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About one of methods for determining the true parameters of the gas-liquid flow in risers

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Annotation.
In oil and gas production, multiphase gas-liquid flows are very typical for risers of fountain and gas lift wells. In the article, a new approach for estimating the real parameters of multiphase flows is proposed, taking into account the phase shift, and the possibility of their determination based on the macroscopic parameters is shown.

Keywords: multiphase flow, gas lift riser, flow parameters, structural mode, phase shift.
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1. Introduction.

It is very important to correctly assess the true characteristics of those flows in order to solve engineering problems related to multiphase flows, to perform hydrodynamic calculations in accordance with thermo-baric conditions in the viewed (researched) section of the lifting pipes. The analysis shows that important parameters such as the real density of the mixture, the real volume capacity of the phases, which characterize such flows, depend to a great extent on the slippage (relative speed) of individual phases, as well as the cross-sectional migration [1-6].

2. Formulation of the problem and solving methods.

In general, the study and determination of the true gas capacity parameter for gas-liquid mixtures has been the subject of research by many scientists, but in many cases, it has concluded with contradictory results. Thus, a number of researchers have emphasized that the real gas capacity (φ) increases with the increase of the relative velocity of the gas phase (displacement relative to the liquid), and some of them have emphasized the decrease of the φ parameter with the increase of the relative velocity of the gas. There were also scientists who claimed that the mentioned dependence does not exist at all and that this effect occurs only at values of speed greater than 2 m/s. The analysis shows that, indeed, the problem of determining the drift factor of gas (bubbles and its germs) for the purpose of estimating the real gas capacity, although there are currently a number of analytical and semi-empirical formulas for determining the velocity of gas bubbles in multiphase flows, solving engineering problems it also necessitates and conditions the construction of simpler models based on well data and dependent on macroscopic parameters [2, 7, 8].

It is known that the relative velocity of gas in vertical pipes can be described by the interaction of Froud (*Fr*), Reynolds (*Re*) and We (*Weber*) criteria. According to these criteria, the diameter of the gas bubbles, the surface tension and the diameter of the pipe have the greatest effect on the relative velocity of the gas. The degree of influence of the last two parameters on the relative speed depends on the dispersion of the system. It happens when the diameter of the pipe, mainly the size of the bubbles (plug) is the same size as the diameter of the pipe. Since the laboratory tests were carried out in small diameter pipes ($<10^{-3}$ *m*), and the diameter of mining pipelines is relatively large, some of the obtained results may not be sufficiently justified. The question of determining the value of the diameter for gas bubbles in the risers in mining practice is also a very problematic issue.

Depending on the volume capacity of the liquid and gas phases in the fountain and gaslift risers, it is possible to have a liquid or gas phase as a dispersion phase. If we take into account that these processes occur with the change of pressure gradients both along the riser (longitudinally) and along the cross-section of the pipe, then the question of determining the true parameters for multiphase flows becomes even more relevant. Taking into account the above, the calculation of the real parameters of multiphase flows (the real density of the mixture, the real gas capacity and the relative velocity of the gas) was considered on the example of a gas lift (Fig. 1), and for this purpose, the operational data of gas lift wells were used (tables 1 and 2).

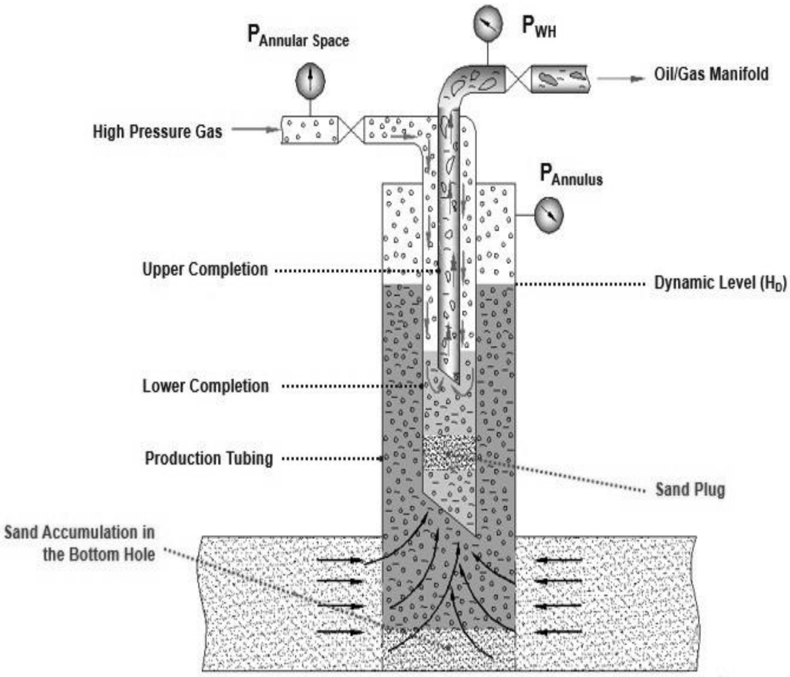

Figure 1. Scheme of the fountain or gas lift riser

Table 1

Tubing of the first and second row of wells in the Gunashli field (Submersible Platform -15) and information about changes in production (28.04.2022)

