Methods for monitoring the technical condition of plate heat exchangers

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Abstract. The article sets the task of developing a method for reducing the complexity of repair of plate heat exchangers by optimizing the method of monitoring the technical condition of equipment. To solve this problem, it is proposed to develop a methodology for determining the optimal location of thermoelectric modules. The article presents an algorithm for solving the problem of choosing the location of thermoelectric modules. The developed method allows to evaluate the condition of the plates for deposits, their thickness in real time and on working plate heat-exchange equipment. The data obtained may be used to decide on repair and restoration operations.

1. Introduction
The task of monitoring in the technological processes of the oil and gas industry is to prevent the potentially dangerous causes of possible accidents and to prevent the failure of technological equipment, which ensures the efficient operation of enterprises in the given modes, thereby improving the quality of products and labor productivity [1-5].

Methods of monitoring the technical condition of heat exchange equipment, namely plate heat exchangers, are based on the control and monitoring of heat exchange equipment using pressure and temperature sensors. After obtaining such indirect monitoring results, the condition of the heat exchanger as a whole and its internal part, including the plates, is estimated using correlation [6-11]. Cleaning this type of equipment is very time-consuming and financially expensive. It is not always possible to objectively evaluate and decide on the need for cleaning of equipment. It is a method in which, in real time and on a working plate heat exchange equipment, it is possible to assess the condition of the plates for deposits, their thickness with a high degree of accuracy and subsequently use such data to decide on repair and restoration operations.

Therefore, the aim of the work is to develop a method for determining the optimal amount and location of instrument on the working surfaces of a plate heat exchanger for determining the thickness of deposits.

2. Description of the method for determining the number and installation location of thermoelectric modules (Peltier elements)
During the operation of heat exchangers on the inner surfaces of the heat transfer plates, various kinds of contamination occur that impede efficient operation [12, 13].

The main types of pollution of plate heat exchangers are:
- crystallization (most often in the form of scale formation);
- sedimentation (deposition of clay, sand, rust);
- growth of organic products and polymers;
- coking of hydrocarbons.

Contamination of the plates in the plate heat exchanger can occur according to two possible schemes, shown in Figure 1.

**Figure 1.** Graph of the ratio of the coefficient of pollution of the heat exchange plate from time to time: A - Crystallization and deposition of solid suspensions; B - Crystallization of pure substances

**Table 1.** The dimensions of the deposits of the plates

| S_3 | S_2 | S_1 | S_{3\text{max}} | S_{3\text{min}} | S_{2\text{max}} | S_{2\text{min}} | S_{1\text{max}} | S_{1\text{min}} |
|-----|-----|-----|----------------|----------------|----------------|----------------|----------------|----------------|
| 0.8 | 0.1 | 0.1 | 0.8            | 0              | 0.1            | 0              | 0.03           | 0.02           |
| 0.9 | 0.075 | 0.025 | 0.9            | 0              | 0.075          | 0              | 0.025          | 0              |
| 0.5 | 0.45 | 0.05 | 0.2            | 0.01           | 0.25           | 0.01           | 0.02           | 0.009          |
| 0.9 | 0.02 | 0.08 | 0.6            | 0.1            | 0.009          | 0.005          | 0.05           | 0.009          |
| 0.4 | 0.5  | 0.1  | 0.2            | 0.01           | 0.25           | 0.01           | 0.05           | 0.009          |
| 0.35 | 0.3  | 0    | 0.1            | 0.01           | 0.2            | 0.05           | 0              | 0              |
| 0.4 | 0.1  | 0.5  | 0.2            | 0.01           | 0.03           | 0.01           | 0.5            | 0              |
| 0.9 | 0.075 | 0.025 | 0.7            | 0.01           | 0.03           | 0.01           | 0.01           | 0.01           |
| 0.6 | 0.35 | 0.05 | 0.6            | 0              | 0.355          | 0              | 0.02           | 0.01           |
| 0.35 | 0.45 | 0.2  | 0.2            | 0.05           | 0.3            | 0.01           | 0.1            | 0.01           |
| 0.45 | 0.35 | 0.2  | 0.9            | 0.01           | 0.2            | 0.05           | 0.12           | 0.01           |
| 0.4 | 0.4  | 0.2  | 0.2            | 0.02           | 0.2            | 0.02           | 0.09           | 0.01           |
| 0.4 | 0.4  | 0.2  | 0.2            | 0.02           | 0.2            | 0.02           | 0.09           | 0.01           |
| 0.7 | 0.2  | 0.1  | 0.6            | 0.01           | 0.1            | 0.01           | 0.04           | 0.01           |
| 0.8 | 0.175 | 0.025 | 0.65          | 0.01           | 0.1            | 0.01           | 0.01           | 0.009          |

The main methods for monitoring and diagnosing the effective operation of technological equipment:
- Monitoring by operating personnel (visual, tactile, aural);
- Monitoring and diagnostics using technical devices (using various pressure and temperature sensors, video surveillance, etc.).

