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DYNAMICAL TUNING OF HELICAL SCREW COMPRESSOR

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ABSTRACT

A helical screw compressor dynamic depends on an instantaneous exhaust in discharge line. The present paper describes a method of flow rate pulsation of gas-oil mixture decreasing based on the developed technique of exhaust calculation. The technique take into account geometrical characteristics of screw pair, intaking window, thermal-gas-dynamic processes in the gas-oil mixture and compressor operating conditions. Flow rate pulsation in discharge line was calculated from developed technique. The intaking window configurations were considered according to calculation from developed technique. The intaking window configurations was modified with designing «auxiliary feed window». This intaking window configurations allows to decrease flow rate pulsation and improve dynamic characteristics of helical screw compressor.

Keywords: Pulsation, Helical Screw Compressor, Dynamic Characteristics
I-INCE Classification of Subject Number: 11

1. INTRODUCTION

Pipelines are widely used in the different types of system. There are power plants, equipment's, mobile machines, process pipes and other. Pressure pulsation and vibration has a great impact on reliability, durability, efficiency and other operation parameters of pipe system.

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Helical Screw Compressor is widely used in various industries. Due to their relatively high rotational speeds compared to other types of positive displacement machines which make them compact, their ability to maintain high efficiencies over a wide range of operating pressures and flow rates and their long service life and high reliability [1, 2]. Despite the fact that a helical screw compressor has a low vibroactivity in comparison with the other energy sources, it has an operating adjustment problem in vibroacoustics. This is due to consumer requirements for a vibroacoustic characteristics (shipbuilders company), supply pressure pulsation and high vibration of pipes caused by batch feeding of gas [2, 3, 4]

A gas-oil mixture injection operation is the main reason of pressure pulsations [5]. When the air sucking in, injected in the cavity, twins cavity has considerable oscillations. These oscillations have not significant influence on the compressor power but may be cause of high dynamic loads on the rotor. The quasi-stationary model of the instantaneous exhaust developed in [5] take into account tooth profile and intaking window and allow to design optimization of intaking window to reducing noise and vibration.

New design of tooth profile and intaking window has been developed based on the quasi-stationary model. That allow decreasing flow rate pulsation of the gas-oil mixture and improving dynamic characteristics of helical screw compressor.

2. QUASI-STATIONARY MODEL OF THE INSTANTANEOUS EXHAUST

For the instantaneous flow rate calculation has been used step-by-step method for the time step corresponds to rotating angle of male rotor 0.15 degrees. The calculation started with the opening discharge port and finished when the port is closed.

Temperature, pressure, density and mass of gas-oil mixture in the working chamber are known for this moment. Flow rate has been calculated from the equations:

$$G_i = \begin{cases} \sqrt{\frac{k}{R}\left(\frac{2}{k+1}\right)^{\frac{k+1}{2(k-1)}}} \cdot S_{H_i}\frac{p_i}{\sqrt{T_i}}, & if\left\{p_i > p_H;\ \frac{p_H}{p_i} < \xi_{cr}\right\}; \\ S_{H_i}\sqrt{\frac{2}{k+1}p_i\rho_i\left(\left(\frac{p_H}{p_i}\right)^{\frac{2}{k}} - \left(\frac{p_H}{p_i}\right)^{\frac{k+1}{k}}\right)}, & if\left\{p_i > p_H;\ \frac{p_H}{p_i} > \xi_{cr}\right\}; \\ -S_{H_i}\sqrt{\frac{2}{k-1}p_H\rho_H\left(\left(\frac{p_i}{p_H}\right)^{\frac{2}{k}} - \left(\frac{p_i}{p_H}\right)^{\frac{2}{k}}\right)}, & if\left\{p_H > p_i;\ \frac{p_i}{p_H} > \xi_{cr}\right\}; \\ -\sqrt{\frac{k}{R}\left(\frac{2}{k+1}\right)^{\frac{k+1}{2(k-1)}}} \cdot S_{H_i}\frac{p_H}{\sqrt{T_H}}, & if\left\{p_H > p_i;\ \frac{p_i}{p_H} < \xi_{cr}\right\}. \end{cases} \quad (1)$$

where p_H, ρ_H, T_H pressure, density and temperature in the discharge port, ξ_{cr} critical pressure ratio, k polytropic coefficient, R gas-oil mixture constant, S_H contact area of twins port and discharge line (Figure 1).

