UDC 622.691.4 **DOI 10.33042/2522-1809-2020-4-157-2-6**

O. Taraevskiy

Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine

IMPROVEMENT OF OPERATION OF GAS PIPELINES PASSING THROUGH THE TERRITORY OF UKRAINE

Currently downloading western section of gas transportation system of Ukraine decreased by 2,5 times compared to the project. This caused changes in the modes of pipelines, pressure fluctuations and gas consumption and, consequently, the number of changes in the system of gas pipelines. Therefore there is a need to study the mode of gas transportation system during underemployment. As a research facility selected western area of the gas transport system of Ukraine, the capacity of which reaches 111 billion. m3 / year of gas intended for export. CCS CONCEPTS: Computer System Organization → Dependable and Fault-Tolerant System and Networks → Maintainability and Maintenance.

***Keywords**: Fatigue, Flood, Stress Concentrator, Welded Joint, Weld Seam, Gas Pipeline, Static Load, Low Frequency Load.*

Introduction

The methodological basis of the work is the joint use of the physical and mathematical modeling of the research object. Studies are based on the application of methods and criteria of fracture mechanics; the first law of thermodynamics for the estimation of the energy balance of the fatigue cracks propagation in terms of load time variables; methods of physico-chemical fracture mechanics cousiderimg the joint action of operational loads, corrosion-aggressive and hydrogen-containing media; calculation and experimental determination of residual stresses;

system analysis of operational parameters of linear sections; methods of making performance characteristics; correlation - regression and factor analysis; methods of mathematical programming and identification of organizational and technical factors influence on the efficiency of operation; non-destructive determination of characteristics of a stressed state.

High stress values in gas pipelines walls are caused by the internal pressure (up to 7.5 MPa) of the pumped over gas and for the welded annular couplings and, in addition, by a high level of residual welding stress which may amount to (0.4..0.6) □T which puts forward special requirements to be met both as to the determination of their values and to the prognostication of gas pipelines operating conditions [4-7].

On the basis of the system approach and analysis of the conditions of transit main gas pipelines operation, analytical studies of the stresses occurring on the internal surface of the gas pipeline under the conditions of the obverse and reverse operation modes have been carried out. Proposed was the method of determination (prognostication) of prolonged working pipelines durability being under complex mining and geological conditions. The technique for determining the permissible level of arbitrarily oriented stresses acting on the investigated section of the gas pipeline with a complex technological structure and laid in the area with a disturbed equilibrium of the earth has been developed. It has been proved that the cyclic operation of pipelines and their structural elements in complex geological conditions leads to an abnormally high background tension, which results in a decrease in their predicted lifetime. It is proposed to carry out an operational control of the stressed-strain state of pipeline sections passing through the areas under complicated mining and geological conditions and having complex technological features.

Material and experiments

Most of the gas mains have been exploited for a long time, and quite a lot of them have used their depreciation period. To reliably estimate the pipelines capacity for work a comprehensive approach is necessary, one of whose most important constituents will be the determination of the influence of inundation environment and stress concentrators upon gas pipelines destruction failures, particularly in the areas containing various flaws and in welded joints (WJ), which account for 50-60% of all the failures of the pipelines which have been operated during 30 years. It particularly concerns the annular weld joints which after welding, as a rule, are not subjected to additional treatment with the view of lessening the residual stress.

The necessity has been proved and the expediency of assessing the efficiency of the existing GTS of Ukraine is shown in a completely new functional

purpose, particular ly in the provision of safe trouble-free supply of natural gas to the EU countries and Ukraine by existing pipelines in obverse and reverse operating modes. It has been established that in order to ensure the security of natural gas supply by diversifying its streams and the functionality of the gas infrastructure, it is necessary to evaluate and develop advanced methods for predicting the durability and residual service life of the long - term operated pipelines under complicated mining and geological conditions and their obverse and reverse modes of operation [2-7].

The gas pipelines operating conditions through the effect of cathode protection envisage the possibility of inundation and accordingly the danger of breakdown failure caused by the hydrogen frangibility phenomenon.

From the above mentioned viewpoints, a valuable information concerning the corrosive endurance capability of gas mains welded joints can be obtained by way of plotting fatigue diagrams in the coordinates a - InN, taking into account the operating parameters and the effect exercised by the hostile, corrosive environment, as the data available relating to the corrosive fatigues of gas mains welded joints are rather limited.

