NEWS

Gazprom gives green light to a liquefaction plant in Vladivostok

The management of Gazprom JSC has approved the investment proposal for the construction of a liquefaction plant near Vladivostok. The plant will have three production lines, each with an annual capacity of 5 million tonnes of liquefied natural gas. It is expected that the first phase of the plant will be commissioned in 2018. Gas will be delivered from Sakhalin offshore fields, as well as from Yakutia and Irkutsk region. This gas will be sold in the Asia-Pacific region.

Pipeline & Gas Journal / April 2013, p. 4

New large gas field in Qatar

According to the official sources of Qatar, a new gas field has been discovered after intensive exploration over the last four years, including the drilling of two exploration wells within the block - 4N. Qatari partners Wintershall and Mitsui were partners of Qatar Petroleum.

Initial gas reserves at the field are estimated at 140 billion m^3.

Pipeline & Gas Journal / April 2013, p. 14

Japan starts extracting methane from gas hydrate deposits

According to a report from Japan, gas production from offshore deposits of methane hydrates started last month, which, according to leading experts, can lead to the development of this promising energy source. It is believed that extracting gas from marine gas hydrates has been performed here for the first time in the world. Experts estimate that carbon content in gas hydrates is at least twice that of all other fossil fuels in total.

Pipeline & Gas Journal / April 2013, p. 14

OIL AND GAS PRODUCTION

Simulation of filter gravel pack in-wash in a well with a significant deviation from a vertical or in horizontal well

E. H. Striukov

“Naftogaz of Ukraine National joint-stock company” PJSC

УДК 622.276

Swirling flow simulation problem is used to develop algorithms for structural optimization of swirlers designed for installation of a gravel filter in horizontal or controlled directional wells. The practical need for study of hydrodynamic processes for circular channels encourages the use of numerical calculations for a set of basic models with a different simplification degree. The paper presents the relevant models and design data.

Mathematical modeling of swirling flows is one of the most important tools of research. This allows in many cases to reproduce a detailed picture of the studied currents, calculate the main characteristics of the flow.

Hydrodynamics in a horizontal borehole of the well is characterized by the velocity vector of the flow, which is perpendicular to the velocity vector of deposition of solid granules of liquid gravel mix. The lack of vertical component of velocity vector makes settling solids on the bottom wall of the borehole. While settling granule gravel moves along the flow, the time of its deposition will affect for the path of its movement. Its shape, size, density, velocity diagrams of horizontal flow, viscosity and density of the liquid carrier also affects on this movement along the borehole. Swirling flow can be created not only through the use of specially designated device that swirl (active methods), but also by the ribs, forming surfaces, using screw guides, winding-up etc. We distinguish types of swirling flows in channels that meet basic types of swirling. These are:

damped swirling flows that occur in a unused channel that is located behind the swirling at the entrance;

swirling flows with a constant level of swirling intensity, which is formed and maintained by swirling means along the entire length of the channel.

We have developed and patented [1] the design and technology of gravel filter installation using the flow tightening of working fluid during deposition of gravel filter pack-in.

Considering the hydrodynamic processes in channels with swirling of all types, we can say that the term "swirling flow" refers to two characteristics of the flow: the fluid motion in the channel is simultaneously vortex and circulating (progressive rotation), that is characterized by local swirling ω and large transverse circulation of flow due to the presence of tangential velocity components, roughly equal to the loss rate in the channel [2].

The difficulty of solving the problem of shape influence of swirling on hydrodynamics in cylindrical channels using Reynolds averaging in time is due to the lack of a universal model for description of turbulent tensor (Reynolds') stresses in channels with complex configurations if they have areas of flow separation, swirling motion with variable intensity of swirling and other complicating factors.

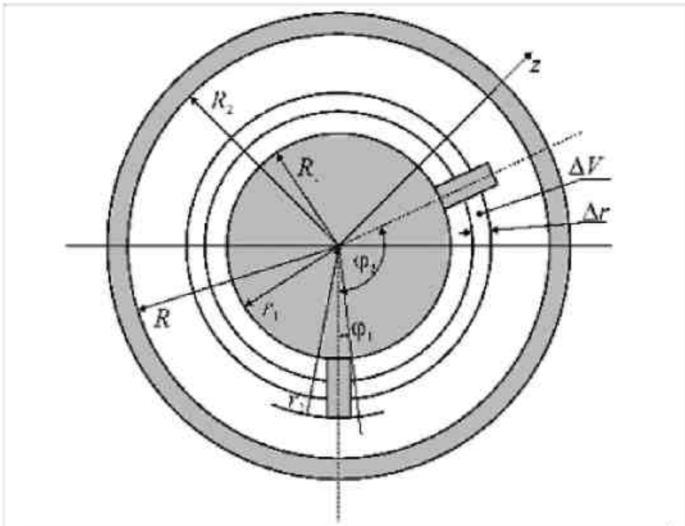

Fig. 1. Cross-section of the channel with swirlers (screw guide)