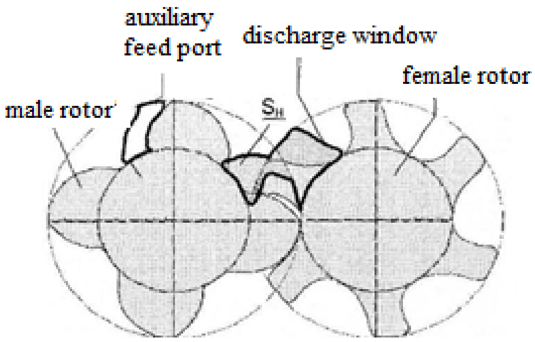

Figure 1. Working chamber and discharge line of helical screw compressor

At any moment of time except the moment when the working chamber opening mass, pressure, density and temperature of the gas-oil mixture in the original interlobe space has been calculated by

$$m_i = m_i - G_{i-1} \cdot \Delta t; \quad p_i = p_{i-1}\left(\frac{p_{i-1}}{p_i}\right)^k; \quad \rho_i = \frac{m_i}{V_i}; \quad T_i = T_{i-1}\left(\frac{p_{i-1}}{p_i}\right)^{\frac{k-1}{k}}, \quad (2)$$

Δt - time iteration.

Instantaneous supplies from working chambers are summarize for calculating instantaneous supply of compressor. Therefore, the cyclic variation coefficient the main cause of compressor dynamic loads calculated from:

$$\delta G = \frac{G_{max} - G_{min}}{G_{CP}}, \quad (3)$$

G_{CP} - compressor weight output.

3. INTAKE PORT DESIGN

Flow rate pulsation of the gas-oil mixture in a discharge line for the original intaking window design has been calculated from quasi-stationary model of the instantaneous exhaust (Figure 2). Cyclic variation coefficient in this case equal to 3.513456.

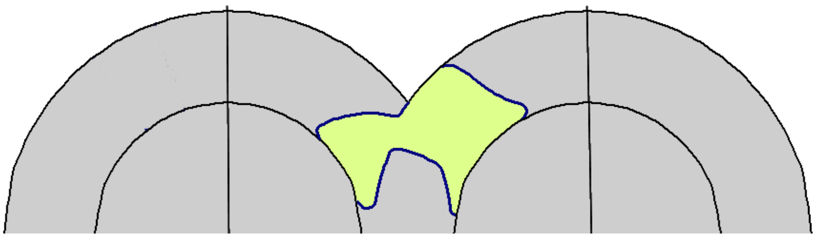

Figure 2. Original intaking window design.

Intaking window configuration modified with designing «auxiliary feed window». This configuration allows to decrease flow rate pulsation and improve dynamic characteristics of helical screw compressor (Figure 3).

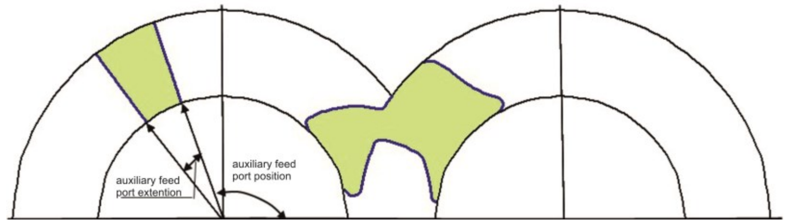

Figure3. First modification of intaking window configuration with auxiliary feed port

Design of intaking window configuration has been chosen according to dependencies between of cyclic variation coefficient and parameters of auxiliary feed port (Figure 4).

