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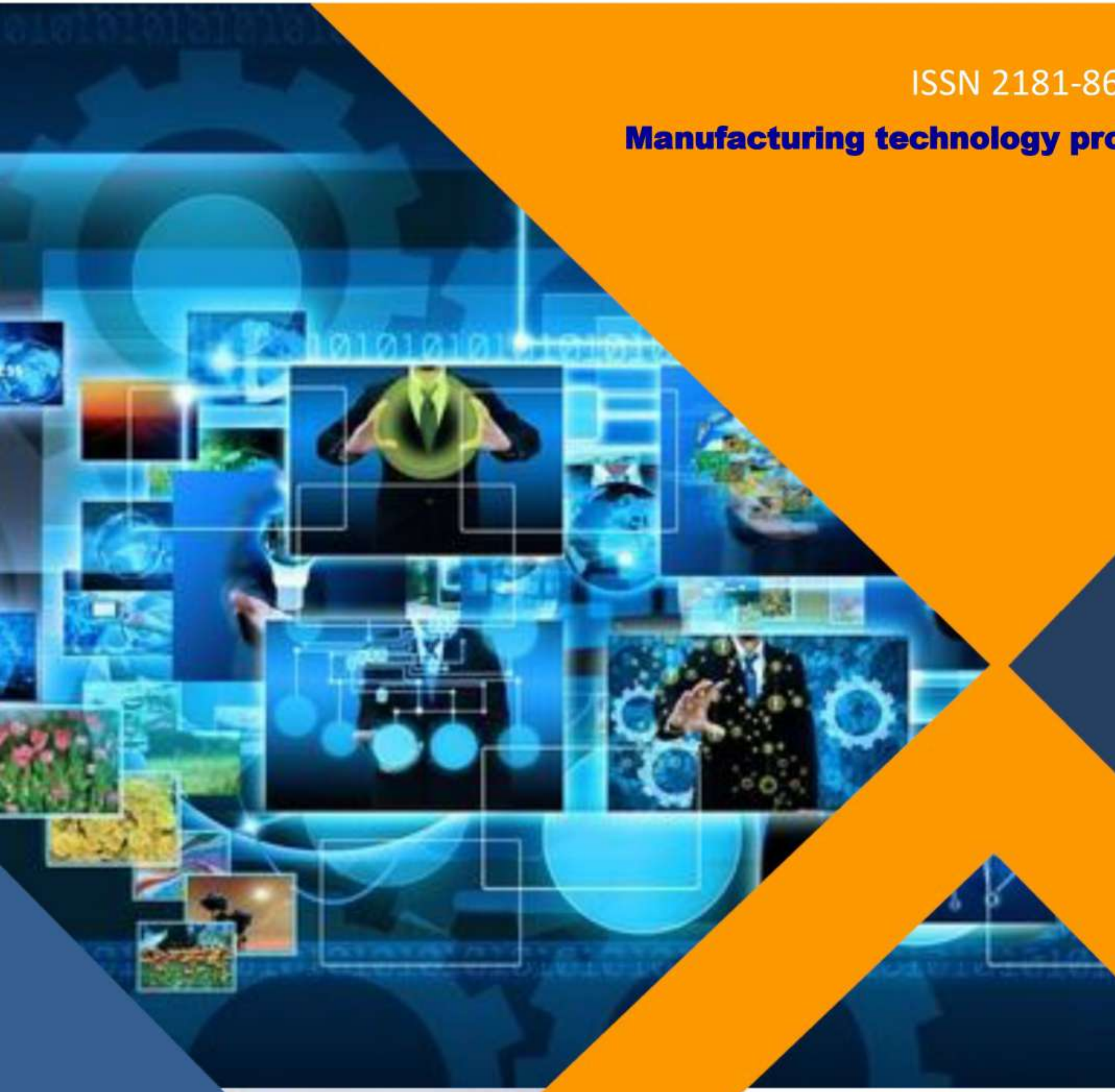

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INFLUENCE OF SURFACE LAYER THICKNESS ON HYDRAULIC RESISTANCE OF THE DEVICE

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Abstract: The increase in the thickness of the scale on the inner surfaces of technological pipes reduces the cross-sectional area of the pipe, thereby decreasing its conductivity. As a result, the coefficient of friction in the pipe increases, which in turn leads to an increase in its hydraulic resistance. This causes a sharp increase in the amount of energy consumed, as the required pump power for fluid transportation rises accordingly.

The main objective of determining the hydraulic resistance of flowing fluids in heat exchange systems through experimental or calculation methods is to identify the power required to drive the flow. Hydraulic resistance mainly depends on factors such as flow velocity, its physical properties, the pipe's structural parameters, and the accumulated mass of the scale within the pipe.

The comparative analysis of the pressure loss ΔP values of the heated water moving through the inner pipe of the shell-and-tube heat exchanger was carried out through calculations.

Keywords: heat exchange, hydraulic resistance, pressure, local resistance, scale mass.

