ANALYSIS OF THE INFLUENCE OF EXTERNAL FACTORS TO HEATER THERMODYNAMIC PARAMETERS

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Abstract. Nowadays the building of buildings is renewing in cities and in rural area. Every building needs a heating system to provide the necessary level of comfort conditions inside premises. The essential part of the heating system is the heater. The analysis of the heater operation is developed. There are the main correlations between the operational and thermodynamic parameters found out. The heat output of the heater depends on heat carrier flow rate, incoming and outgoing heat carrier temperatures and air temperature of premises. The correlations between these parameters are investigated and worked out. These correlations are usable to develop the computer model of heat system operation

Key words: heating, heater, heat flow, parameter.

Introduction

In the heating systems, where water is used as the heat carrier, the heat is delivered to premises by the heater. To develope heating systems and control of them as well as computer models of them, it is necessary to make the analyses of heater parameters and correlation between them and different external conditions, that is changing during operation. Also it is necessary to analyse the correlations between operational and thermodynamic parameters of them.

Analyses of heater operational and thermodynamic parameters

Nowadays steel plate heater is used very frequently in heating systems with water as the heat carrier. The delivered heat power from the heater is described by the following formula:

$$P_f = M_f \cdot c_{H2O} \cdot (T_k - T_a), \qquad (1)$$

where P_f – actual heat power delivered by the heater, W;
M_f – actual flow rate of the heat carrier through heater, kg·s⁻¹;
c_{H2O} – specific heat capacity, J·kg⁻¹·K⁻¹;
T_k – supplied carrier temperature, ᵒC;
T_a – return heat carrier temperature, ᵒC.

Return heat carrier temperature T_a depends on power delivered from heater. The actual heat power delivered by the heater changes in dependence on the temperature coefficient that is proportional to average temperature difference ΔT. It is possible to express this correlation by the formula:

$$P_f = \frac{P_n}{k}, \qquad (2)$$

where P_n – nominal heat power of the heater, W;
k – temperature coefficient (k = f(ΔT));

and
$$\Delta T = \frac{T_k - T_a}{\ln \dfrac{T_k - T_a}{T_a - T_g}}, \qquad (3)$$

where T_g –average temperature of indoor air in premises, ᵒC.

The curve presenting correlation between average temperature difference ΔT and the temperature coefficient k (Fig. 1) is obtained making use of the tables for corrections of the heater power given by the manufacturers [1]. Making approximation of this curve, the correlation between the average temperature difference ΔT and the temperature coefficient is obtained. The nominal power of the heater is given by manufacturers for the temperature regime 75/65/20, it means T_k = 75 ᵒC, T_a = 65 ᵒC for average T_g = 20 ᵒC. One way of the heat output control is changing of the heat carrier flow rate with constant temperature of the supplied carrier. As the result, the amount of the delivered heat by the

heater changes because T_a and ΔT changes. It is possible to calculate T_a using the formula (1) with given T_k and flow rate. The certain T_k, was accepted and using the formula (4) there was calculated the delivered power P_f if $T_g = 20$ °C for different T_a. Next, using the formula (1), the necessary actual flow rate M_f was calculated to provide the delivered heat corresponding to T_k, T_g and T_a.
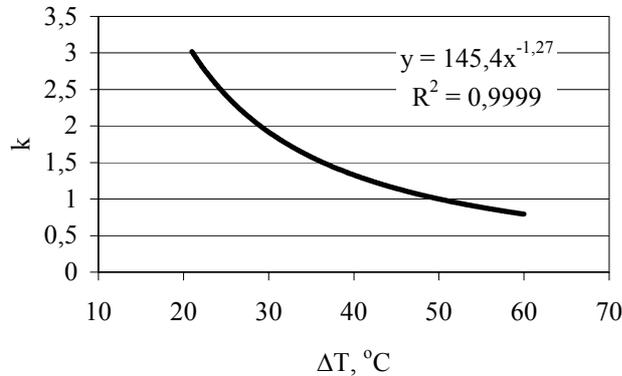

Fig. 1. **The temperature coefficient as a function of the temperature difference**

The example of calculation results for the steel heater with nominal heat power $P_n = 1000$ W is given in Table 1. For calculations the computer program *Exel* was used. There were built curves (Fig. 2) in the range of flow rate $M_f = 0,002374…0,02374$ kg·s⁻¹ (10…100% M_n). The conclusion is that increasing the flow rate over the nominal gives little impact to the heater power and it is inexpedient to increase it, because the flow velocity of the heat carrier and hydraulic resistance increases.