Spatial averaging is one of the ways to simplify the formulation of the problem and identify the influence of geometrical factors on the hydrodynamics of complex turbulent flows. While the use of spatial averaging leads to an approximate solution of the problem based on the consideration of integral equations, this approach makes it possible to develop methods of calculations that allow to take into account the influence of swirlers with different geometry on hydrodynamics in the channels.

Using the averaging by volume, the dimensions of which are defined by the characteristic scale of spatial inhomogeneities currents that associated with features of the geometry of complex channels, helps to come to the consideration of averaged continuum as an effective homogenized medium. In particular, the procedure application of local averaging by volume for turbulent flows and flows in porous structures can lead to a nonzero value of the average velocity at the wall, i.e. to the slip condition on the boundary. Therefore, the spatial averaging procedure requires redefining the boundary conditions and taking into account the maintenance of integrated balance of momentum, mass, and entering the appropriate description of effective coefficients of momentum transfer, which is related to the friction with distribution of velocity averaged flow.

Problem setting of mathematical modeling of hydrodynamics of swirling flows in channels with swirlers can be simplified as compared with the setting in the form of known differential equations, in case of averaging these equations by space considering the characteristics of the geometry of the channels [3].

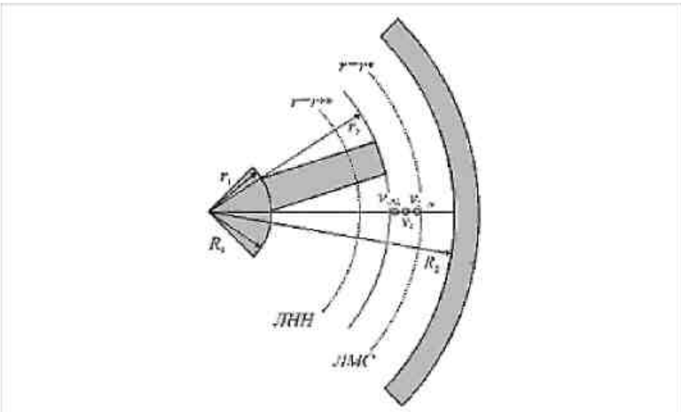

Fig. 2. Calculation model of annular channel with a random placement of screw guides: R1, R2 – inner and outer radii of the annular channel; r1, r2 – radii that limit the placement area of screw guides; r = r* – LMV – the line of maximum velocity uz = uz max; r = r** – ZVL – zero-voltage lines τrφ = 0

Considering the specificity of turbulent flows in flowing swirlers, including the fact that the main features of currents are in the volume of annular module $r1 \le r \le r2$ (Fig. 1), where the spiral swirlers for the carrying out of procedure of the averaging volume choose an elementary volume ΔV in a form of annular sphere with infinitesimal thickness and width Δz: $\Delta V = 2\Delta r \Delta r \Delta z$, where Δr, $\Delta z \to 0$ (see Fig. 1). Region of the swirlers in a radius ($r1 \le r \le r2$, $r2 \le R$) and their cross-sectional shape can be random.

Numerical calculations of currents

An important feature of turbulent swirling flow of fluid in annular channels is a complex nature of the influence of inertial forces not only on the formation of averaged velocity fields and pressure in the channel, but also on the characteristics of turbulent wall surface transfer. This is due to the fact that besides the spatial curvature of the current lines of swirling flow, it leads to the transverse gradient pressure, the surfaces of channel, which are limiting the area of flow, have the opposite sign of curvature in relation to the flow. The local inhomogeneities of inertia forces near surfaces lead, on the one hand, to the stabilization of the flow and reduction of the turbulent transport near the convex surface of the channel, and on the other hand, they lead to destabilization of the flow and enhancing of turbulent transport concave surface.