Introduction. The primary objective of determining the hydraulic resistance of flowing fluids in heat exchange systems through experimental or computational methods is to identify the power required to drive the flow. Hydraulic resistance mainly depends on factors such as flow velocity and its physical properties, the pipe's structural parameters, and the accumulated scale mass within the pipe [1-4]. The comparative analysis of pressure loss ΔP values for heated water moving through the inner pipe of the shell-and-tube heat exchanger was carried out through calculations [4-8].

The total loss of pressure ΔP_{gen} in the flow within the inner pipe of the heat exchanger is formed by the pressure loss due to friction (ΔP_{fr}) and the pressure loss due to local resistances in the pipe ($\Delta P_{local\ res}$) [1, 6-11]:

$$\Delta P_{gen} = \Delta P_{fr} + \Delta P_{local\ res} \tag{1}$$

The pressure loss due to friction ΔP_{fr} is dependent on the viscosity of the hydrocarbon feedstock moving through the pipe [1, 10-12]:

$$\Delta P_{fr} = \lambda(\upsilon^2\rho/2)(L_{gen}/d_i), \tag{2}$$

where: λ- is the friction coefficient, ν-is the flow velocity, m/s, ϱ-is the density of the material, kg/m³, L_{gen} - is the length of the heat exchange pipe, d_i-is the internal diameter of the pipe, m.

The pressure loss due to local resistances $\Delta P_{local\ res}$ is calculated using the following formula [1, 13-30]:

$$\Delta P_{local\ res} = \sum_{i=1}^{n} \xi_i\, \rho\upsilon^2/2. \tag{3}$$

Methods. The values of the local resistance coefficients ξ_i, in heat exchange systems are provided in the literature. In shell-and-tube heat exchangers, the following local resistance coefficients are typically used: For a low-corrosion welded steel pipe with smooth joints, the resistance coefficient is - ξ_1=0.2; (For entry into a sharp-edged pipe, the resistance coefficient is - ξ_1=0.5), For exit from a sharp-edged pipe, the resistance coefficient is ξ_2=1,0; For sudden expansion of flow, the resistance coefficient is ξ_1=0,5; For sudden contraction of flow, the resistance coefficient is ξ_1=0,35 [1].

Results. According to the company regulations, a two-way heat exchange system is installed for the cationic filtration line of the water. The main parameters of the system are provided in table1

Table 1. Operating parameters of the heat exchanger

№	Indicators	Unit of measurement	Size
1	The diameter of the outer pipe, D_{ext}.	mm	420
2	Inner pipe length, L	mm	3000
3	Total number of pipes, n	grain	122
4	Number of roads, z	grain	2
5	The temperature of the water at the entrance to the device, t_1	^oC	20
6	The temperature of the water at the outlet of the device, t_2	^oC	80
7	The temperature of the steam at the entrance to the device, t_3	^oC	150
8	The temperature of the steam at the inlet from the device, t_4	^oC	121
9	Water pressure at the inlet to the device	kPa	250
10	Steam pressure at the inlet to the device	kPa	600

From the experiments conducted on the heat exchanger, it was found that during the movement of water in the internal pipe of the device, the outer mass accumulates. As a result, the cross-sectional area of the pipe decreases. This leads to a sharp decrease in the throughput of the pipe and, at the same time, an increase in the amount of energy spent on driving the flow.

Table 2 shows the change in the hydraulic resistance in the internal pipe of the heat exchanger used in the preparation of water for technological processes at "Uchkurgan-Yog" JSC, depending on the thickness of the outer layer.

According to the results of the hydraulic calculations, it was found that when the thickness of the outer layer in the internal pipes of the heat exchange device is δ,=0.1 mm, the pressure loss due to friction during the movement of water increases to ΔP_{fr} = 168 kPa, the pressure in local resistances to $\Delta P_{\text{local res}}$, = 82 kPa, and the total hydraulic resistance of the device increases to ΔP_{gen} = 250 kPa. It was found that with an increase in the thickness of the outer layer from 0.1 mm to 3.0 mm, ΔP_{fr} increases by 11.7 times, $\Delta P_{\text{local res}}$ by 10.2 times, and ΔP_{gen} by 11.3 times.

Table 2. The influence of the thickness of the coating on the hydraulic resistance indicators of the heat exchanger

The thickness of the coating layer on the surface of the pipe is δ, mm	Pressure lost due to frictional forces ΔP_{fr}, kPa	Pressure lost from local resistances $\Delta P_{local\ res}$, kPa	Hydraulic resistance ΔP_{gen}, kPa
0.1	168	82	250
0,5	314	166	480
0,8	410	211	621
1,0	590	227	817
1,5	864	381	1245
2,0	1230	490	1720
2,5	1587	663	2250
3,0	1975	840	2815

Conclusion. The results obtained show that increasing the thickness of the outer layer on the surface of the heat exchange pipe, in addition to reducing its heat transfer characteristics, also leads to a sharp increase in the hydraulic resistance in the pipe. This increases energy consumption and negatively affects the operation of the device at full capacity.

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