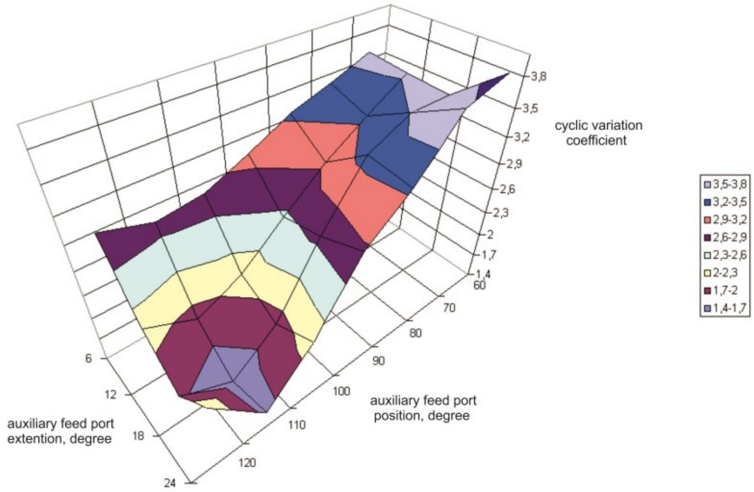

Figure 4. Dependencies between of cyclic variation coefficient and parameters of auxiliary feed port

The second modification of intaking window configuration is shown in the Figure 5.

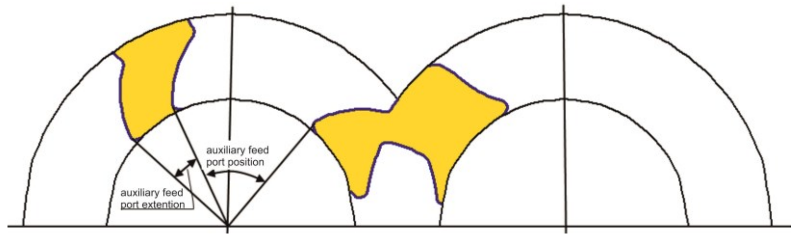

Figure 5. Second modification of intaking window configuration with «auxiliary feed port»

Design of the second modification of intaking window configuration has been chosen according to dependencies between of cyclic variation coefficient and parameters of auxiliary feed port in the Figure 6.

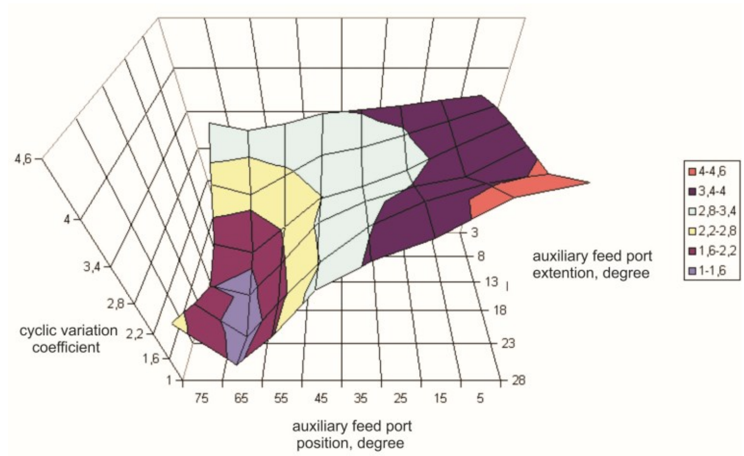

Figure 6. Dependencies between of cyclic variation coefficient and parameters of the second modification of auxiliary feed port

4. CALCULATION RESULTS

Calculation results of intaking window instantaneous square, flow rate of twins cavities, and compressor are shown in the Figure 7-9.