In addition to these methods, a method is proposed that is based on the laws of changes in voltage on a thermoelectric module depending on the thickness of the deposit. But the disadvantage of this
method is the lack of recommendations for the precise installation of thermoelectric modules on a heat exchanger [14-16].

For the study, 15 plates with a surface area of 1 m² were used. In terms of intensity, deposits were divided into 3 groups: strong (S₃), medium (S₂), and without deposits (S₁). Next, an analysis was made of the size of these deposits and the maximum and minimum spot sizes were revealed (Table 1).

After analyzing the obtained data, it is concluded that deposits on the plates are formed as a solid "spot" and small inclusions. Further, to highlight the most common places of contamination on the plates, each plate is 200 points (Figure 2).

On the tables reflecting deposits on the plates, deposits are indicated by groups: 0 - no deposits, 5 - medium deposits, 10 - strong deposits (require cleaning).

A total table with average values of deposit thicknesses, on which zones of severe pollution can be seen, is shown for 15 test plates (Figure 3).

A clear picture of deposits with average deposit thicknesses is shown in the deposit distribution chart (Figure 4).

|   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 4.3 | 3.7 | 6.3 | 4.7 | 5.3 | 6.0 | 4.0 | 4.0 | 3.7 |   |
| 4.3 | 4.0 | 4.3 | 6.3 | 5.3 | 6.3 | 4.0 | 4.0 |   |   |   |
| 4.3 | 3.7 | 4.3 | 6.7 | 6.7 | 6.0 | 6.0 | 6.0 | 4.7 | 6.0 |   |
| 6.7 | 6.7 | 6.7 | 5.7 | 8.0 | 6.7 | 7.7 | 8.0 | 8.3 | 6.3 | 7.3 |
| 6.3 | 7.3 | 7.7 | 6.3 | 8.7 | 8.0 | 8.0 | 7.3 | 7.3 | 7.0 |   |
| 6.7 | 7.7 | 7.7 | 6.3 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| 8.7 | 7.0 | 7.7 | 7.7 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 7.3 |
| 6.0 | 7.3 | 7.0 | 7.7 | 7.7 | 8.7 | 8.3 | 7.7 | 8.0 | 7.7 |   |
| 6.7 | 7.3 | 7.7 | 6.3 | 8.0 | 7.0 | 7.7 | 7.7 | 8.0 | 8.0 |   |
| 8.0 | 7.0 | 7.0 | 7.0 | 8.0 | 8.0 | 7.7 | 7.7 | 7.7 | 8.0 | 8.0 |
| 4.3 | 6.0 | 6.3 | 7.3 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |   |
| 7.0 | 7.3 | 8.7 | 9.0 | 7.7 | 9.0 | 9.0 | 9.0 | 9.7 | 9.0 | 9.0 |
| 7.7 | 8.0 | 9.0 | 8.7 | 8.0 | 9.0 | 9.0 | 9.0 | 9.7 | 9.3 |   |
| 8.0 | 8.3 | 8.7 | 8.3 | 8.0 | 8.0 | 8.7 | 9.7 | 9.3 | 9.7 | 9.0 |
| 7.7 | 7.3 | 8.0 | 9.0 | 8.3 | 8.3 | 9.7 | 9.3 | 9.3 | 9.7 | 9.3 |
| 8.3 | 8.3 | 8.3 | 9.0 | 8.3 | 9.3 | 8.7 | 8.7 | 9.3 | 9.3 | 9.3 |
| 8.0 | 9.0 | 8.7 | 8.0 | 9.3 | 8.7 | 8.7 | 8.0 | 9.3 | 8.3 | 9.0 |
| 5.7 | 5.7 | 7.0 | 7.7 | 7.7 | 7.0 | 6.3 | 6.7 | 6.7 | 5.3 |   |
| 5.7 | 5.7 | 7.3 | 7.0 | 7.7 | 8.3 | 8.3 | 6.7 | 6.3 | 4.7 | 4.7 |
| 6.7 | 6.7 | 6.7 | 6.7 | 8.0 | 7.3 | 6.3 | 5.3 | 5.3 | 6.0 |   |

Figure 2. Plate divided by 200 points

Figure 3. General table with average deposit values
After obtaining a clear picture of the average distribution of deposits on plate heat exchangers, installation locations are selected for thermoelectric modules in the predicted strongest areas of deposits and the optimal number of elements is determined for monitoring the technical condition of the plate heat exchanger (Figure 5).

**Figure 4.** The diagram of deposit distribution

**Figure 5.** Installation diagram of thermoelectric modules
3. Conclusion

The proposed method for selecting the installation locations of thermoelectric modules allows you to objectively assess the technical condition of plate heat exchangers and reduce the complexity of the repair of technological equipment.

Based on this method, it becomes possible to develop a system for diagnosing and monitoring deposits, which is a set of devices and mechanisms that determine the thickness of pollution on a heat exchanger plate of a plate heat exchanger.

The results can be used to develop a method of automatic chemical cleaning of the apparatus when the threshold value of the deposition thickness is reached and to develop a device that allows for real-time measurement of the deposition thickness on operating heat-exchange equipment.

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