Diagnostics of Sediment Occurrence in Interblade Channel of Injector Impeller of Gas Compressing Station by Changes of Gas Flow and Torque

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Abstract. Today no gas purification method exists which can be considered absolutely efficient. Thus, when gas compilation in conducted a problem of sediment formation occurs in a flow passage of the gas compression station (GCS) injector. The paper considers the mathematical simulation of the force moment change at the injector impeller of GCS caused by sediment occurrence in the interblade channel of impellers. In addition, the authors study the change of force moment in relation to the thickness of a sediment layer. Also, the research concentrates on the change of circumferential force at the impeller due to the change of force moment.

1. Introduction
Today no gas purification method exists which can be considered absolutely efficient. Thus, when gas compilation in conducted a problem of sediment formation occurs in a flow passage of the gas compression station (GCS) injector. The most evident manifestation of the issue one observes at the injectors, operated by gas processing plants, and also at gas compilation after underground gas storage in those cases when gas pressure after extraction is lower than the pressure in the main pipeline; in this case it should be pressed to the pressure level in the main pipeline.

Figure 1. Deposits in the interblade channel of the injector rotor impeller.
2. Relevance literature review
Balancing the rotor of the GCS injector is one of the main problems for the station stable operation. Misalignment of the rotor rotation axis with the inertia gravity axis causes the occurrence of uncompensated centrifugal efforts and moments, which induce additional dynamic loads. In its turn, it causes increased wear and the reduction of the station service life [1-21].

3. Problem statement
The contamination of the injector flow passage is one of the causes of the rotor balancing fault. Paper purpose: mathematical simulation of the force moment change in the interblade channel of the impeller at the rotor step due to the presence of sediment on a blade.

4. Theory. Experimental studies
The mathematical model is made by the example of the injector NC-16/76-1.44.

| Table 1. Reference characteristics of the injector applied for calculation. |
|--------------------------------|-----|
| Indicator name                  | Value                   |
| Injector capacity, MW           | 16                        |
| Gas pressure at the input, atm. | 51                         |
| Gas pressure at the output, atm.| 75                         |
| $Q_{ob}$ – gas volume flow, m$^3$/sec | 5.6             |
| $\omega_{ob}$ – rotor rotation frequency, rpm | 5,200             |
| $r_1$ – impeller internal radius, m  | 0.243             |
| $r_2$ – impeller external radius, m  | 0.455             |
| $\rho$ – gas density, kg/m$^3$      | 0.7168             |
| $\gamma$ – indicator of the isentropic (adiabatic) contraction process | 1.31             |
| $\beta_1$ – width of the input interblade channel, m  | 0.0236             |
| $\beta_2$ – width of the output interblade channel, m  | 0.0362             |
| $k$ – number of interblade channels in the impeller | 26                 |
| $T_{nach}$ – gas temperature at the input to the impeller, K     | 286                 |
| $T_{nach}$ – gas temperature at the input to the impeller, K     | 354                 |
| $\alpha_{1grad}$ – entrance angle of the blade profile, degree | 45                 |
| $\alpha_{2grad}$ – outlet angle of the blade profile, degree | 70                 |

The equation of force moment in the interblade channel is equal to:

$$ M = Q_k \left[ \omega (r_2)^2 - (r_1)^2 - \frac{Q_{ob}}{\rho_2 S_2} \alpha_2 + \frac{Q_{ob}}{\rho_1 S_1} \alpha_1 \right] $$

where:

$\rho_1 = \rho_{gaza}$ 51 - gas density before the input to the impeller at the pressure 51 atm. (gas pressure at the impeller input);

$Q = Q_{ob} \cdot \rho_1$ – mass flow in the impeller, kg/kg

$Q_k = \frac{Q}{k}$ – mass flow in the interblade channel, kg/sec

$\omega = \frac{\omega_{ob}}{60} \cdot 2\pi$ – rotation frequency, rad/sec

$\Delta T = \frac{T_{nach} - T_{nach}}{2}$ – temperature difference in the impeller

$\rho_2 = \rho_1 \cdot \left( \frac{T_{nach} - \Delta T}{T_{nach}} \right)^{\frac{1}{\gamma - 1}}$ – gas density at the output at the impeller

$\alpha_1 = \frac{\alpha_{1grad}}{360} \cdot 2\pi$ – entrance angle of the blade profile, rad

$\alpha_2 = \frac{\alpha_{2grad}}{360} \cdot 2\pi$ – outlet angle of the blade profile, rad

$S_1 = \frac{2\pi \cdot r_1 \cdot \beta_1}{k}$ – section area at the input of the channel, m$^2$
From the equation 1 it follows that the force moment in each interblade channel of the impeller is 560 N·m while the general force moment at the impeller is 14,560 N·m. Thus, the circumferential force at the rotor impeller is equal to:

\[ F_{kom} = \frac{M}{R_{kol}} \]

where:

\[ R_{kol} = \frac{r_1 + r_2}{2} \]

From the formula 2 one can obtain the circumferential force value at the impeller is equal to 1,603 N.

Simulate the change of the moment of force due to the presence of sediments in the interblade channel, assuming the sediment layer thickness is within the range 1-15 mm.

\[ M_X(b) = \frac{2\pi \cdot r_2 \cdot b_2}{k} \]

\[ F_{kon}(b) = \frac{2\pi \cdot r_2 \cdot b_2 \cdot r_3}{5} \]

**Figure 2.** The force moment change in the interblade channel of the injector impeller due to the sediment presence.

**Figure 3.** Change of the circumferential force at the impeller of the injector rotor due to the presence of sediments in the interblade channel.
Fig. 1, 2 show that the presence of sediment significantly influences the force moment and circumferential force which leads to the rotor disbalance causing the occurrence of forces and moments that result in the increase of vibrations both of the rotor and the whole machine. In addition, due to the change of the section of the interblade area caused by sediment, one can observe the change of gas rate in the channel.

5. Conclusions
1. The cause of unstable gas flows in the flow passage of GCS is its insufficient cleaning causing the occurrence of various sediments at the injector blades.
2. Sediment occurrence is caused by the disbalance of the injector rotor due to the occurrence of unstable force moment in the interblade channel.
3. The presence of sediments causes the change of torque at the impeller as well as the change of gas flow in the channel.

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