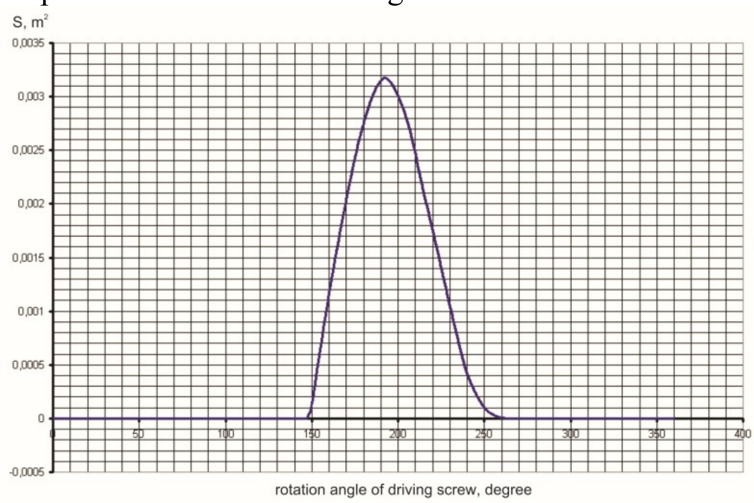

Figure 7. Instantaneous square of intaking window original design

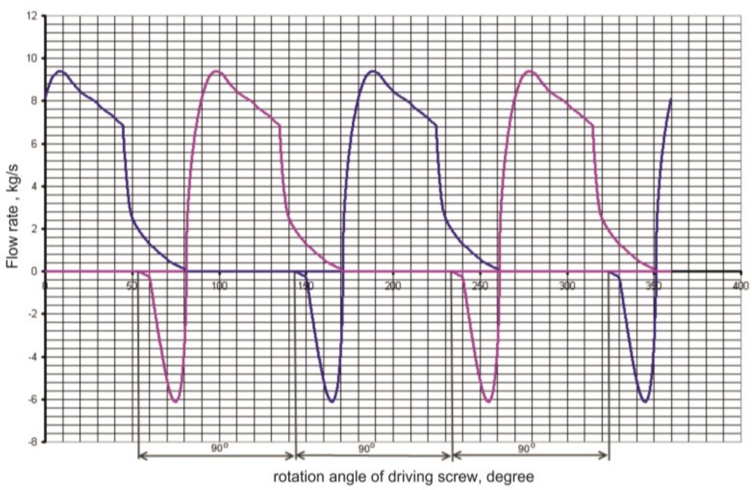

Figure 8. Flow rate of twins cavities of intaking window original design

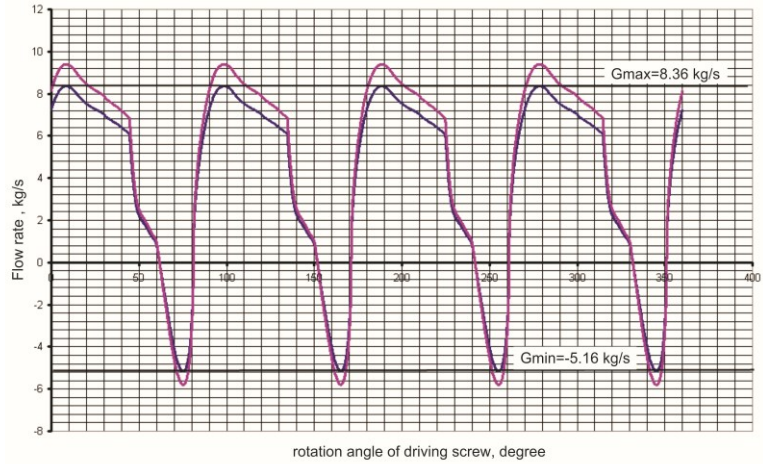

Figure 9. Flow rate pulsation of twins cavities of intaking window original design (with and without leakage)

Calculating results for the first modification of intake port configuration are shown that the cyclic variation coefficient is mínimum $\delta G = 1.467663$ and the average fuel consumption $\overline{G} = 3.822441 kg/s$.

Calculating results of intaking window instantaneous square, flow rate of twins cavities and compressor are shown in the Figure 10-12.

