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To cite this article: G Budaev *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **589** 012035

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Research of centrifugal gas-liquid separator

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Abstract. The article is devoted to research of centrifugal gas-liquid separator. The fields of application of gas separators are described. Parameters on which depends the separation process are revealed. The mathematical model used in computer simulation of the two-phase flow is presented. The figures of the scalar physical quantities distribution in the flow part of the separator are shown. Graphs of the gas separator's characteristics are given.

1. Introduction

A separator is a device that separates a product into fractions with different characteristics. These devices are widely used in various spheres of human activity, such as agriculture, mining, medicine, food industry, etc. Figure 1.

In this article the gas separator intended for reduction of volume content of gas to admissible values in a mix arriving in the centrifugal pump as at the raised gas content its work becomes unstable and is characterised by fluctuations of working parameters: feed, created pressure and consumed power is considered [1,2]. Fluctuations in pump parameters lead to increased vibration of the unit and, consequently, to low operating hours.



Fig. 1. Example of a gas separation plant



A further increase in gas content leads to a feed failure. There are three types of gas separators: gravity, eddy and centrifugal. The last one is the most effective and was discussed further. Figure 2.

The principle of operation of such separator is based on the action of centrifugal force separating gas from water. The arriving mixture enters the intake ports and moves to the screw type inducer, from where it moves to the centrifuge with increased pressure, where it is divided into phases (under the influence of inertia forces the heavier fraction is pressed against the walls, and the lighter one remains near the shaft). After that the liquid is fed to the pump and the gas goes into the annulus.

Numerous studies have shown that the efficiency of the separator depends on parameters such as flow rate and gas content of the mixture [3,4,5,6]. With the help of modern methods of hydromodelling, the influence of these factors on the pressure, power and separation coefficient of the unit has been considered in this article.[7,8,9,10]. The mathematical model of running processes was also described. In addition, the negative influence of backflow was revealed. [11,12,13].



Fig. 2. Centrifugal gas separator design scheme

The main purpose of this work is to study the influence of input parameters on the efficiency of the gas separator.

2. Mathematical model and methods.

This paper uses the model of multiphase flow of incompressible liquid ($\rho = \text{const}$). Numerical modeling is based on solving discrete analogues of basic equations of hydrodynamics.

Calculation is carried out on the basis of mathematical model of divided multiphase flow.[14,15,16] That is, the equations of mass transfer and the amount of motion are solved separately for each phase, but the pressure field is the same for all phases.

The mathematical model consists of a set of differential and algebraic equations:

1. The phase volume in each calculation cell is calculated as follows:

$$V_i = \int_V \alpha_i dV$$

where α_i – the concentration of the i-phase in the cell.

The sum of concentrations of all phases in the cell is equal to one

$$\sum_{i=1}^n \alpha_i = 1$$

2. Mass conservation equation (continuity equation):

$$\frac{\partial}{\partial t} \int_V \alpha_i \rho_i dV + \int_A \alpha_i \rho_i \bar{V}_i d\vec{a} = 0$$

where ρ_i – i-phase density

$\bar{V}_i$ – i-phase velocity (in case of modeling of turbulent flow by RANS-type model - time averaged)

3. Equation of the change in the amount of motion:

$$\begin{aligned} \frac{\partial}{\partial t} \int_V \alpha_i \rho_i \bar{V}_i dV + \int_A \alpha_i \rho_i (\bar{V}_i \bar{V}_i) d\vec{a} = & - \int_V \alpha_i \nabla p dV + \\ & + \int_V \alpha_i \rho_i \bar{g} dV + \int_A [\alpha_i (T_i + T_i^t)] d\vec{a} + \int_V \bar{M}_i dV \end{aligned}$$

where $(\bar{V}_i \bar{V}_i)$ – tensor product of velocity vectors of the i-nd phase.

p – pressure

$\bar{g}$ – mass force intensity vector (in this case, gravity force 9.81 m/s² and inertia force from the rotation of the calculation area)

