RT&A, Special Issue № 6 (81), Part-1,
Volume 19, December 2024

ON THE RELIABILITY AND EFFICIENCY OF OPERATION OF MULTIPHASE PIPELINES UNDER HYDRAULIC İMPACT

Elman Iskandarov, Fidan Ismayilova , Magamed Shukurlu ,
Ramin Aghasanli

•

Azerbaijan State Oil and Industry University
e.iskenderov62@mail.ru
fidan.ismayilova.2014@mail.ru
mahammadshukurlu@gmail.com
ramin.agasenli@mail.ru

Abstract

The issues of reliability and efficiency of operation of field and main oil and gas pipelines and control of energy characteristics during their operation are of no small importance. The efficiency of pipelines depends on the technical condition of facilities and equipment and the rationality of their use. The practice of operating pipelines shows that emergency and abnormal cases occur in them. Significant irregular pressure and flow pulsations are observed in pipelines. Waves of high and low shock pressure often occur and propagate along the pipeline.

Along with density, additional pressure in the system from hydrodynamic impacts also arises from the elasticity of the pumped liquid and the pipeline itself. This pressure is determined by the elastic compression of the transported system and the elastic expansion of the pipeline as the pressure in it increases. The pipeline through which the multiphase flow is pumped, and its structures and other components must withstand dynamic loads.

The work analyzes various modes of water impact. The volume of oil caused by its compression during hydraulic impact was calculated. The results of calculating the increase of an oil pipeline volume due to a dynamic impact are presented.

Keywords: Water impact, dynamic load, energy feature, elasticity, multiphase flow, flow structure.

I. Introduction

As it is known, any change in the parameters of pumping oils (petroleum products) through a pipeline can be called a hydraulic impact. Such a change can occur slowly or quickly; the cause of the shock can be the slow or fast closing or opening of shut-off valves, stopping or starting a pump, the destruction of a pressure pipeline with the release of the pumped product onto the relief, as well as various dynamic loads that arise during the operation of multiphase pipelines [1 ,2,3,4].

The pressure value during water impact according to Zhukovsky can be calculated using the following formula:

$$P = c \cdot \Delta\upsilon \cdot \rho \qquad (1)$$

Where c is the speed of sound propagation in a fluid at rest;
$\Delta\upsilon$– reduction of flow velocity in the pipeline;
ρ– density of pumped oil.

The practice of operating field pipelines shows that significant irregular pulsations of pressure and flow are observed in pipelines transporting multiphase mixtures. The working environments of the oil field are characterized by the presence of liquid and gas phases, which coexist in almost all oil field pipelines [6-9].

Analysis of the parameters of water impact pressure distribution along the length of the pipeline allows to choose tactics and methods for protecting the system from impact. It was found that transient conditions during the transportation of gas-saturated oils through oil pipelines are a consequence of the same reasons as during the transportation of degassed oils. Waves of increased and decreased impact pressure, propagating along the pipeline also occur [2,10]. In this case, the wave of increased pressure has the greatest magnitude and, propagating towards the previous operating station, is superimposed on the existing pressure in the oil pipeline, summing up with it. A wave of low pressure, which moves at the speed of impact wave propagation in the liquid towards the subsequent pumping station, can cause the release of gas from gas-saturated oil and lead to the formation of gas accumulations in the oil pipeline and cavitation of pumps. As for transient regimes when pumping gas-saturated oils, they do not introduce significant changes and can be assessed using existing methods for calculating transient regimes in degassed oils. In this case, the relative change in the pressure increase in the disturbed gas-saturated flows will be determined by the relative change in the bulk elasticity modulus of gas-saturated oil.

In [6,9], taking into account changes in the structural forms of flow of multiphase systems based on an estimate of the critical flow velocity, the issues of distribution of dynamic loads were considered and it was found that when the gas phase dominates in the system, with increasing ratio of the density of liquid and gas, the dynamic load grows significantly.

II. Methods

As a rule, additional pressure during the operation of pipelines due to water impact arises from the density of the transported liquid, its elasticity and the elasticity of the pipeline itself. The practice of operating field and main pipelines shows that, due to impact pressures, the energy characteristics of pipeline systems can change significantly depending on the intensity of hydraulic pressure. Water impact pressure is determined by two factors: the elastic compression of the transported oil or petroleum product and the elastic expansion of the pipeline itself when the pressure in it changes. The change in the density of transported oil with changes in pressure can be assessed using the following relationship:

$$\rho(P) = \rho_{20}[1 + \beta_o(P - P_{atm})] \tag{2}$$

Where ρ_{20} is the density of oil at 20 ^{0}C, kg/m ^{3};
P– pressure, Pa;
P_{atm}– atmospheric pressure, Pa;
β_o– oil compressibility coefficient (β= 0.00078 MPa $^{-1}$)
The change in the volume of oil in the pipeline (ΔV_o) depends on its modulus of elasticity $E_o = 1/\beta_o$ and the level of hydraulic pressure (P):

$$\Delta V_o = P \cdot V_o / E_o \tag{3}$$

Where V_o *is* the volume of oil in the pipeline, m^3;

$$V_o = V_p = \frac{\text{пд}^2}{4} \cdot l \tag{4}$$

D and l are the diameter and length of the oil pipeline, respectively, m
The change in pipeline volume during water impact can be calculated using the following formula [5]:

$$\Delta V_{т} = \frac{ПД^3 \cdot P \cdot l}{2E_{т} \cdot \delta} \tag{5}$$

Here δ is the thickness of the pipeline wall;
E_p– modulus of elasticity of the pipe material ($E_p = 2{,}1 \cdot 10^{11}\ Pa$)

It should be noted that the duration of the change in liquid volume is equal to the duration of the impact phase, which is equal to the travel time of the pressure wave from the disturbance to the barrier and back

$$t = 2l/c$$

The speed of sound propagation in oil is determined by the well-known formula [3,5]:

$$c = \frac{\sqrt{E_o/\rho_o}}{\sqrt{(1+E_o \cdot Д/(E_p \cdot \delta)}} \tag{6}$$

Let's consider an example of calculating changes in the volume of oil and a pipeline during a hydraulic shock.