Table 1

**Results of heater actual power calculations if the temperature
of the supplied heat carrier is $T_k = 75$ °C, $P_n = 1000$ W**

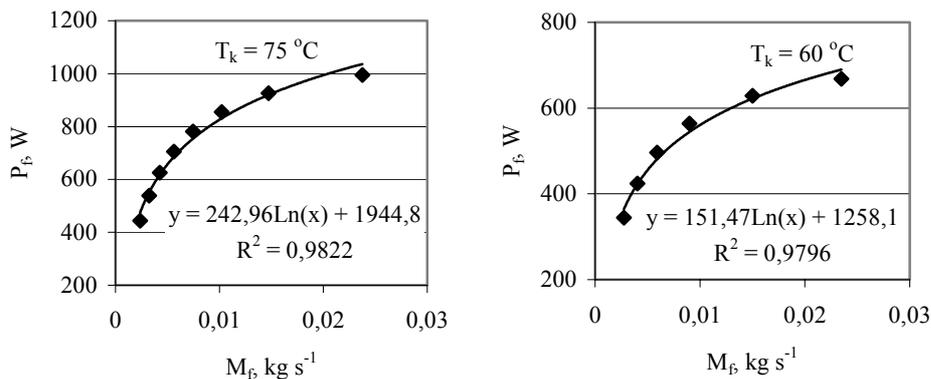| T_a	30	35	40	45	50	55	60	65
T_g	20	20	20	20	20	20	20	20
P_f, W	443	539	625	706	782	855	926	996
M_f, kg·s⁻¹	0,00235	0,00321	0,00426	0,00561	0,00747	0,01021	0,01473	0,02374

Fig. 2. **Actual heat power as a function of the flow rate of the heat carrier M_f (10…100%)
for different temperatures of the supplied carrier**

The way how to gain a functional correlation between necessary P_f and temperature of supplied heat carrier to heater T_k is to use the formula (4), to calculate the heat power delivered by the heater for different T_k using nominal flow rate M_n and constant indoor air temperature T_g.

$$P_f = \frac{P_n \cdot \Delta T^{1,27}}{145,4} = \frac{P_n}{\dfrac{145,4 \cdot (T_k - T_a)^{1,27}}{(\ln \dfrac{T_k - T_a}{T_a - T_g})^{1,27}}} \qquad (4)$$

The delivered heat power P_f depends also on indoor air temperature T_g. The correlations between P_f and flow rate M_f ($T_k = 75$ $^{\circ}$C), for different indoor temperatures are shown in Figure 3 (approximated equations in Table 2), between return heat carrier temperature T_a and M_f for different T_g in Figure 4, but between P_f and T_g for different M_f in Figure 5 (Table 3) [2].
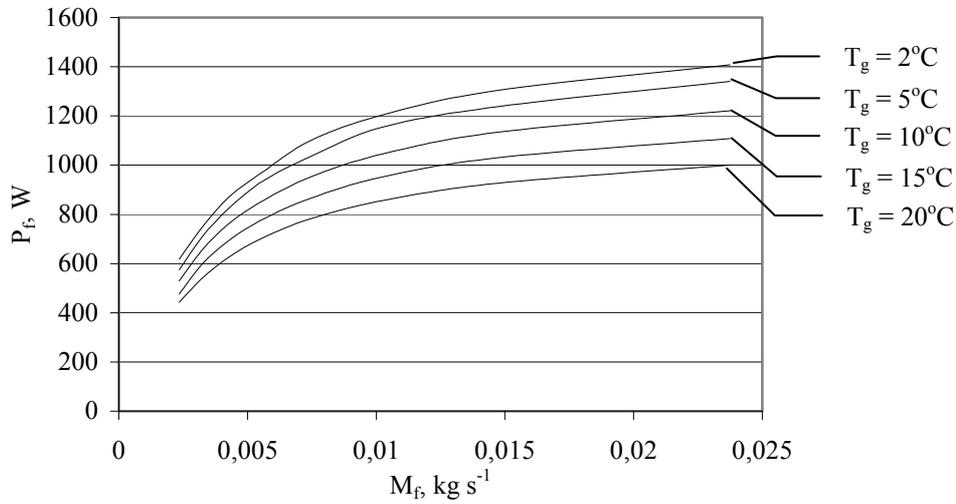

Fig. 3. **The heat power delivered by the heater as a function of the heat carrier flow rate for different indoor air temperatures** ($10\ldots100\%$ M_f)

Table 2

The heat power delivered by the heater as a function of flow rate ($T_k = 75$ $^{\circ}$C)