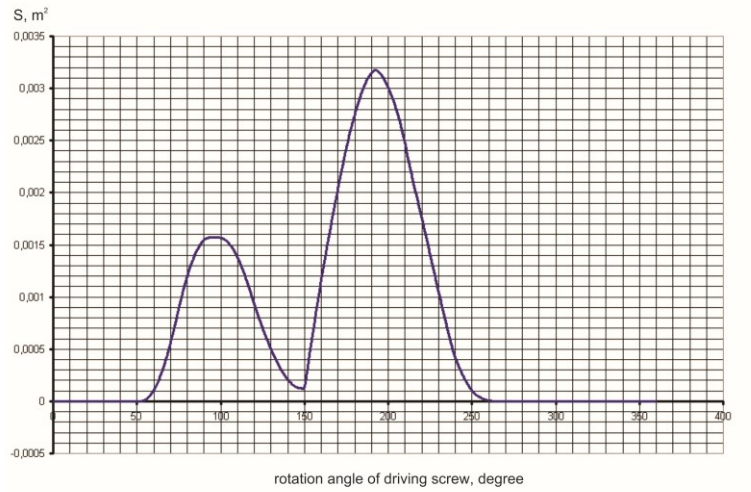

Figure 10. Instantaneous square of the first modification intaking window

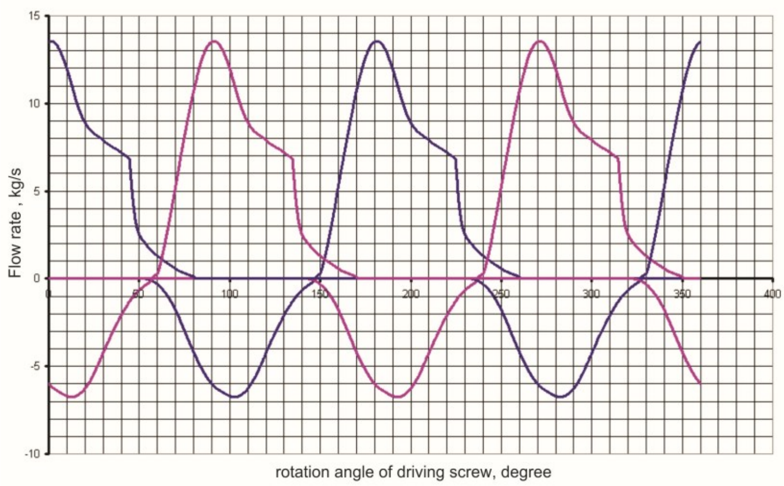

Figure 11. Flow rate of twins cavities of the first modification intaking window

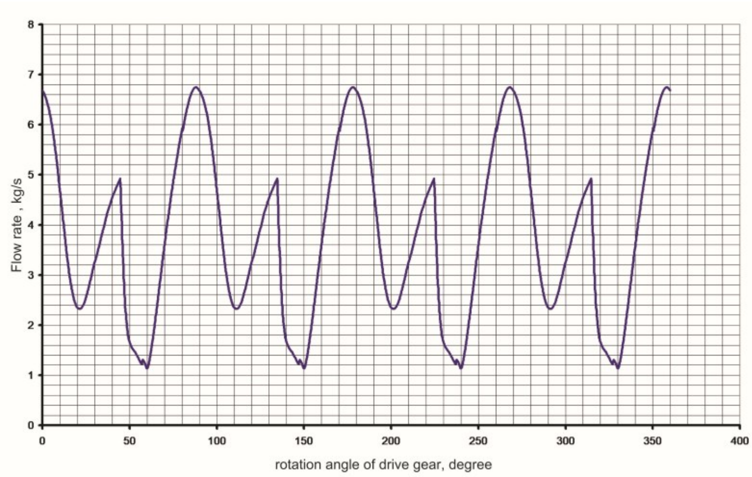

Figure 12. Flow rate pulsation of twins cavities for the first modification

Calculating results for the second modification show that the optimum modification of intaking window configuration allows to receive minimum cyclic variation coefficient $\delta G = 1.173398$ when the average fuel consumption $\overline{G} = 3.822308\, kg / s$.

Calculating results of intaking window instantaneous square, flow rate of twins cavities and compressor are shown in the Figure 13-15.