T_i – molecular viscosity stress tensor

T_i^t – turbulent stress tensor

$\bar{M}$ – vector of total intensity of interphase interaction forces per unit volume, for the vector $\bar{M}_i$:

$$\sum_i \bar{M}_i = 0$$

Vector $\bar{M}_i$ characterizes all the forces by which the individual phases interact with each other.

$$\bar{M}_i = \sum_{j \neq i} (F_{ij}^D + F_{ij}^{VM} + F_{ij}^L + F_{ij}^{TD} + F_{ij}^{WL})$$

$$\bar{M}_i = \sum_{i \neq j} (\bar{F}_{ij}^D + \bar{F}_{ij}^{VM} + \bar{F}_{ij}^L + \bar{F}_{ij}^{TD} + \bar{F}_{ij}^{WL})$$

Where

$\overline{F_{ij}^D}$ – resistance force

$\overline{F_{ij}^{VM}}$ – virtual mass strength

$\overline{F_{ij}^L}$ – lifting force

$\overline{F_{ij}^{TD}}$ – force caused by turbulent dispersion

$\overline{F_{ij}^{WL}}$ – the force caused by the wall effects

The semi-empirical model k- ω SST turbulence model well-proved in the calculation of dynamic machines was used for this task[17,18,19,20]. The flow part of the gas separator was simulated on a grid consisting of 580 thousand cells. The cells in the flow core have a multi-faceted shape, while the solid walls of the pipe have a prismatic shape. The design grid for fluid body is shown in Figure 3.

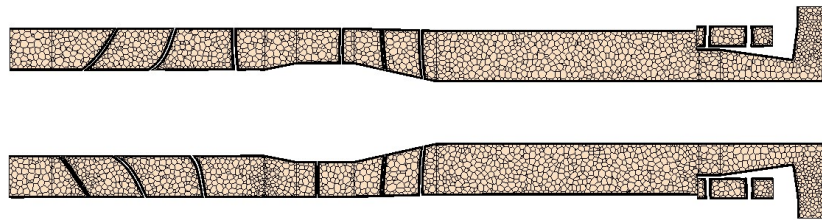


Fig.3.Mesh

3. Results and analysis

The calculated speed as an initial condition was set at the outlet boundary of the separated water in order to comply with the condition of equal pressure at the inlet and outlet of the gas separator into the pipe with unseparated fluid. Therefore, in order to compare the data at different phase ratios, graphs of the gas separation factor (Fig. 4), power (Fig. 5), head (Fig. 6) on the flow rate at the boundary where the speed was specified were made.

