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THE ESTIMATED REASON FOR THE LOW EFFICIENCY OF HYDROCYCLONES IN PETROLEUM INDUSTRY

Gafar Ismayilov, Amrah Gulubayli, Samir Musayev, Shafa Musayeva

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Azerbaijan State Oil and Industry University
asi_zum@mail.ru
emrah_qulubeyli@yahoo.com
musasf@bp.com
shafamusayeva@mail.ru

Abstract

The real media encountered in oil and gas production are usually dispersed, i.e., they are systems consisting of at least two phases, with one of the phases being distributed into the other. Production, collection and transportation of oil and gas are based on multiphase technology, including the processes of lifting from the reservoir, transportation to separation points, separation and infield transport of multiphase mixtures, which consist of oil, gas, formation water and mechanical impurities.

In most technological processes of oil and gas production and transport of hydrocarbons, the separation of dispersed systems is necessary. In practice, the unsuitability of hydrocyclone technology for separating emulsions has been established, although hydrocyclones are effectively used for cleaning suspensions, for separating solid particles from liquids, for example, for cleaning drilling fluids from sludge.

Recent studies have established that cylindrical multiphase flows are based on the interaction of continuous and dispersed phases, the driving force of which is an additional shear force directed towards the flow axis.

In the paper, according to the multiphase technology, the reason for the low efficiency of hydrocyclones for multiphase disperse systems was analyzed. The condition of equality of the shear and centrifugal forces during the operation of the hydrocyclone is shown. It has been established that, based on the correct choice of technological parameters, it is possible to avoid the negative effect of the shear force in cylindrical flows on the operation of hydrocyclones.

Keywords: Dispersed systems, hydrocyclone, multiphase flow, shear force, phase interaction, suspension

I. Introduction

As it is known, oil and gas extraction, gathering, transportation to processing sites, separation, as well as oil, gas, formation water and mechanical particle cleaning processes are based on multiphase technologies.

Dispersed multiphase systems are also found in industry as aerosols, mists and suspensions, which can be classified according to the particle size of the dispersed phase.

For most technological processes of oil and gas production and transportation of hydrocarbons it is necessary to separate the dispersed systems. Depending on the type of disperse system, the following methods of separation can be used: sedimentation, filtration, centrifugation and flotation.

Centrifugation is a method of separating heterogeneous, disperse liquid systems into fractions by density under the action of centrifugal forces. Centrifugation is carried out in centrifuges, the principle of which is based on creating a centrifugal force, which increases the speed of separation of the mixture components compared to the speed under the influence of gravity. The separation of substances by means of centrifugation is based on the different behavior of particles in the centrifugal field. Particles with different density, shape or size are deposited at different speeds.

From the physical point of view, separation of heterogeneous systems by centrifugation can be considered as a process of free or constrained deposition of suspended particles in a liquid under the action of a centrifugal force. Suspended particles can be solid or liquid.

Centrifugal force is generated by the rotation of the centrifuge and the liquid in it. Centrifugal forces also cause separation in hydrocyclones, which differ in design from centrifuges. A distinction should also be made between cyclones and hydrocyclones. Cyclones are used for dust collection and gas purification and hydrocyclones for slurry purification.

In hydrocyclones, when the mixture to be separated enters it tangentially through the inlet nozzle and acquires circular motion, significant centrifugal forces arise, which many times exceed gravity, and under the action of which the heavier phase moves from the hydrocyclone axis to its walls on a spiral trajectory and downwards through walls and is discharged through the bottom nozzle from the hydrocyclone. The lighter phase moves in an upward along the axis and is discharged from the hydrocyclone through the upper product outlet. Close to the hydrocyclone axis, the centrifugal forces increase so much that an air column appears due to a liquid rupture.

In the oil industry, researchers [1-3] studied the issues of application of hydrocyclones for separation of water-oil emulsions. However, to this day, the issues of increasing the driving forces of separation in some cases raise doubts on the efficiency of operation of hydrocyclones. Practically, the unsuitability of hydrocyclone technology for separation of emulsions is established, although hydrocyclones are effectively used for separation of mechanical impurities from gases and air, for separation of solids from liquid, for example, for cleaning of drilling fluids.

II. Problem of research

The reason for the low efficiency of hydrocyclones for the separation of water-oil emulsions can be explained based on the theory of gradient-velocity field dynamics and the mechanism of phase interaction during their separation can be explained.

As it is known, the rate of separation of heterogeneous systems in the field of centrifugal forces is higher than the rate of separation of these systems in the field of gravity. Centrifugal force arises as an inertial force during the rotation of objects and is always directed radially outward from the axis of rotation.