Parameters of liquid and gravel mixture

Parameters	Fluid density $P_ж$, kg/m^3	Fluid Viscosity $V_ж$, mPa·s	Gravel density $P_г$, kg/m^3	The concentration of granule gravel $K_Г$, kg/m^3	Grain size gravel $d_{min}/d_{max}/d_{mid}$, mm	Mass flow rate $G_ж$, kg/s	Volumetric flow rate Q, m^3/min	Mass flow gravel $G_г$, kg/s	Concentration of gravel $K_г$, kg/m^{33}	The velocity of the particles V, m/s	The value of static pressure at the outlet P, mPa
Option 1	1250	2	2630	100	0.2/0.4/0.3	20.83	1	1.67	100	0.786	10
Option 2	1250	30	2630	100	0.2/0.4/0.3	20.83	1	1.67	100	0.786	10

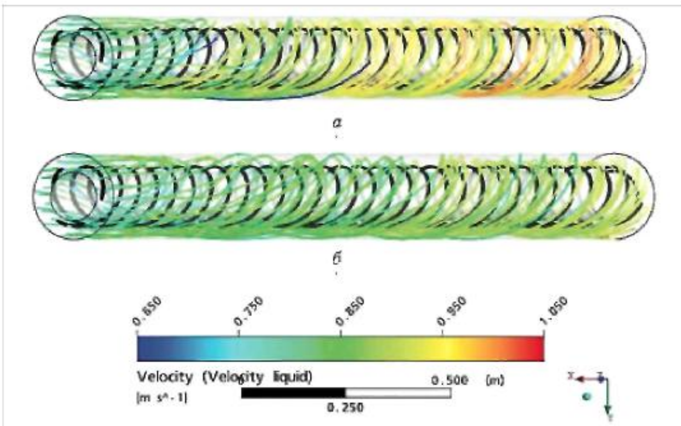

Fig. 3. Isolines of velocity in the pipe (*a* – at the viscosity of the fluid □ж = 2 mPa•s, *б* – at the viscosity of the liquid □ж = 30 mPa•s)

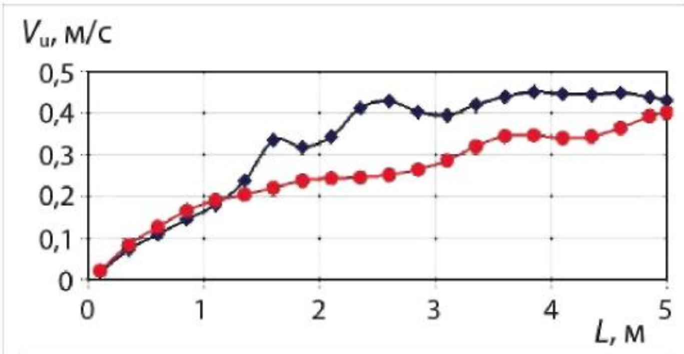

Fig. 4. The dependence of the value of the rotating component of the flow velocity (V_u) from the path length (*L*) (rhombus - at the viscosity of the liquid □ж = 2 mPa•s, circle - with the same viscosity of the fluid □ж = 30 mPa•s)

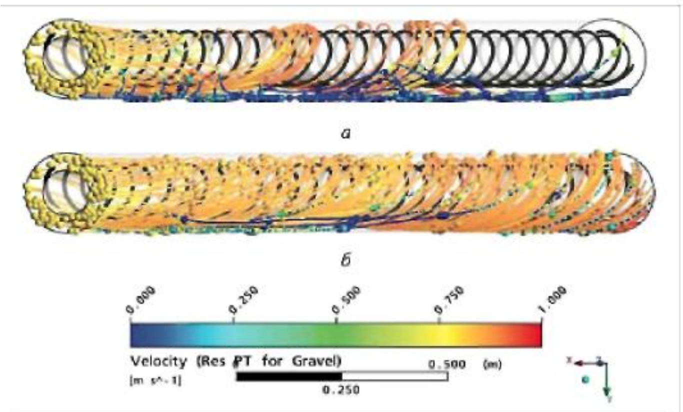

Fig. 5. Trajectory of the particles of gravel (*a* – at the viscosity of the liquid □ж = 2 mPa•s, *б* – at the viscosity of the liquid □ж = 30 mPa•s)