Well №	Row I		Row II		Production, t/day		Gas, ths. m^3/day		Gas factor (GOR) m^3/t	Gas consumption for 1 t oil
	73 mm	114 mm	48 mm	73 mm	Q_{oil}	Q_{water}	Injection	Production		
93	1358	1514	1199	1001	47.0	7.0	18.0	25.2	153.2	383.1
98	1547	1482	1100	1304	9.0	1.0	12.0	17.2	578.3	1334.6
220	1561	1466	595	1203	34.1	82.9	17.0	26.7	284.4	498.4
235	1468	1548	901	1303	37.0	24.0	17.0	26.5	256.6	459.3
237	1328	1591	901	1496	47.0	0	20.0	26.5	138.4	425.8
248	2305	703	1802	604	46.0	15.9	20.5	29.0	184.7	445.4
271	1260	1620	695.4	1503.6	35.0	1.0	17.0	34.8	508.8	485.9
272	1390	1405	1202	1201	37.0	1.0	21.0	36.6	421.6	567.6
274	1877	940	1496	706	34.1	1.0	6.0	34.5	836.9	176.2
275	1470	1488	805	1297	39.0	18.0	26.5	59.0	833.1	679.3
277	1348	1489	997	604	34.0	0	14.0	51.4	1099.0	411.4
279	1400	1492	698	1357	83.0	0	21.0	29.9	107.3	253.1
281	1509	575	1700	205	17.1	1.0	18.0	28.3	604.4	1056.2
283	1566	1444	1153	1252	9.0	1.0	27.0	34.2	800.7	3002.8
285	1356	1552	805	1302	35.0	0	23.0	31.9	254.1	656.8
294	876	1997	403	1974	57.0	0	19.0	28.5	166.6	333.2
431	2260	1081			20.0	0	31.5	44.0	624.6	1573.9

Table 2

Pressure and production changes in wells in the Gunashli (Submersible Platform-15) field

Well №	P_{wh}. atm	$P_{ann.sp.}$. atm	$P_{annulus}$. atm		Diameter of choke.mm	$Q_{oil.}$ m^3/day	Q_{gas}. m^3/day
98	18/19	20	30		10	10.3	15400
220	34/38	90/92	152		11	124.1	25800
235	46/64	96/100	140		8	67.7	25000
271	17/20	49	53		14	40.8	33700
274	19/24	53	58		15	40.8	33800
98	18/19	20	30		10	10.0	15700
220	34/38	90/92	156		11	124.6	25800
235	46/64	96/100	142		8	68	26000
271	17/20	49	53		14	41.0	33700
274	19/24	53	58		15	41.5	33500
98	18/19	20	30		10	10.5	15700
220	34/38	90/92	156		11	124.4	25800
235	46/64	96/100	142		8	68.6	27000
271	17/20	49	53		14	41.9	33700
274	19/24	53	58		15	42.0	33500
237	18/20	58	65		15	58.0	25800
281	21/22	43	53		11	21.6	25900

To calculate the actual density (ρ) of the mixture in the riser. the following formula was used based on the actual well data:

$$\rho_{act} = \frac{P_{op} - P_{buf}}{g \cdot h} \quad (1)$$

where P_{op} - working pressure;

P_{buf} – buffer pressure (it can also be wellhead pressure);

h is the length of the gas lift.

If we take into account that the density of the mixture is determined by the expression $\rho_{act}=\rho_{liq}(1-\varphi)+\rho\cdot\varphi$ based on the true gas capacity (φ) according to the rule of additivity. then we get the following expression for determining φ:

$$\varphi = \frac{\rho_{liq} - \rho_{act}}{\rho_{liq} - \rho_{gas}} \quad (2)$$

where ρ_{liq} and ρ_{gas} are the liquid and gas phase densities. respectively.

It is known from experience that the real gas capacity is $\varphi<\beta$ during the vertical movement from bottom to top due to the displacement of gas relative to the liquid in the fountain (gas lift) riser. Taking into account the slippage factor. the following expression can be written for the determination of the actual gas capacity:

$$\varphi = \frac{Q_{gas}}{Q_{gas} + Q_{liq} + Q_{slip}} \quad (3)$$

where Q_{slip} is the slippage consumption of gas;

Q_{gas} and Q_{liq} - gas and liquid consumption in the riser at medium pressure and temperature. respectively.