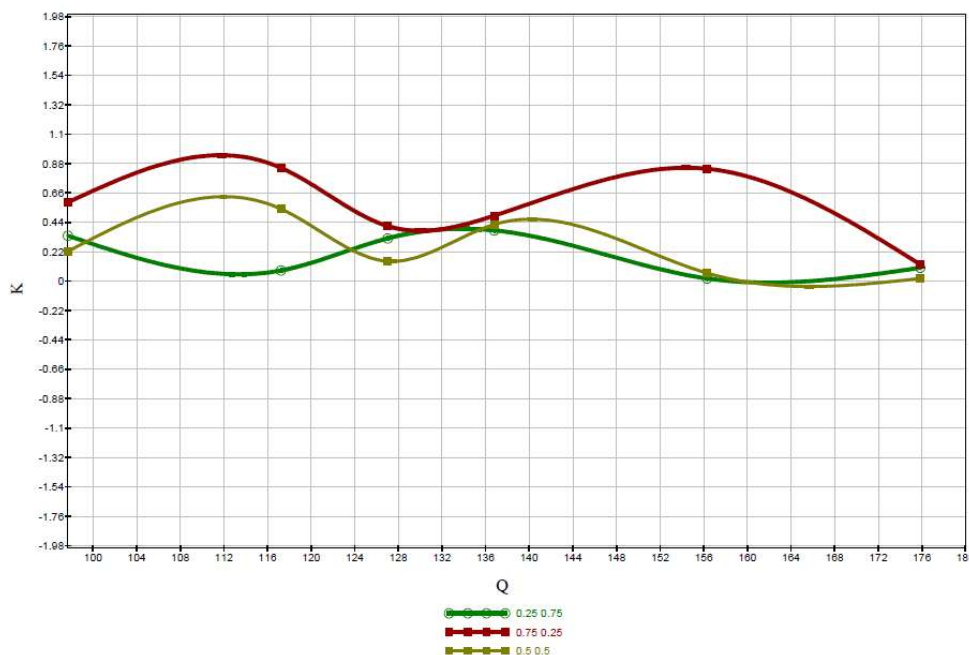


Fig.4. Gas separation factor

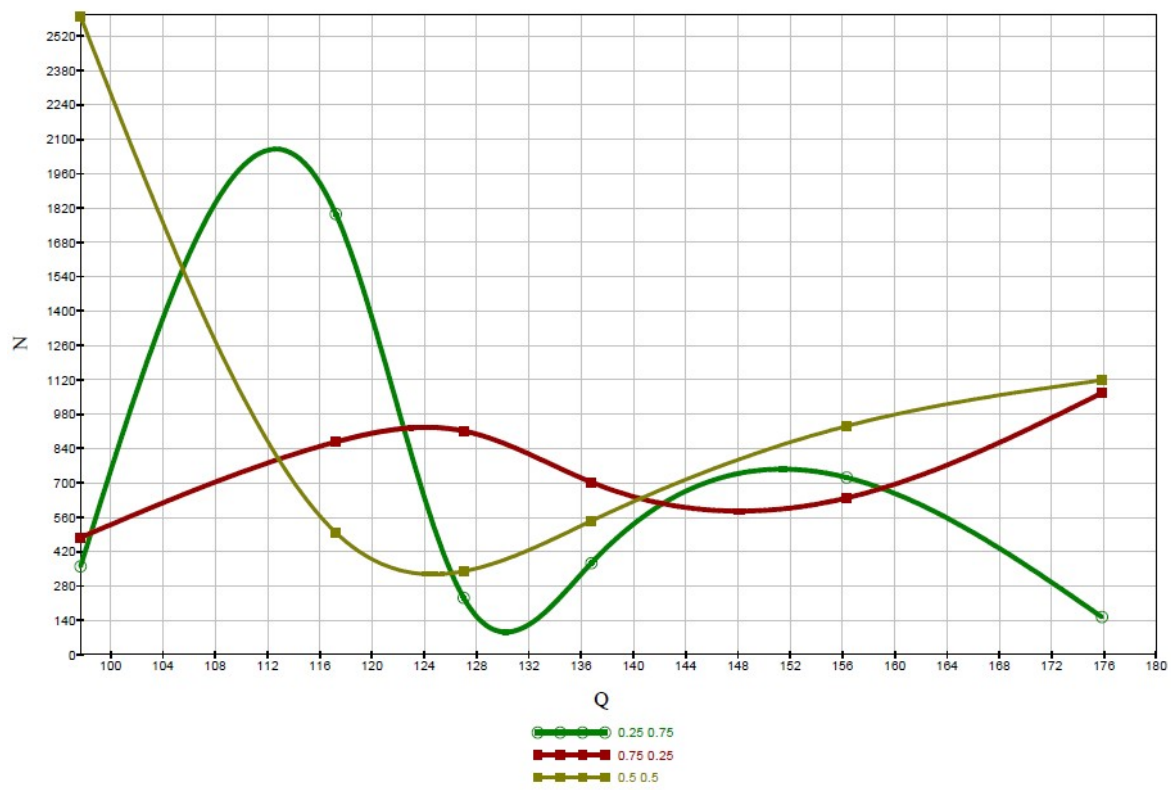


Fig.5. Power

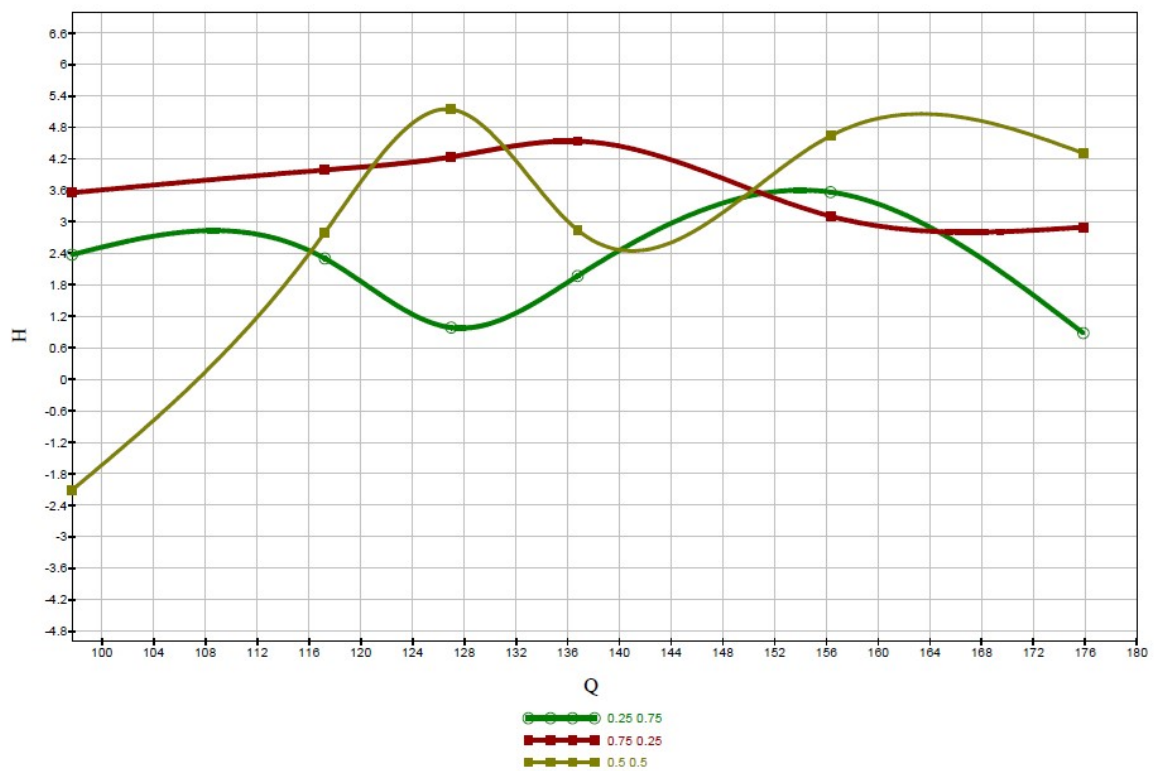


Fig.6. Head

Figure 7 shows the scene of volume fraction distribution. One can observe that the heavier fraction is pressed against the walls under the influence of inertial forces, while the lighter fraction remains near