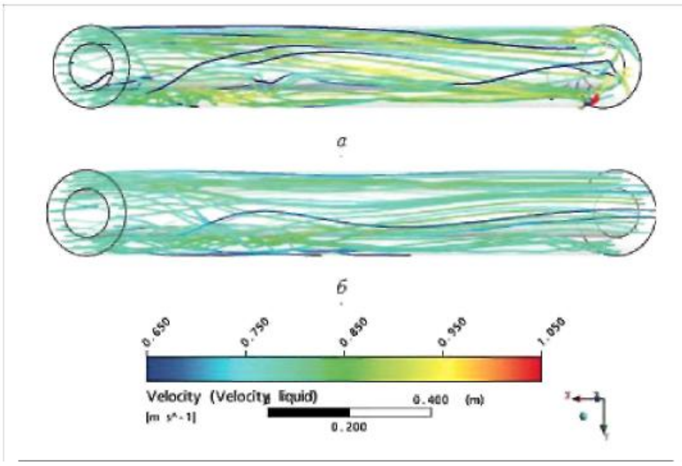

Fig. 6. Isolines of velocity in the channel (*a* – at the viscosity of the liquid □ж = 2 mPa•s, *б* – at the viscosity of the liquid □ж = 30 mPa•s)

According to the calculating analysis being carried out, it is important to highlight the following. The result of a complex influence of uneven distribution of forces of inertia and pressure on the flow during the swirling flow in annular channels is divergence of lines of maximum velocity rate (LMV) and zero-voltage lines (ZVL), i.e. the position of the points in which derivative of velocity is becoming zero along the radius and friction voltage are different. These circumstances should be considered for the organization of the calculation process (Fig. 2).

According to this scheme, it is assumed that the region of swirler location r1 ≤ r ≤ r2 can be random, and, in the extreme case, take the full width of the channel or be absent at all, i.e. $R_1 \le r_1 \le R_2$, $R_1 \le r_2 \le R_2$. The numerical solution of equations is conducted in the areas between each of the surfaces of the channel and maximum velocity rate LMV line or zero-voltage lines ZVL. The field of swirler location is highlighted in Fig. 2 with large shading, it can be placed on one or both sides of LMV and ZVL. The components of the tensor impedance k_{ij}, and hence the resistance components f_φ i f_z are nonzero only in the middle of the field with $r_1 \le r \le r_2$ [3].

The use the results of simpler models makes it possible to include them in iterative procedures for more complex variational finite-difference methods.

The number of nodes in the grid (finite elements) is sufficiently large. Then we give the results of numerical calculations for the geometry described swirlers.

The aim of this calculation was the modeling based on introduced equations of possibilities for sustainable rotational-translational motion of liquid and gravel mix using set screw guides on the outer surface of the tube concentrically located inside a pipe with larger diameter.

Three-dimensional model was created using the software package SolidWorks. The calculation was performed using the software package Ansys.

Initial data for calculation

The parameters of gravel-liquid mixture, which are close to the actual parameters, were set to perform the numerical calculation. The following table describes the parameters of liquid and gravel mixture.

The calculation was carried out for three western screw guides. The length of pipe was installed in 5 m. The move of the guide screw is 0.5 m.

The calculated grid is unstructured, tetrahedral. Near the walls of the pipe and screw guides 10 layers of prismatic cells are mounted for improved scaling of the wall layer. The number of cells of calculated grid is approximately 3,350,000. According to the calculation results pressure losses are obtained in the pipe five-meter length Δp = 1112 Pa – for fluid viscosity, $V_ж$ = 2 mPa·s, Δp = 1804 Pa – for the same viscosity of the fluid $V_ж$ = 30 mPa·s.

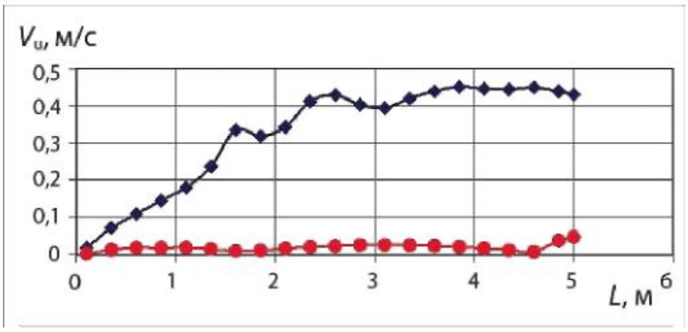

Fig. 7. The dependence of the rotating component of the flow velocity (V_u) of path length (L) at the viscosity fluids □$_ж$ = 2 mPa•s (channel with a screw guides – rhombus, channel without screw guides – circle)

