Numerical analysis of the heat loss of stop valves of heat networks

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Abstract. The results of mathematical modeling of heat regimes of stop valves of heat networks were given. It was revealed that for the stop valves with a relatively small nominal bore the equivalent pipe length can be reduced more than twice.

1 Introduction

Stop valves are used in various industries [1-5]. It is known [5] that heat loss of a thermal network are made up of linear (heat loss of pipeline sections that do not have fittings and fittings) and local heat loss (heat loss of shaped parts, stop valves, supporting structures, flanges).

2 Problem statement

Heat loss of bends, bent compensators and other parts are calculated by the formulas for straight pipes [6]. Heat loss of flanges, fittings and fittings are determined in equivalent pipe lengths of the same diameter by the formula [5]:

$$Q_l = q \cdot l_e \quad (1)$$

Heat loss from a non-insulated valve or gate are assumed to be equal to heat loss of an isolated pipeline of length l_e = 12-24 m of the same diameter. The equivalent length of a valve or gate isolated on 3/4 of a surface, depending on the diameter of the pipeline and the temperature of the heat carrier, can be taken as 4-8 m of an insulated pipeline. The equivalent length of the uninsulated flange can be taken as 4-5 m of an insulated pipeline.

This approach to the assessment of local heat loss is empirical, based on years of operation of heat networks, but has no theoretical basis. The main reason for the absence of theoretical studies of the thermal regimes of fittings and shaped parts (flanges, latches, etc.) of heat pipes of thermal networks is their rather complicated geometry.

This problem can be solved with using modern approaches to modeling thermal conditions and heat loss of heat transfer systems [5], based on numerical modeling of physical processes.

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The purpose of this paper is to analyze of heat loss of ball valves, as one of the types of typical stop valves of heat networks.

3 Mathematical model and method of solution

As an example, we consider not an isolated ball valve of the company Broen Ballomax of the lineup 62.102.000. The heat transfer on the external surfaces of the ball valve is carried out under conditions of radiative heat transfer and natural convection, the ball valve is in the open state, and the internal surfaces are maintained at a constant temperature equal to the temperature of the heat carrier.

For the case under consideration, a three-dimensional stationary heat conduction problem is solved in the "ball valve – environment" system. The mathematical model for the problem under consideration includes the heat conduction equation for the valve body with the corresponding boundary conditions setting the problem. The solution of the problem was obtained using tools and functions of the COMSOL Multiphisics modeling software package. The studies were carried out on a non-uniform finite element mesh. The number of elements was chosen from the conditions for the convergence of the solution.

4 Initial data

Investigations were carried out for ball valves with nominal conduit diameters of 125, 250 and 500 mm. Ball valves are made of steel ST 37, the degree of blackness of the surface was assumed equal to 0.8. The temperatures of the heat carrier and the environment were 100 °C and 25 °C, respectively The average value of the heat transfer coefficient on the outer surface of the valve body was assumed equal to 5 W/(m2·ºC) [5, 6].

5 Results of numerical simulation

The main results of the numerical study of thermal conditions and heat loss of the ball valves are given in the table in the figure.

Validity and reliability of the obtained results follow from tests of the methods for convergence and stability of solutions on multiple meshes, fulfillment of the energy balance conditions at boundaries of the calculation domain. The relative calculation error in all versions of the numerical analysis did not exceed 0.1%, which is acceptable for investigations of thermal conditions of the system under consideration.

The table presents the results of a numerical calculation of the heat loss from non-isolated ball valves Q, the local heat losses Q_l calculated from formula (1), the values of the standard linear heat losses q [6], the equivalent tube lengths l_e, chosen on the basis of recommendations, equivalent lengths pipes l, calculated as a function of Q, as well as a comparison of Q and Q_l with each other.

The results of numerical simulation of heat loss from non-isolated ball valves indicate an increase in heat loss with an increase in the diameter of the conditional passage of a ball valve.

Comparison of the results of numerical modeling Q and local heat losses Q_l (table) allows us to conclude that the discrepancy between them is from 6.9 % to 123.3 %. Therefore, it is possible to reduce the estimated equivalent length of the pipeline l_e for relatively small conventional diameters.

Recalculation of the equivalent lengths of pipelines l in accordance with the results of numerical simulation (table) allows us to say that for ball valves with relatively small conditional passages, le can be reduced by more than two times.

Table. Results of numerical analysis.

Nominal conduit diameters, mm	125	250	500
Q, W	204.2	633.9	1894.6
Q_l, W	456	855	1764
q, W/m [5]	38	57	98
l_e, m	12	15	18
$l = \dfrac{Q}{q}$, m	5.37	11.12	19.33
$\dfrac{\lvert Q - Q_l \rvert}{Q} \cdot 100\ \%$	123.3	34.9	6.9

In the figure, as an illustration of the simulation results, a typical temperature field of a ball valve with a nominal conduit diameter of 500 mm is given for the conditions considered in this paper.

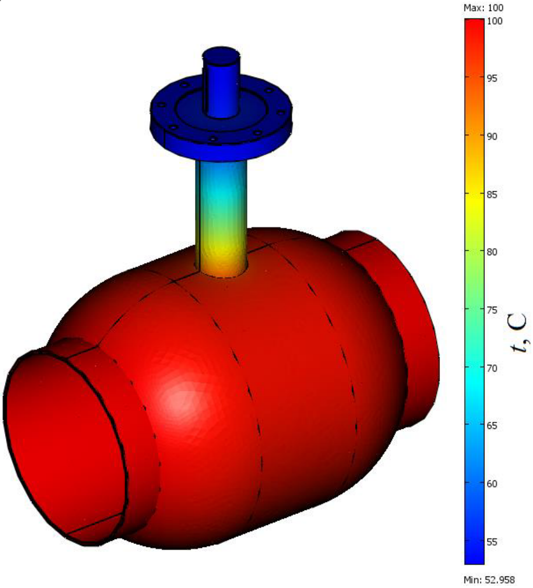

Fig. 1. The temperature field of a ball valve with a nominal conduit diameter of 500 mm.

6 Conclusion

Based on the numerical simulation of thermal regimes of typical stop valves of thermal networks, the scales of heat loss of ball valves were theoretically established for the first time.

It is shown that for ball valves with relatively small conditional passages the equivalent length of the pipeline can be reduced by more than two times.

7 Notations

Q_l – local heat loss, W; q – linear heat loss, W/m; l_e – equivalent pipe length, m.

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