the shaft. Significant phase separation occurs in the centrifuge.

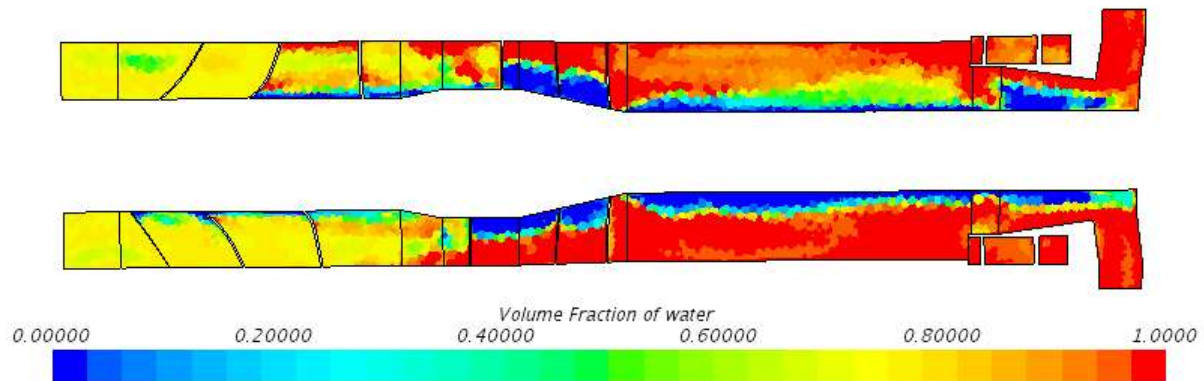


Fig.7. Volume Fracriion of water

For the most visual representation of a picture of a flow in a gas separator flowing part in figure 8,9 scalar scenes of pressure and speed distribution at $Q=136,7\text{m}^3/\text{day}$ and a phase ratio on an input 75 % water, 25 % gas are shown.