From the last expression. we get to calculate the consumption of slipped gas:

$$Q_{slip} = \frac{1-\varphi}{\varphi} \cdot Q_{gas} - Q_{liq} \quad (4)$$

Taking the average pressure in the gas lift as the arithmetic mean and taking into account the static level at the wellhead. the following expression can be written to determine gas consumption (Q_{cons}) under normal conditions:

$$Q_{cons} = (Q_{liq} + Q_{slip}) \cdot \frac{(P_{op} + P_{buf}) \cdot P_{buf}}{2P_0 \cdot (P_{op} - P_{buf})} \quad (5)$$

where P_0- is normal atmospheric pressure.

From the last statement. we get the following formula for the determination of Q_{slip}:

$$Q_{slip} = \frac{Q_{cons}}{A} - Q_{liq} \quad (6)$$

her

$$A = \frac{(P_{op}+P_{buf})\cdot P_{buf}}{2P_0\cdot(P_{op}-P_{buf})} \quad (7)$$

From the last expression. the parameter Q_{slip} can be calculated based on the operating data of the gaslift well. Considering that $Q_{slip} = 0.785D^2\cdot v_{rel}$ (D is the diameter of the lifting pipes). then the relative speed of the gas can also be determined:

$$v_{rel}=\frac{Q_{slip}}{0.785D^2} \quad (8)$$

Based on the data on the wells of the "Gunashli" field (Submersible Platform-15). using the pressure and other data on several gas lift wells. the real parameters of the multiphase gas-liquid flows in the lifters were calculated in the order mentioned above. and the results are given in table 3.

First. according to the formula (1). the gas-liquid mixture is calculated based on the worker ($P_{op} = P_{ann.sp}$). buffer pressure (wellhead pressure. $P_{buf} = P_{wh}$) and riser length (h) for wells № 98. 220. 235. 271 and 274. real density (ρ_{act}) is determined.

Table 3

The pressure on the wells in the Gunashli field (Submersible Platform-15) and values of the true parameters of the multiphase mixture in the riser

Well №	$P_{wh.}$ atm	$P_{ann.sp.}$ atm	$P_{annulus.}$ atm	$\rho_{act.}$ kg/m³	φ	A	$Q_{slip.}$ m³/day	$V_{rel.}$ m/sec
98	18/19	20	30	20.37	0.977	171.0	90.6	0.25
220	34/38	90/92	156	466.04	0.471	41.56	525.4	1.45
235	46/64	96/100	142	336.40	0.618	77.08	282.8	0.78
271	17/20	49	53	264.51	0.700	21.53	1580.0	4.35
274	19/24	53	58	447.60	0.492	26.61	1271.9	3.50

Note: P_{wh}. $P_{ann.sp}$ and $P_{annulus}$ - wellhead. annulus. pipe respectively are the pressures behind it.

Taking into account the calculated true density of the mixture. the densities of the liquid and gas phase. the value of the true gas capacity of the multiphase mixture was determined for the wells according to the formula (2).

Taking into account that the liquid phase is small. the density of the liquid is ρ_m= 880 kg/m³. and the density of the gas phase is $\rho_{gas}=1.2\ kg/m^3$.

Then. the part of the gas in the liquid phase that is subject to displacement (expenditure) was calculated according to the expression (5). Finally. according to the formula (8). the slippage (relative) speed of the gas phase was determined.

The values of the parameters reflecting the true characteristics of the multiphase flow calculated based on the macroscopic operating data are given in table 3. As can be seen from Table 3. the characteristics of the liquid-gas mixture in individual lifters of the studied gas lift wells are significantly different from each other due to the gas phase shift. and in some cases this difference is up to 20 times different.

Thus. in order to control the operation of gas lift wells. the possibility of estimating the real parameters of the multiphase flow in the riser based on the actual data of the well. taking into account the phase shift. was determined.

3. Conclusion

1. A new approach based on well operation data is proposed to determine the true characteristics of multiphase flows in gas lift (fountain) risers as well as in vertical pipes of underwater pipelines.

2. On the example of the wells of the "Gunashli" field (Submersible Platform-15) based on the actual operational data. the feasibility of estimating the real density. real gas capacity and phase shift of the gas-liquid flows in the risers and their suitability for engineering calculations have been shown.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research.

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Research on the possibility of hydrocarbon emissions control.

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Abstract.

All processes in the chemical and petrochemical industry generally consist of a number of comparable standard processes, although the products produced may vary. In the chemical engineering industry and related industries, a typical process is a fundamental step in technology. For example, in the production of ammonia (NH_3), gasification, reforming and synthesis of NH_3