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The effect of dependence between vapor heat capacity, specific heat of evaporation-condensation of irrigating liquid and temperature on thermodynamic parameters of processes gases

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Abstract. The results of parameters calculations of the vapor-gas flow and droplets of irrigating liquid in application to the conditions of flue gas cooling in the reactors of the soda ash workshop at "Azot" limited company, Kemerovo, are compared.

Some engineering processes require gas cooling to a certain temperature through water irrigation. It is impossible to calculate such a process without mathematical models on contact heat and mass transfer between gas and liquid droplets sprayed by the nozzles. Such a model was developed and verified at the Department of cooling and ventilation of TSUAB. This was made for the moderate air temperatures, when heat capacities of steam c_1, air c_2 and heat of water evaporation r are assumed constant. In calculations they were assumed c_1 =1.8 kJ/kg K, c_2 =1.005 kJ/kg K and r = 2500 kJ/kg. However, at high temperatures the above parameters depends significantly on temperature, and this should be taken into account in equations of the model. Therefore, $c_1(T)$, $c_2(T)$, $r(T)$ are introduced into model [1] as approximations of tabular empirical data of [2], obtained by us:

$$\begin{aligned} c_1(T) &= \frac{T}{155}\left[1 + \mathrm{e}^{0.045(T-590)}\right], \mathrm{kJ/kg\cdot K}, \\ c_2(T) &= 1.8024 \cdot 10^{-4} T + 0.9511, \mathrm{kJ/kg\cdot K}, \\ r(T) &= \left[2548 - T^{0.5627}\mathrm{e}^{0.006119T}\right], \mathrm{kJ/kg\cdot K}. \end{aligned} \quad (1)$$

In the current work we compare calculations of the parameters of the vapor-gas flow and droplets of irrigating liquid in application to the conditions of flue gas cooling in the reactors of the soda ash workshop at "Azot" limited company, Kemerovo (Figs. 1, 2 and 3).

According to the figures, at high temperatures of the vapor-gas flow the differences between calculated thermodynamic parameters at constant heat capacities and specific heat of evaporation-condensation (curves *1*) and their values, changing depending on temperature (curves *2*) vary significantly, whereas at the temperatures of about 400 °C and low irrigation coefficients this difference is not so significant (Fig. 2).

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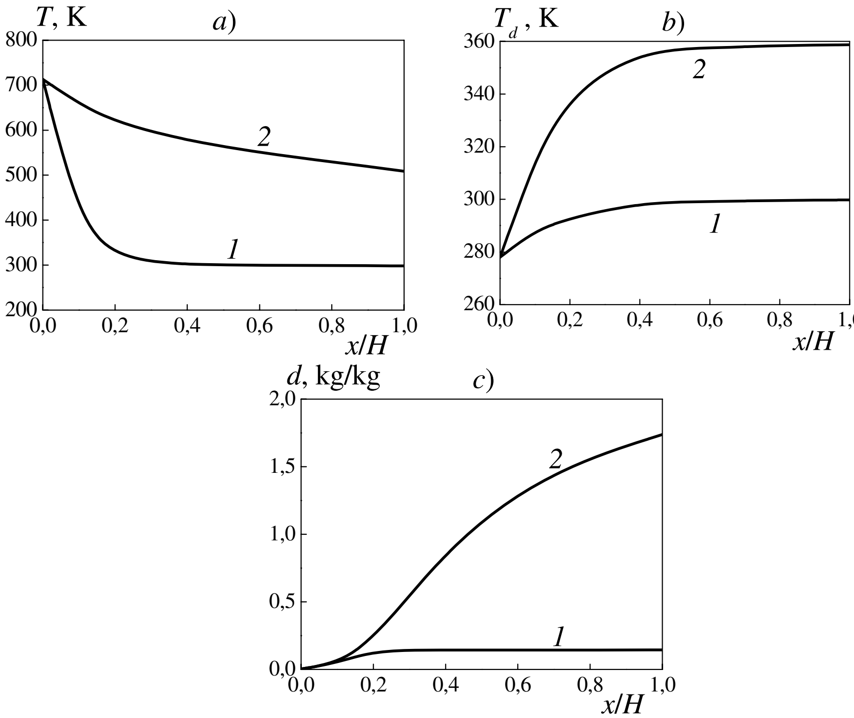

Figure 1. Calculation of flue gas temperature – a), temperature of droplets – b), moisture content – c) in reactor: $H = 10.9\,\text{m}$, $q = 0.0024\,\text{m}^3/\text{m}^3$, $\delta_{d_0} = 700\,\mu\text{m}$, $V_{d_0} = 30$ m/s, $T_{d0} = 278$ K (+5 °C), $d_0 = 3,79 \cdot 10^{-3}$ kg/kg dry gases, $T_{00} = 713$ K (+440 °C), $U_0 = 3.79$ m/s; *1* – c_1, c_2, r – constants, *2* – $c_1(T)$, $c_2(T)$, $r(T)$ – by approximations (1).