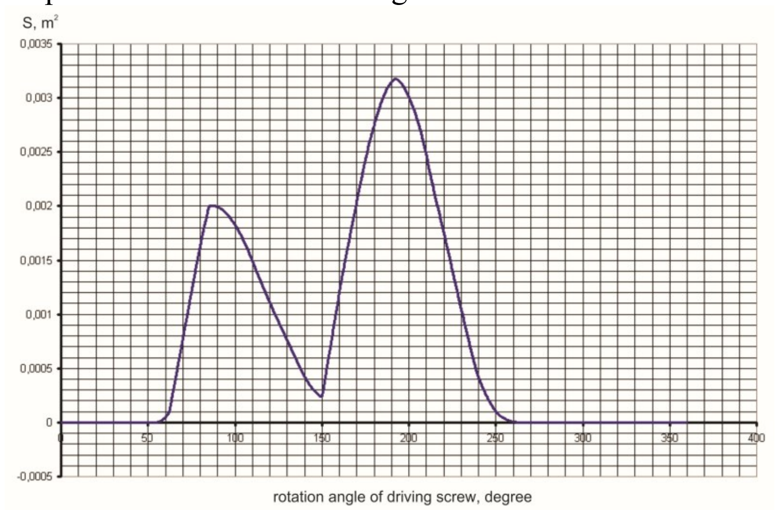

Figure 13. Instantaneous square of the second modification intaking window

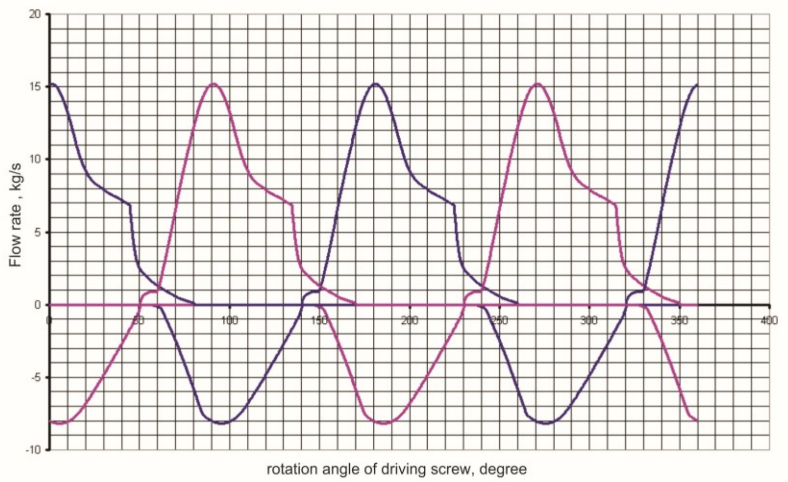

Figure 14. Flow rate of twins cavities of the second modification intaking window

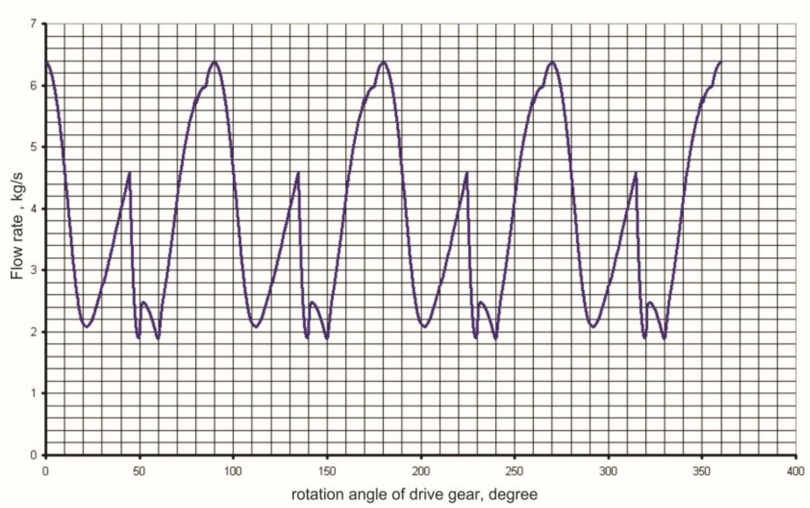

Figure 15. Flow rate pulsation of twins cavities for the second modification

4. CONCLUSIONS

The paper describes a method of flow rate pulsation of gas-oil mixture decreasing based on the developed technique of exhaust calculation. The technique take into account geometrical characteristics of screw pair, intaking window , thermal-gas-dynamic processes in the gas-oil mixture and compressor operating conditions. Flow rate pulsation in discharge line has been calculated from developed technique. The intaking window configuration considered according to calculation from developed technique. The intaking window configuration has been modified with designing auxiliary feed ports.

The paper consider two different modifications of auxiliary feed ports. Those modifications allows to charging up twins cavity by the opening most of part of intaking window and allows to significant smooth out of pressure undershoot and a small increase the level of maximum.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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