Technical and Economic Analysis of Injecting Enhancers into High-Paraffin Oil Heaters

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Abstract. This paper covers an algorithm of how to optimize the selection of preferred solutions to upgrade heat-exchange equipment. The algorithm is discussed in terms of high-paraffin oil heaters as compared with other heat-exchange surface features.

Usually, a technical and economic analysis is performed whenever it is required to differentiate between several solutions available and pick an optimum one to upgrade the heat-transfer equipment. The analysis uses the calculation of a single or multiple performance indicators (payback period, reduced cost, cost-effectiveness etc.), which show a degree of preferability of one or another solution [1].

Particularly, with consideration of a profit tax $N_{pr}$, the net annual income of an undertaking gained from equipment upgrading is determined by the formula, kRUB per annum:

$$\sum E_{res} = \sum E_{res} \cdot (1 - N_{pr}) , \quad (1)$$

where $E_{res}$ is the resulting economic benefit from implementing technical solutions, which can be defined by the formula:

$$\sum E_{res} = E - S , \quad (2)$$

$E$ is the effective (revenue) side of technical solution, kRUB per annum;
$S$ is the additional OPEX of technical solution, kRUB per annum.

However, the main procedural troubles are related to correct determination of positive and negative effects coming from changes in operating expenses to be spent for running the equipment throughout the year (or service life between overhauls).

As is shown in [2, 3], the comparison of how the heat exchangers with clean surfaces are efficient is not exactly correct for the cases when the surfaces become less contaminated while in service. Seasonal periodicity, weather conditions or other changes in initial conditions of heating up or cooling down the high-viscosity fluids in terms of their effective viscosity versus temperature are also important.

All these aspects can be fully related to the paraffin oil heaters as well, where both the surface
contamination and the initial temperature fluctuation of the environment cannot be ignored.

In addition to operating expenses, the innovation introduction stage will also require significant capital expenses for the heat exchanger itself as well as for its foundation, room, if required, etc. Mainly, all these factors depend on particular operating environment in a particular undertaking. There is, however, a general indicator, which shows material content of new (or upgraded) equipment. The metal content is such an indicator for heat exchangers [4]. Therefore, increase or decrease in allowance for depreciation of equipment should be related to either positive or negative benefits.

Considering all the above said, the algorithm of technical and economic analysis of injecting enhancers into high-paraffin oil heaters looks as follows:

**Phase 1.** Analysis of thermohydraulic performance of exchangers-preheaters of oils with neat surfaces.

Heat power stability is typical for heat exchangers running at rated values. Owing to the Kirpichyov correlation analysis, it means that the thermal effectiveness coefficient is constant, kW/(m²·K) [2]:

$$K_Q = \frac{Q}{F} = K \cdot \Delta t = \text{const}. \quad (3)$$

The factor of power required for circulating the coolant is defined by the formula, kW/m²:

$$K_N = \sum \frac{N}{F}. \quad (4)$$

For heat exchanger, the energy efficiency ratio is:

$$\bar{E}_0 = \frac{K_Q}{K_N}. \quad (5)$$

Considering the ratio (3), the equation (5) demonstrates that the correlation analysis of thermohydraulic efficiency of enhanced preheaters versus the baseline model is limited to the comparison of pressure loss ratio (the power required for carrying the coolants) in such kind of machinery, i.e.

$$\frac{\bar{E}_0}{E_{0i}} = \frac{K_{N_i}}{K_N}. \quad (6)$$

Where the index $i$ shows the type of an enhanced heat exchanger.

If the heat exchanger is running (or planned to be run) under alternating load conditions, the measures of formulas (3)-(6) should be averaged taking typical modes of operation and equipment service life into consideration.

**Phase 2.** Analysis of thermohydraulic regimes as a function of initial temperature of oils (oil products).

**Phase 3.** Calculation of hot coolant rate as a function of initial fluid temperature.

**Phase 4.** Determination of heat transfer ratio of a preheater depending on fluid and hot coolant rates $K_{TA} = f(Re_{in}, Re_{out})$. 


Phase 5. Calculation of heat transfer area and verification of its compliance with the actual heat exchanger area.

Phase 6. Determination of how the heat transfer in an oil heater depends on transfer surface contamination. These dependencies are also reduced as the re-configuration of tube bundle surface reduces flow throat area. Changes in surface on the hot coolant side reduce build-up rate on the outer walls, while changes in surface on the oil (oil products) side reduce the build-up rate on the inner walls. Particularly, it is shown in [2] that spiral or annular grooves drop build-up rate up to 3 times in rated duty. A temperature drop variation coefficient is also determined considering contamination and variation coefficient of hot coolant flow rate to prevent from this negative effect. The measures of item 4 are re-calculated to ensure that the fluid is heated up as required.

Phase 7. Calculation of integral technical and economic magnitudes as per formulas (1)-(2) followed by conclusions.

Estimating calculations performed for two types of surfaces – bare tube and enhanced surface with spiral grooves – have shown that the enhanced surface approach is compensated less than within 1.5 years.

References

[1] Nazmeev Yu G and Konakhina I A 2002 Heat and energy systems and power balances of production plants (M.: Publishers of Moscow power engineering institute)

[2] Konakhina I A and Voropayev A N 2010 The question of how to select high-performance heat exchangers-oil coolers considering actual conditions of their operation Thermal physics and heat power engineering: collection of scientific articles – Magnitogorsk pp 146-41

[3] Voropayev A N and Ukhanov K V 2009 Evaluation of effect of seasonal temperature variations of cooling water on the efficiency of heat exchangers-viscous fluid coolers Izvestiya vuzov. power engineering issues V 5-6 pp 137-32

[4] Simonov V F 1985 Increasing power consumption efficiency in petrochemical industries M.: Chemistry p 238