Results of comparative calculations of flue gas temperature are shown in Fig. 3 at: $c_1 =$ 1.8 kJ/kg K, c_2 =1.005 kJ/kg K and r =2500 kJ/kg (curves *1*); c_1 =3.6 kJ/kg K, $c_2 =$ 1.05 kJ/kg K and $r = 1820$ kJ/kg, corresponding to the average temperature of calculated range $T = 570$ K (curves *2*); $c_1(T)$, $c_2(T)$, $r(T)$ according to approximations (1) (curve *3*). It can be seen that curves *1* and *2* coincide. This is a sequence of the fact that parameters $c_1(T)$ and $r(T)$ effect heat transfer in opposite directions, and within the region of temperature calculation they compensate the thermal effect; whereas, when they change, depending on temperature, the difference between flue gas temperatures is significant.

The following conclusions can be made on the basis of analysis presented:

1. At high temperatures of processed gases and considerable irrigation coefficients dependence of vapor heat capacity and condensation-evaporation heat on temperature should be taken into account by the model. At that, it was determined that dependence of air heat capacity on temperature does not affect the thermodynamic parameters of the flow in a wide temperature range.
2. At moderate irrigation coefficients, below 0.25 l/m^3, it is possible to calculate the thermodynamic parameters of devices at the temperatures up to 400 °C, at c_1 =1.8 kJ/kg and r =2500 kJ/kg for the air-water droplet system. For other systems it is reasonable to take into account dependence of these parameters on temperature.

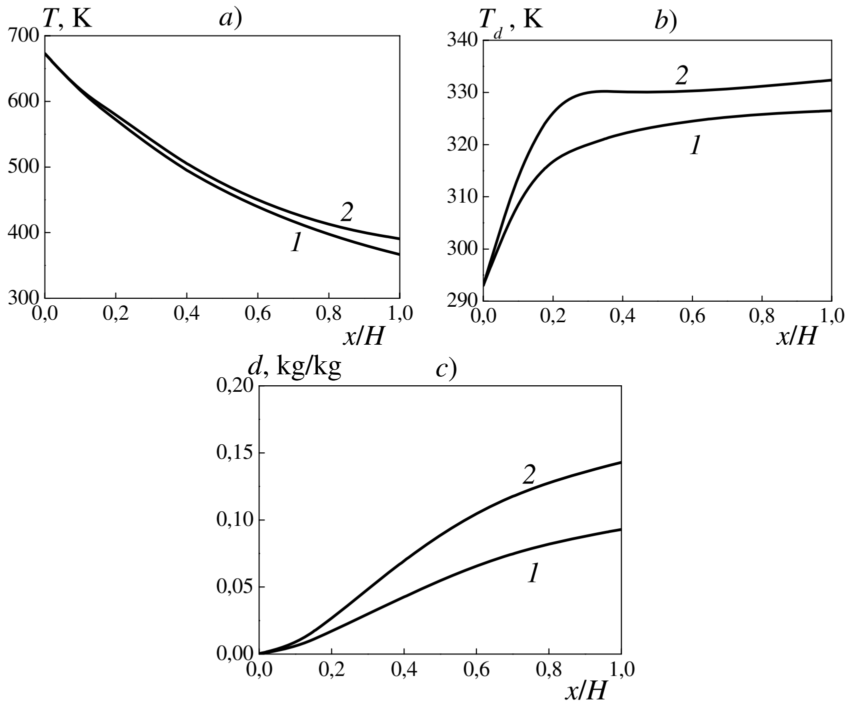

Figure 2. Calculation of flue gas temperature – a), temperature of irrigation liquid droplets – b) and moisture content – c) in reactor at $T_{00} = 673$ K (+400 °C), $T_{d0} = 293$ K (+20 °C), $q = 0.24\,\mathrm{m^3/m^3}$, other parameters and symbols are the same as in Fig. 1.

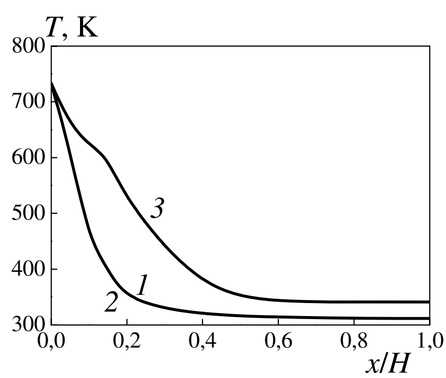

Figure 3. Calculation of flue gas temperature in reactor at $T_{00} = 733$ K (+460 °C), $T_{d0} = 293$ K (+20 °C), $q = 2.4 \cdot 10^{-3}\,\mathrm{m^3/m^3}$, other parameters and symbols are the same as in Fig. 1. Nomenclature is in the text.

References

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