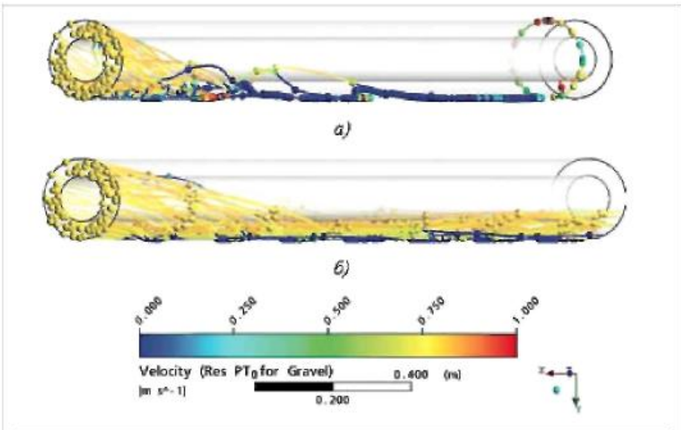

Figure. 8. Trajectory of the particles of gravel (*a* – at the viscosity of the liquid □= 2 mPa•s, *б* – at the viscosity of the liquid □= 30 mPa•s)

Fig. 3 shows the line of fluid current in motion in the annular channel in the presence of a screw guides. It can be seen that the flow passing over 25 % of the way, has a stable rotational-translational motion.

It is seen more clearly the presence of the annular velocity of the flow in quality and quantitatively, which is illustrated in Fig. 4 in a graph that represents the dependence of the flow value of annular velocity from the path length. It should be noted that the greater viscosity is, the slower increase of annular component is.

Fig. 5 shows the trajectory of the grains of gravel in the annular channel in the presence of a screw guides.

It may be noted that the greater the viscosity of the liquid is almost all granules are suspended, and with less viscosity the solids are left in the bottom wall of the outer tube (both with screw guides).

The calculation in the channel without screw guides

As a comparison, we can give the above described calculation of the initial data, which was performed for the annular channel without screw guides. Estimated grid is structured hexahedral.

Near the walls of the pipe and screw guides there are seals done to improve grid scaling of the wall layer. The number of grid cells is around 350 000.

According to the calculation results the value of pressure losses in the pipe of five-meter length is obtained Δp = 531 Pa – for the viscosity of the fluid $V_Ж$ = 2 mPa·s, and Δp = 766 Pa – for the viscosity of the fluid $V_Ж$ = 30mPa·s

Fig. 6 shows the line of fluid path in motion in the annular channel in the presence of a screw guides. It is evident that the process is without annular component

Fig. 7 shows the comparison of dependency of the annular velocity component of the path length. We can say that the annular component in the channel without screw guide is practically zero.

Fig. 8 shows the trajectory of the grains of gravel in the annular channel without screw guides. It is evident that with less viscosity of fluid gravel granules begin almost immediately to settle to the bottom and then to roll along the bottom. With greater viscosity granules settling takes place away from the entrance to the channel, and it is clear that some of the solid phase moves without depositing until the end of the channel.

Using the known results of swirling flows it can be concluded that the proposed model is suitable for numerical calculations of flows in annular channels with swirlers. Spatial averaging, taking into account stationary, phenomenological assumptions lead to a set of basic models that can be used for decision support systems with structural optimization of swirlers that are used in the oil and gas industry, in particular for making gravel filters in horizontal wells.

References

1. **Пат. 97518А** Україна, МПК С2 Е21В 43/08. Спосіб спорудження гравійного фільтра у свердловині та відновлення його фільтраційних характеристик у процесі експлуатації свердловини / Є.Г. Стрюков, Р.С. Яремійчук, І.В. Ніколенко, О.В. Бачеріков [та ін.]. – Бюл. № 4.

2. **Халатов А.А.** Теория и практика закрученных потоков. – К.: Наук. думка, 1989. – 192 с.

3. **Стрюков Е.Г.** Закрученные потоки в задачах гидродинамики горизонтальных скважин / Е.Г. Стрюков, В.А. Лукьяненко // Динамические системы. – 2011. – № 1. – Т. 1(29). – С. 169–190.

Author of this article

Ievgen Gennadijovych Striukov

The Head of Central Production and Dispatch Management of Public Joint Stock Company "State Joint-Stock Company "Chornomornaftogaz". "The main activity is a production logistics. Research interests: production of hydrocarbons from the unstable manifolds filters against sand.