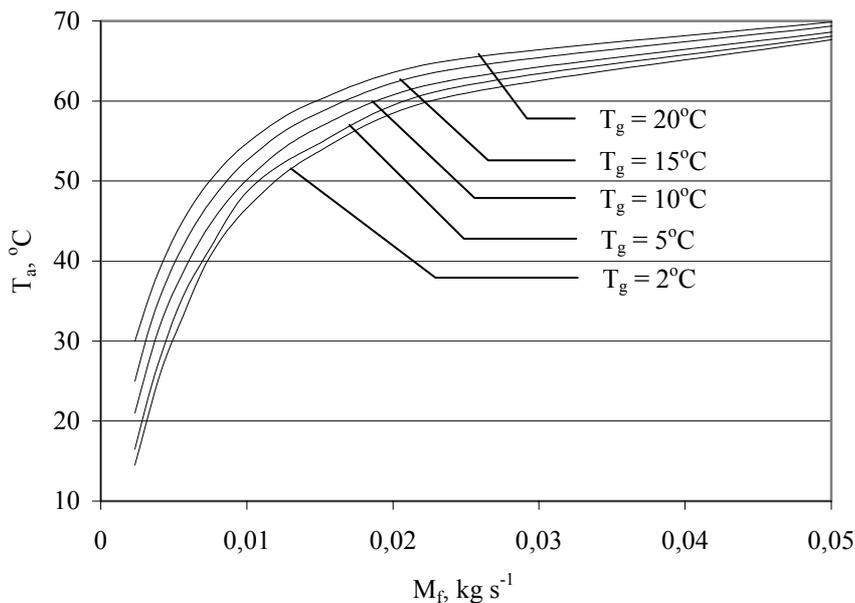| Indoor air temperature T_g, $^{\circ}$C	$P_f = f(M_f)$	Coefficient of determination R^2
20	$P_f = 242{,}6 \ln M_f + 1944{,}8$	0,9822
15	$P_f = 276{,}1 \ln M_f + 2188{,}4$	0,9804
10	$P_f = 303{,}2 \ln M_f + 2405{,}3$	0,9830
5	$P_f = 337{,}4 \ln M_f + 2657{,}9$	0,9828
2	$P_f = 350{,}2 \ln M_f + 2773{,}1$	0,9849

Fig. 4. **The return heat carrier temperature as a function of the flow rate for different indoor air temperatures** ($T_k = 75$ $^{\circ}$C)

Table 3

Correlations between the heat power delivered by the heater and the heat carrier flow rate for different indoor air temperature

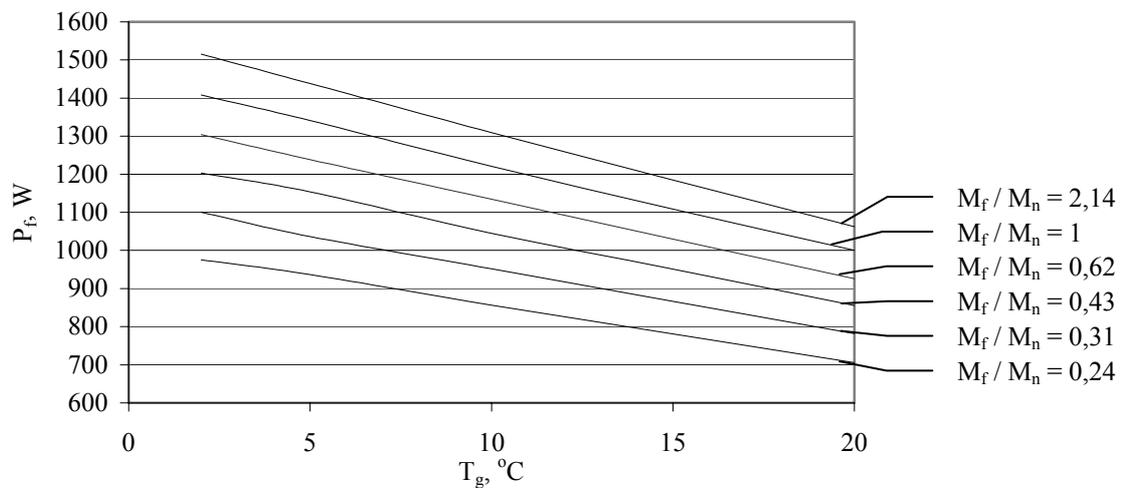| M_f / M_n	$P_f = f(T_g)$
2,14	$P_f = -25,2\, T_g + 1569$
1	$P_f = -23,7\, T_g + 1467$
0,62	$P_f = -20,9\, T_g + 1344$
0,43	$P_f = -19,6\, T_g + 1245$
0,31	$P_f = -17,5\, T_g + 1129$
0,24	$P_f = -15,1\, T_g + 1008$

Fig. 5. **The heat power delivered by the heater as a function of indoor air temperature** ($T_k = 75\ ^oC$)

Conclusions

1. Increasing the flow rate of heat carrier over the nominal value gives little impact to the heater power and it is inexpedient to increase it, because the flow velocity of the heat carrier and hydraulic resistance increases.
2. Delivered heat power by heater depends on several external and operational parameters as the heat carrier flow and temperature and indoor air temperature, therefore when developing heating control systems and modelling operation of heating processes it is necessary to evaluate these correlations.
3. Performing control of heating by changing heat carrier flow rate it is possible to use correlations from Tables 3 and 4 as a basic correlations to choose operational parameters for the system.

References

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