The data obtained concerning the corrosive fatigue in hostile water-flooded environment, the surface stress concentrators in various areas of the welded joint including, will make it possible during the design of gas pipelines to make use of the error-free initial data which are indispensable for the prognostication of gas main life time.

The mechanism of the crack nucleation in the conditions of simultaneous action of internal and external loads was established, the clear assessment of the long - term operated pipeline in the presence of the structural elements local defects was given. In the process of repeated static loads in structural elements of durable oparated pipes the areas with microplastic deformations are formed. Such obtained results indicate the appearance of areas with a step-wice character, the nucleation and sometimes propagation of microcracks, and subsequent equalization in the process of further operation, and there occurs stress relief. It was established that in the period of pipelines operation from 18 to 30 years there is certain strengthening of the metal structure of the pipe in welded zones as a result of strain hardening (the phenomenon of cold working), as well as the equilibrium of microstructure of the metal.

Result

It has been confirmed that the service residual life of the actual technical state of the long - term operated pipeline under the studied loads will enable the pipeline operational use beyond the planned (established) depreciation period (see Figure 1).

On the basis of the comparative estimation, one can conclude that the change in the operation modes of Bohorodchansky UGS causes a change in the intensity of the NPEMFE in the areas of rock masses where complex design elements of the pipelines are located. This is due to the fact that the deformation of the pipeline is transferred to rock masses. Violation of the integrity of the rock masses intensifies this impact as a stress concentrator. The classification of certain anomalies of the sections of the UGS gas pipeline in terms of size and form is developed, the presence of a background model field with corresponding characteristics is shown, as well as the availability of abnormal, excessive background values of intensity on individual supports and bends.

Fig. 1. The plot of the gas pipeline from the transition of underground laying in the ground. (gas pipeline Urengoy - Pomary - Uzhgorod)

The given research data allow to assert that there are separate sections of gas pipelines, for which it is necessary to develop separate classification schemes, new methods of diagnostic control and prediction of

their durability. Thus, the use of the NPEMFE method (see Figure. 2) is a reliable sensitive tool for detecting local deep-seated stresses occurring in areas with disturbed equilibrium, regardless of the nature of their occurrence.

The principle of gas transportation optimization by pipelines, passing in one technological corridor based on the criterion of minimum negative impact on the environment is improved. The method of determination of the potential impact radius, which simultaneously takes into account the mode of the gas pipeline operation, its actual technical state, as well as the parameters of abnormal areas with disturbed equilibrium of the earth, is proposed.

Fig. 2. Results of stress intensity of NPEMFE gas pipeline Union and UPU.

Discussion

Natural soils refer to materials with low viscosity and are characterized by considerably greater compressive strength than tensile strength, which is explained by the manifestation of internal coulomb friction, which is described by the Mora - Coulomb hypothesis. The internal coulomb friction contributes to the formation of tangential stresses, which deformation surface (Coulomb surface) in the preliminary stage deviates from the axis of normal stresses. For a natural soil, the deformation surface in shape resembles a conoid. In the phase of destruction, the deformation surface becomes the shear surface.

The influence of real operating conditions shall be taken into account by the coefficient Kr and by the formula adapted to the system of measuring units SI:

$$r = 99 \cdot D \cdot К_p \cdot \sqrt{p} \qquad (1)$$

where r - the radius of potential impact, m;

p - maximum working (operating) pressure, MPa;

D - external diameter of the gas pipeline, m;

Kp - coefficient which takes into account real operating conditions of gas pipelines.

The coefficient of real operating conditions (Kr) is determined by the formula:

$$К_p = К_1 \cdot К_2 \cdot К_3 \qquad (2)$$

where K1 is a coefficient that takes into account the stressed state of the surface layer of the land plot;

K2 - coefficient which takes into account the operation mode of the pipeline;

K3 is a coefficient that takes into account the technical condition of the pipeline.

The stress ratio (K_1) takes into account the properties of the surface layer of the soil mass in the place of laying the gas pipeline. The RPV determined by the formula (1) is measured in the slip plane and its real value acts on the surface of the Earth.

This difference takes into account the coefficient K_1 and is determined by the formula:

$$К_1 = \cos\varphi. \qquad (3)$$

For new gas pipelines operating at frequencies below ≥0.3 Hz, the coefficient K_2 = 1, at frequencies 0.3 Hz, the given coefficient K_2 = 1.05. Laidexploited pipelines at a frequency ≥ 0.3 Hz, K_2 = 1.1, at a frequency < 0.3 Hz, K_2 = 1.05. If, after conducting the in-pipe diagnostics of the pipeline, there are no defects accumulated from fatigue and corrosion, then the coefficient taking into account the technical condition of the pipeline is equal to one (K_3 = 1). If defects are detected, then they can develop in fatigue modes, then K_3 <1 and depends on their number and size. (K_{3max} = 1.2).

