ξ_9 = 1.10; ξ_{DSH2} = 1.20; ξ_{KP} = 0; $\Sigma\xi_{KM} = \Sigma\xi_{KS}$ = 0; λ_{L1} = 0.18; λ_{L2} = 0.35; λ_N = 0.56; λ_1 = 0.35; λ_2 = 0.35; λ_{SH1}=0.14; λ_{SH2} = 0.06; ρ' = 915.164kg/m³; ρ'' = 2.668kg/m³; h= 2109000J/kg; $\partial h'/\partial p$ = 0.007kJm²/(kgN); g=9.81kg/s²; Δh_C = 0J/kg; L_{EK} = 0.8m. Calculations are done according to the respective program.

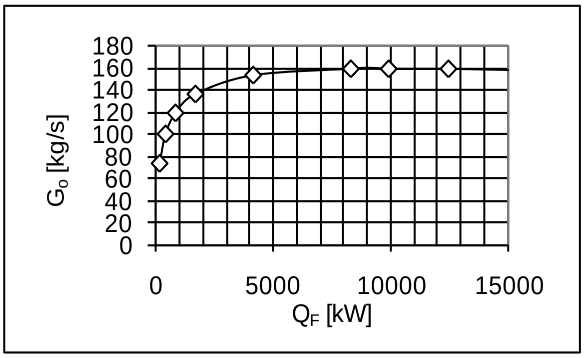

Fig.2. $G_o = f(Q_F)$

Variables of the model, in this paper are calculated for several levels of incoming values of thermal loads, meanwhile the presented results above are obtained for average values of thermal loads: q_P=17653 W/m², q_M=9655 W/m2 and q_S= 2669 W/m².For example, in fig. 2, fig. 3. and fig. 4. is shown dependence $G_o = f(Q_F)$, $\omega_0 = f(Q_F)$ and $x_D = f(Q_F)$, for a wider range of change of quantity of heat (1/5, 1/2, 1, 2, 5, 10, 12, 15 and 20 x Q_F)

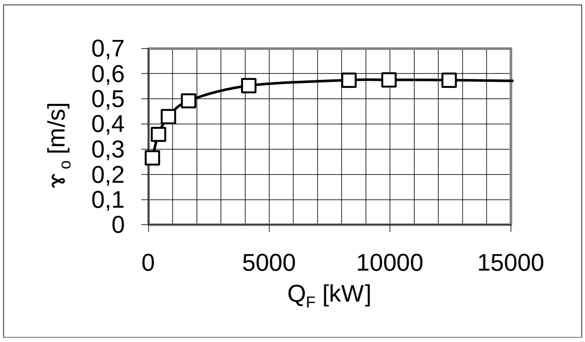

Fig.3. $\omega_0 = f(Q_F)$

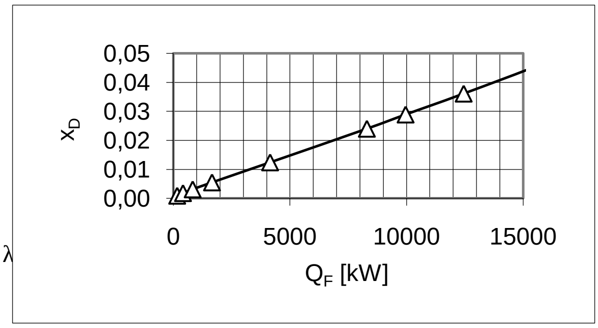

Fig.4. $x_D = f(Q_F)$

4. CONCLUSION

Dependence $G_o = f(Q_F)$ and $\omega_0 = f(Q_F)$ is characterized with circulation consumption and speed low circulation for small thermal loads.

By increasing of thermal loads we have consumption increase (G_o) and circulation speed (ω_0) up to a certain level. In addition, with further increase of thermal loads appears reduce of consumption (G_o) and speed (ω_0) because the other factors who act in the opposite direction affect on this.

By increasing the thermal load increases the content of steam (x_D) in the outline, and moving effort where at once increases the circulation consumption (G_o) and on the other hand, increases hydraulic resistance in upper parts outline, that have steam content.

For the average parameters of the work regime in the furnace, is generated a considerable amount of steam in the furnaces coolant (FP, FM, FS) as: D_{AP}' = 0.168 kg/s, D_{AM}' = 0.150 kg/s, D_{AS}' = 0.057 kg/s and D_{AF}' = 0.375 kg/s.

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