In general case, the centrifugal force (F_c) is expressed by the following equality:

$$F_c = \frac{mv^2}{r} \quad (2)$$

Where, m-mass of the rotating particle,

$r -$ radius of rotation, m,

$v -$ is the circumferential speed of rotation, which is equal to:

$$v = \frac{2\pi nr}{60} \quad (3)$$

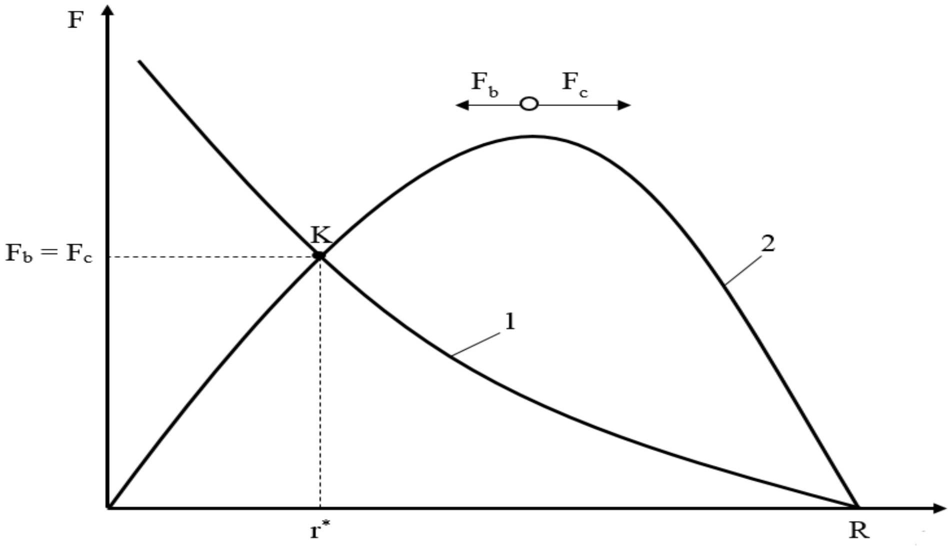
Where, n-number of revolutions per minute.

Given (2) to determine the centrifugal force can be written:

$$F_c = 1.85 \cdot 10^{-3}\pi d^3 \rho_p n^2 \cdot r \quad (4)$$

Here d and ρ_p-are respectively the diameter and density of the rotating particle.

Graphs of the distribution of driving forces of separation of multiphase water-oil mixtures in the hydrocyclone can be represented as in Fig. 1. As can be seen from Fig. 1, line 1, which characterizes distribution of centrifugal force increases with decreasing distance to the cyclone axis. Line 2 characterizes the distribution of Bernoulli forces, which has a maximum at a 0.577R distance from the cyclone axis (R is the cyclone radius). It is also seen from Fig. 1 that these forces are opposite forces, as a result, when Bernoulli force exceeds centrifugal force (F_s) dispersed water drops move to cyclone's axis but not to its walls. As a result of counteraction of the noted forces, it is not always possible to obtain in the hydrocyclone the components of the mixture in pure form.



1- Centrifugal force. 2- Bernoulli force

Fig. 1: *Driving forces of hydrocyclones*

III. Solution of problem.

In view of the above, the conditions of equality of Bernoulli force and centrifugal force in the hydrocyclone were analyzed. Bernoulli force in the general case according to the equation of the second law of mechanics in the presence of dispersion medium of mechanical particles with diameter (d) can be determined by the following formula [4,5,6]:

$$F = 8.39\rho d^3 u^2 \alpha(1-\alpha^2)/D \quad (4)$$

Where ρ - is the density of the dispersion medium kg/m^3 ,

$\alpha = r/R$

Given that at point K (Fig. 1) the noted forces are equal, then according to expressions (3) and (4) we can write

$$1.85 \cdot 10^{-3}\pi d^3 \rho_p n^2 \cdot r = 13{,}172 d^3 \rho u^2 r \left(1-\frac{r^2}{R^2}\right)/R^2$$

After some abbreviations we obtain the following condition for calculating the parameter r^*, corresponding to $F_c \geq F_b$:

$$r \leq R\sqrt{1-0.00044\cdot\frac{\rho_p}{\rho}\cdot\frac{n^2R^2}{u^2}} \quad (5)$$

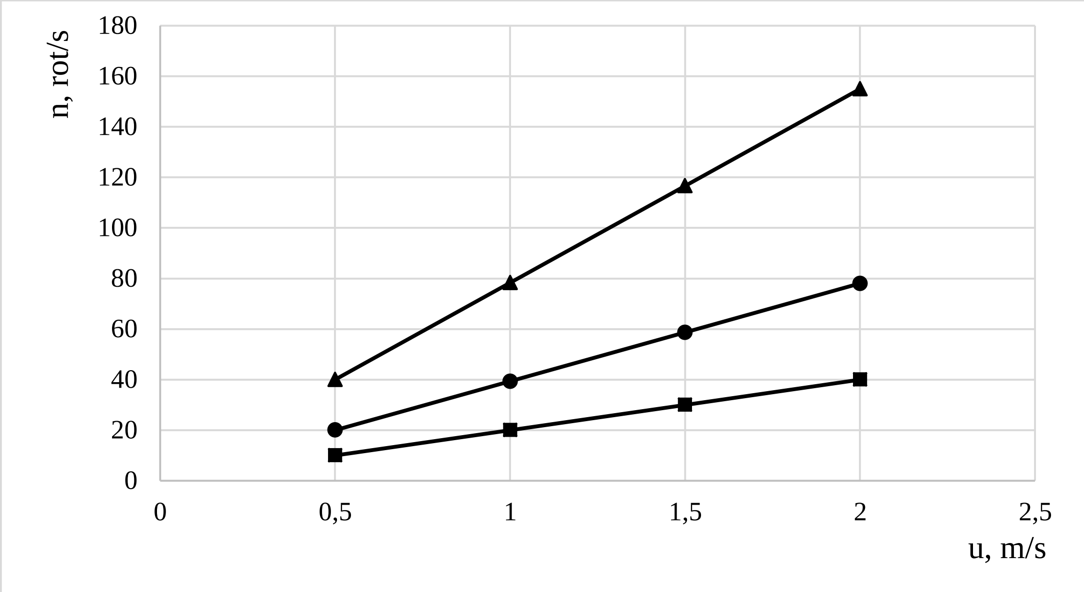
Condition 5 will be fulfilled according to the following equation:

$$n \leq \frac{u}{0.021\cdot R\cdot\sqrt{\rho_p/\rho}} \quad (6)$$

According to formula (6), we investigated the effect of flow velocity (u), radius of hydrocyclone (R) and the ratio of densities of particles and liquid on the number of rotation n. For this purpose, the calculation of the number of rotation was derived with the following initial data:

- flow velocity u=0.5; 1.0; 1.5; and 2.0 m/s.
- radius of the hydrocyclone R=0.2; 0.4; 0.6; 0.8; 1.0 and 1.5m
- ratio of densities $\frac{\rho_p}{\rho}$= 1,3; 1,5; 2,0; 2,5.

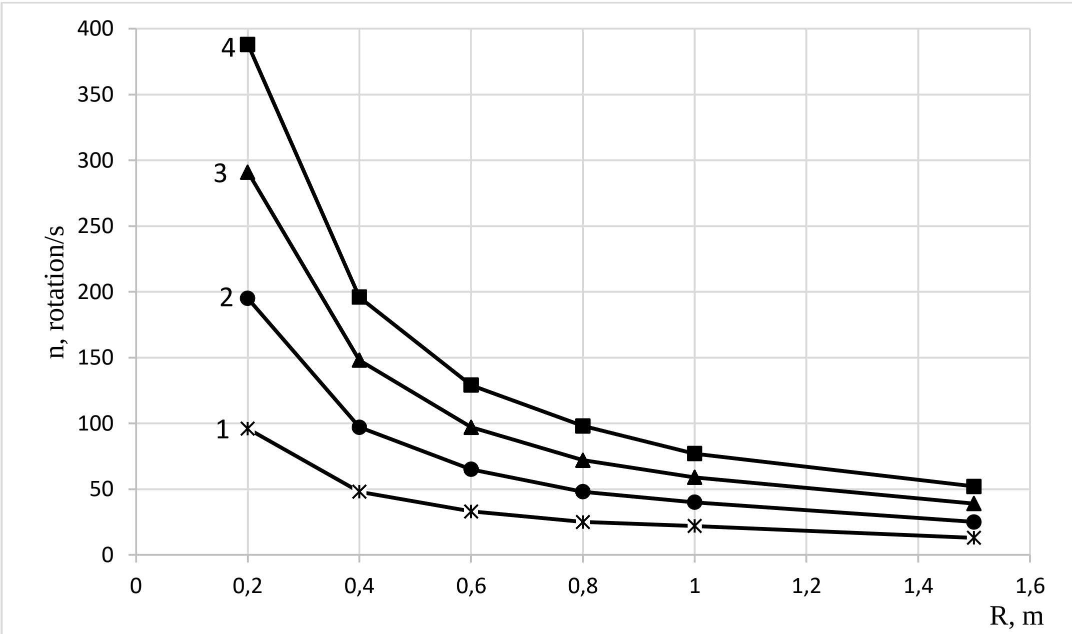
Based on the results of the calculations, the dependences n=f(u) and n=f(R) were plotted, which are shown in Fig. 2.



1 – R=0.5m. 2 – R=1.0m. 3 – R=2.0m

Fig. 2: D*ependence of n=f(u)*

As can be seen from Fig. 2, the number of rotation increases proportionally as the flow velocity increases in accordance with condition (5). At this time, the number of cycles decreases monotonically with the increase of the radius (R) of the hydrocyclone. (Figure 3)



1 – u=0.5m/s. 2 – u=1.0m/s. 3 – u=1.5m/s. 4 – u=2.0m/s

Fig. 3: *Variation of the number of rotation (n) as a function of R .*

It should be noted that, with the help of the constructed dependences, it seems possible to avoid the negative influence of Bernoulli's force on the operation of hydrocyclones based on the choice of the above-mentioned parameters.

IV. Conclusions

According to multiphase technology, the reason of low efficiency of hydrocyclones for separation of multiphase systems was analyzed. It has been determined that, based on the correct selection of technological parameters, it is possible to prevent the negative impact of the force generated along the cross section in cylindrical flows on the operation of hydrocyclones.

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