In order to ensure the safety of operation and reduce losses during accidents, it is necessary to clearly identify and impart a site of potentially hazardous impact. We will analyze and calculate the potential impact zone for parallel pipelines, in particular Urengoy - Pomari - Uzhgorod and Union (see Figure.3).

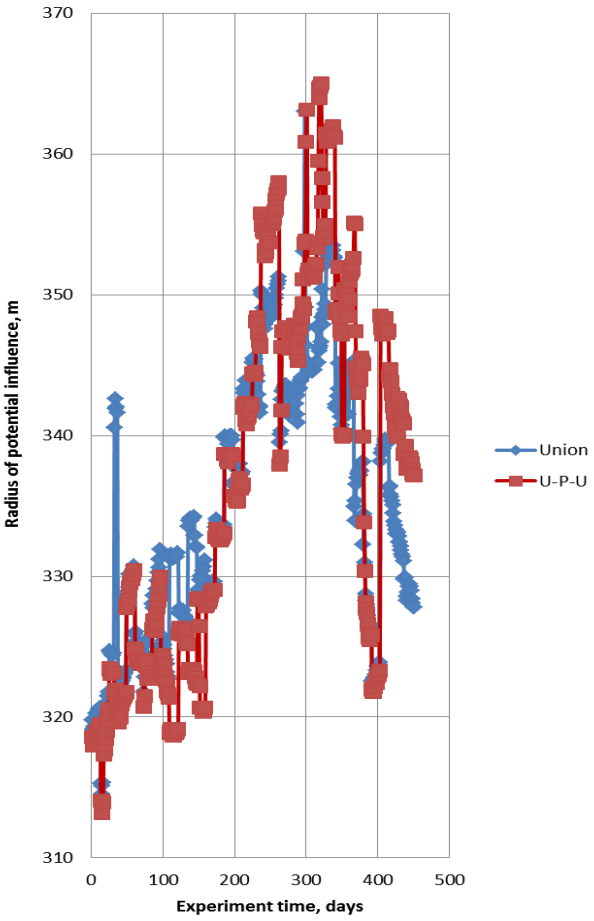

Fig. 3. The radius of potential impact, in meters, resulting from the change in the mode of transportation of gas (by the formula 1 Kp = 1,1).

Conventional combustion can turn into an explosion due to the speed of propagation of the flame when it is propagated along the relief and in the forest massifs.

In addition, with the guillotine rupture of the high pressure gas pipeline, there is a diffusion of metal pieces and pipe fragments, as during the destruction of the pipeline, the energy of expansion of gas is spent on the deformation of the pipe, its destruction, the formation of primary and secondary fragments.

Conclusions

As a result of system filling and emptying of UGS as well as mode processes of gas pipelines operation, it has been established that in the areas with turns and branch pipes, technical inspections should be carried out by 32% more often. The given research data allow to assert that there are separate sections of gas pipelines, for which it is necessary to develop separate classification schemes, new methods of diagnostic control and prediction of their durability. Thus, the use of the NPEMFE method is a reliable sensitive tool for detecting local deep-seated stresses occurring in areas with disturbed equilibrium, regardless of the nature of their occurrence [2-5].

In order to increase the reliability of operation of overhead trunk gas pipelines in common technical corridors, it is necessary to increase their resistance to explosions, as well as to reduce the likelihood of the impact of neighboring gas pipelines in an explosion on one of them. It is known that it effectively counteracts the spontaneous growth of a crack in the wall of the gas pipeline - this is the strengthening of its outer surface by composite polymer materials (CPM). In case of local damage to the wall and depressurization of the gas pipeline of the strengthened CPM, there is an outlet of gas, which, when externally heated, is not accompanied by an intrinsic explosion. If such a powerful fire jet is directed toward the adjacent gas pipeline, then the likelihood of its damage is high. In this case, for the effective protection of neighboring gas pipelines, it is necessary to install, in the interval between them, shielding engineering structures. This role can be performed by specially constructed intermediate backup bypasses.The methodological basis of the work is the joint use of the physical and mathematical modeling of the research object.

References

[1] Dagdale D.S.Yielding of steel sechts cortaining shits.– *J.Mech. and Phys.Solids*.–1960.–№2, V.8.–P.100–104.