We take as initial data:

- Pipeline length l= 5000 m ;
- Pipeline diameter D = 500 mm;
- Wall thickness $\delta = 10$mm ;
- Oil pipeline volume $V_p = \frac{ПД^2}{4} \cdot l = \frac{3{,}14 \cdot (0{,}5)^2}{4} \cdot 5000 = 981{,}25\ m^3$;
- Oil consumption Q_o=1500 m^3/hour= 0.4166 m^3/s ;
- Oil density $\rho_o = 860\ kg/m^3$

We can calculate the water hammer pressure for the full shock that occurs when the valves are instantly closed. The oil velocity in the pipeline was :

$$v = \frac{4Q}{ПД^2} = \frac{4 \cdot 0{,}4166}{3{,}14 \cdot (0{,}5)^2} = 2{,}12\ m/s$$

We calculate the speed of sound propagation in oil using formula (4):$C = 1074{,}2\ m/s$

Then from formula (1) the pressure from the water hammer will be:

$$P = 1074{,}2 \cdot 2{,}12 \cdot 860 = 1958481\ Pa = 1{,}96\ MPa$$

As it can be seen from the calculation of hydraulic pressure, such pressure can arise with a long pipeline length exceeding the value $l > 2 \cdot c \cdot t$; t– valve closing time.

Let's consider calculations of the volume of oil caused by its compression during a hydraulic shock. It is known that the elastic property of oil when it encounters a valve will continue until the compression wave reflected from the beginning of the oil pipeline meets a direct compression wave. The duration of the increase in pressure in the oil pipeline will be :

$$t = \frac{2l}{c} = \frac{2 \cdot 5000}{1074{,}2} = 9{,}31\ s$$

Then the compression of oil in the pipeline by additional pressure at the elastic modulus of oil $E_o = \frac{1}{\beta_o} = 1{,}3 \cdot 10^9$ Pa will be (according to formula (3)):

$$\Delta V_o = 1958481 \cdot \frac{981{,}25}{1{,}3} \cdot 10^9 = 1{,}4782\ \text{m}^3$$

At the end, we will determine the increase in the volume of the oil pipeline itself due to impact according to formula (5):

$$\Delta V_p = \frac{3{,}14 \cdot (0{,}5)^3 \cdot 1958481 \cdot 5000}{2 \cdot 2{,}1 \cdot 10^{11} \cdot 0{,}01} = 0{,}9151\ m^3$$

It is also possible to calculate changes in oil density when pressure changes as a result of impact. Using formula (2) we obtain:

$$\rho = \rho_{20}[1 + \beta_o(P-1)] = 860[1 + 0{,}00078 \cdot 10^{-6}(1958481 - 10^5) = 861{,}29\ kg/m^3$$

Then the water impact pressure will have the following value:

$$P = 1074{,}2 \cdot 2{,}12 \cdot 861{,}29 = 1961419\ Pa$$

In this case, the effect of changes in density will be 1961419 – 1958481 = 2938 Pa

III. Results

1. Various dynamic loads arising during the operation of multiphase pipelines were analyzed.
2. In order to ensure the reliability of pipelines, in addition to single-phase movement, dynamic loads must also be taken into account for gas inclusions and multiphase flow with various structural forms of movement in field pipelines

References

[1] Vasiliev G.G., Korshak A.A., Lurie M.V. etc. vol.1. Pipeline transportation of oil. M.: Nedra, 2002, 341 p.

[2] Tugunov P.I., Brot R.A., Kutukov S.E. Determination of impact pressure in an oil pipeline with gas-saturated oil under transient conditions // Oil and Gas Business, Transport and Storage 2005, Volume 3, p. 199-205.

[3] Basniev K.S., Dmitriev N.M., Rosenbert G.D. Oil and gas hydromechanics. M.: 2005, 544 p.

[4] E.Kh.Iskenderov ., Improving the efficiency of the functioning of gas pipelines, taking into account the structural features of gas flows. // Izvestia NAS RK. Series of Geology and Technical Sciences No. 3 (447) May-June, 2021

[5] Lurie M.V. Problem book on pipeline transport of oil, petroleum products and gas. M.: Center "Litneftegaz", 2004, 351 p.

[6] Sitenkov V.T., Lebedeva E.V. Reducing dynamic loads on field pipelines // Oil Industry 6 / 1998, p. 67-69.

[7] Guzhov A.I. Joint collection and transportation of oil and gas. M.: Nedra, 1973, 280 p.

[8] Ismayilov G.G. Ismailov R.A., Akhundzade A.N. Diagnosing the presence of liquid inclusions in gas pipelines. // SOCAR PROCEEDINGS. Special issue №. 1 (2022), pp. 154-161.

[9] Ismayilova F.B., Cafarova X.T. Assessment of dynamic loads in multiphase pipelines. // ANT, 09, 2021, pp 29-31.

[10] Brot R.A., Kutukov S.E. Determination of rheophysical parameters of gas-saturated oils. Oil and gas business. 2005, http://www.ogbus.ru