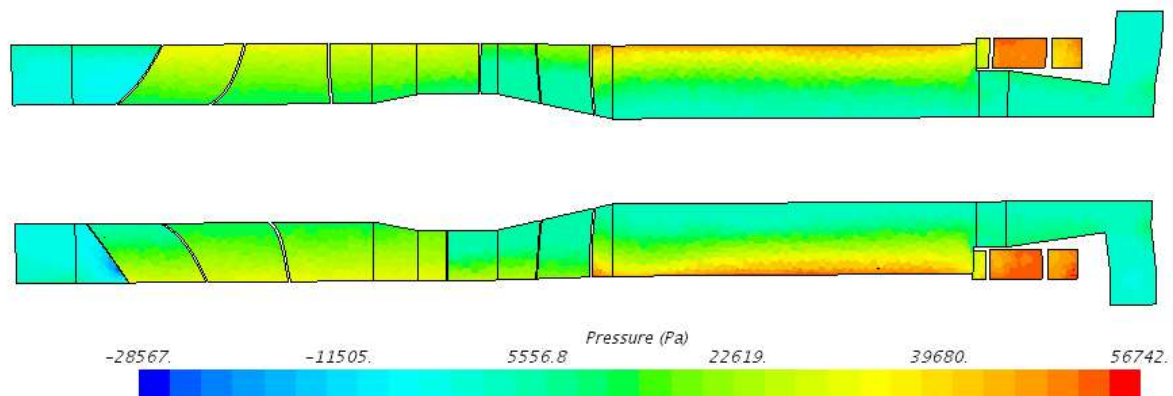


Fig.8. Pressure

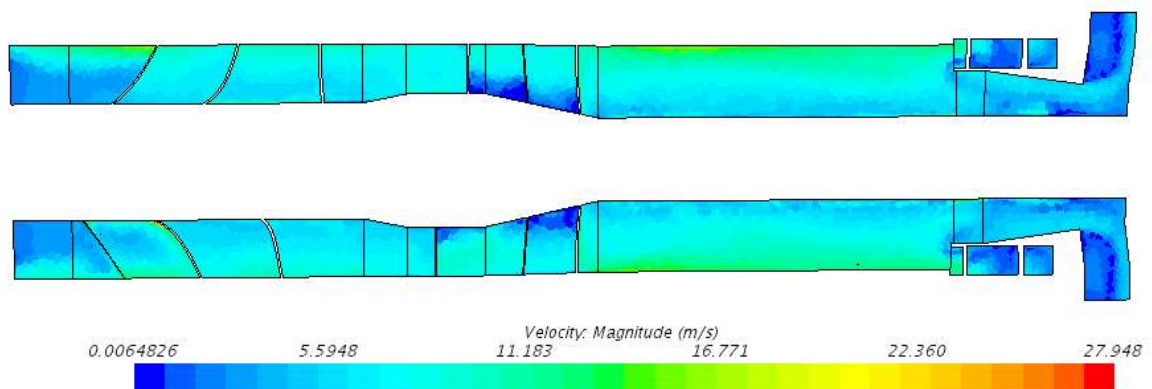


Fig.9. Velocity

4. Conclusions.

According to the results of the performed calculations, ambiguous dependences of the gas separation coefficient on the flow rate at different gas contents were obtained. Similar behavior of the coefficient value is apparently related to the mechanism of interaction between the screw inducer and the centrifuge when working on a mixture of air and water. In this paper, the study of the entire gas separator without studying the nature of the flow in its individual elements was carried out. Also it can be noticed that separation coefficient is high at low gas content. In addition, there is a flow rate range in which the optimum operating mode is observed (the lowest power with a high separation factor, in this case at a flow rate of 130....150m³/day). To obtain a more detailed picture and explanation of the dependencies type further research is required including the flow simulation of individual components of the unit.