[2] Dowling A.R., Towley C.H.A. The effect of defect on structural failures: a two-criterial approach//Int.J. Pres. Ves. And Piping.-1975.-Vol.3 №2.-P.77-107.

[3] O. Taraevskyy. Calculation models aspect for pipelines joint welds evaluation for the purpose of their endurance life increasing // *Metallurgical and mining industry*. 2015. №4. P. 91-93.

[4] Taraevsky O.S. Maintenance of the efficiency of long – term operated gas pipelines under complicated mining and geological conditions. – Academic qualification work on the rights of a manuscript.

[5] Tarayevs'kyy O. Key factors determining state of metal pipe during operation of main oil and gas pipeline // *Metallurgical and mining industry*. – 2015. –№2. – P. 62-66.

[6] Ye. I. Krizhanivskiy, O.S. Taraevskyy, O.M. Makovkin Research on pipelines elements strength with stress raisers in the area of slide // *Metallurgical and mining industry*. 2015. №10. P.202-204.

[7] Ye. I. Krizhanivskiy, O.S. Taraevskyy. Factors determining the intensity of loading of long operated gas pipelines under complex mining and geological conditions // *Metallurgical and mining industry*. 2015. №8. P.516-520.

Рецензент: доктор технічних наук, професор, професор кафедри нафтогазової інженерії і технологій Б.С. Ільченко, Харківський національний університет міського господарства імені О.М. Бекетова, Харків, Україна

Автор: ТАРАЄВСЬКИЙ Олег Степанович
професор кафедри газонафтопроводи та газонафтосховища
Івано-Франківський національний технічний університет нафти і газу
E-mail – tzng@ukr.net

ВДОСКОНАЛЕННЯ РОБОТИ ГАЗОПРОВОДІВ, ЯКІ ПРОХОДЯТЬ ТЕРИТОРІЄЮ УКРАЇНИ

О.С. Тараєвський
Івано-Франківський національний технічний університет нафти і газу, Україна

Упродовж останніх років створюються нові перспективи та особливості транспортування газу діючою газотранспортною системою (ГТС) України. Однією з основних задач буде забезпечення надійного постачання газу як до країн ЄС, так і до України, використовуючи аверсно-реверсні режими експлуатації трубопроводів. Починаючи з 2013 року, Україна одночасно пережила практично 50% зниження імпорту газу, внаслідок чого відбулися ґрунтовні зміни його структури. Зважаючи на звільнені потужності, з'явився імпорт із Заходу, що виріс з нуля до 10 млрд. куб. м. у 2015 році та поступово зростає. Зважаючи на суттєві зміни як зовнішніх, так і внутрішніх навантажень на лінійну частину трубопроводів значну увагу необхідно також приділяти гірничо-геологічним умовам, у яких експлуатуються транзитні газопроводи, значна частина яких проходить через Івано-Франківську, Львівську та Закарпатську обл., які відзначаються складними гірничо-геологічними умовами, великою частиною зсувонебезпечних ділянок, а також багатьма природніми та штучними перешкодами.

В роботі представлено принцип забезпечення надійності тривалоексплуатованих газопроводів за складних гірничо-геологічних умов на базі комплексних теоретичних і практичних досліджень. Вдосконалено наукові основи визначення працездатності ГТС України з урахуванням тривалого терміну експлуатації та складних гірничо-геологічних умов. Встановлено механізм зародження тріщин в умовах одночасної дії внутрішнього та зовнішнього лавинного навантаження на газопроводи в зоні впливу концентраторів напружень. Досліджено вплив аверсно-реверсних режимів на показники надійності магістральних газопроводів, які експлуатуються в гірській місцевості. Запропоновано та удосконалено методику визначення допустимого рівня довільно орієнтованого навантаження на найбільш небезпечні конструктивні елементи газопроводу в зсувонебезпечних умовах, що дозволяє попередити їх аварійне руйнування. Також методика оцінки експлуатаційної надійності ділянок магістральних трубопроводів, що проходять через природні та штучні перешкоди дала можливість запропонувати детальний моніторинг технічного стану. Запропонована методика забезпечення надійної експлуатації трубопроводів, що проходять у спільному технологічному коридорі, та введений критерій, що враховує одночасний вплив терміну експлуатації, режимів роботи та місце прокладання трубопроводу.

Ключові слова: *магістральний газопровід, кільцевий зварний шов, зона термічного впливу, воднева крихкість, низькочастотна втома.*