References.

- [1] SWAROOP KOLLA, S., MOHAN, R.S. and SHOHAM, O., 2018. Structural Integrity Analysis of Gas-Liquid Cylindrical Cyclone (GLCC) Separator Inlet. *Journal of Solar Energy Engineering, Transactions of the ASME*, 140(5),.
- [2] HE, X., LIU, Q., ZHANG, H., KUI, M.-., TAN, X.-. and LI, X.-., 2019. Numerical investigation of the performance of moisture separators based on two-way coupling model by Lagrangian-Eulerian methodology. *Annals of Nuclear Energy*, 124, pp. 407-417.
- [3] XU, W., LI, Q., WANG, J. and JIN, Y., 2016. Performance evaluation of a new cyclone separator - Part II simulation results. *Separation and Purification Technology*, 160, pp. 112-116.
- [4] XIONG, Z., JI, Z. and WU, X., 2014. Development of a cyclone separator with high efficiency and low pressure drop in axial inlet cyclones. *Powder Technology*, 253, pp. 644-649.
- [5] XU, M., YANG, L., SUN, X., WANG, J. and GONG, L., 2019. Numerical analysis of flow resistance reduction methods in cyclone separator. *Journal of the Taiwan Institute of Chemical Engineers*, 96, pp. 419-430.
- [6] SELVAGANESH, P., RESHI, O. and SCHLAUTMAN, J., 2018. Numerical prediction of engine air oil separator efficiency, FISITA World Automotive Congress 2018 2018.
- [7] A Protopopov and V Vigovskij 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **492** 012003
- [8] N Egorkina and A Petrov 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **492** 012015
- [9] T Valiev and A Petrov 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **492** 012038
- [10] PAREKH, J. and RZEHA, R., 2018. Euler–Euler multiphase CFD-simulation with full Reynolds stress model and anisotropic bubble-induced turbulence. *International Journal of Multiphase Flow*, 99, pp. 231-245.
- [11] ZHARKOVSKY, A., 2003. Mathematical modeling of working processes in centrifugal pumps of low and medium speed for the solution of problems of the automated designing . Dissertation and the abstract on HAC RF 05.04.13.
- [12] LOYTSYANSKIY, L., 2003. Mechanics of Fluid and Gas Textbook for HEIs. - 7th edition, Prosp. - Moscow: Drofa.
- [13] GUO, H., ZHOU, C., JIANG, Z. and ZHOU, X., 2018. Study on separation characteristics of two-phase flow in double helical separator, *VibroengineeringProcedia* 2018, pp. 274-278.
- [14] MADHANIA, S., MUHAMMAD, Y., WINARDI, S., PURWANTO, W.W. Mechanism of molasses–water mixing behavior in bioethanol fermenter. Experiments and CFD modeling (2019) *Energy Reports*, 5, pp. 454-461.
- [15] LIU, M., TAN, L., CAO, S. Dynamic mode decomposition of gas-liquid flow in a rotodynamic multiphase pump (2019) *Renewable Energy*, pp. 1159-1175.
- [16] HOSANGADI, A., LIU, Z., WEATHERS, T., AHUJA, V., BUSBY, J. Modeling multiphase effects in CO₂ compressors at subcritical inlet conditions (2019) *Journal of Engineering for Gas Turbines and Power*, 141 (8)
- [17] A Trulev et al 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **492** 012041

- [18] A Sinitsyna et al 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **492** 012007
- [19] Loginov, V.F. Compression pumps for oil production in complicated conditions (Kompressionnyenasosydlaneftedobychi v oslozhnennykh usloviyakh) (2016) Oil and Gas Journal, pp. 54-56.
- [20] YAKHOT, V. and ORSZAG, S.A., 1986. Renormalization-group analysis of turbulence. Physical Review Letters, 57(14), pp. 1722-1724.