Specific features of diagnostic of wellhead equipment and gas field pipelines at the stage of declining production

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Abstract. The paper presents the results of studies of climatic factors impact on the processes of aging and degradation of materials of field equipment in the Subpolar climatic zone. On the basis of diagnostic measures and analysis of dispatching data on daily pressure fluctuations in pipelines, ambient temperature variations, frequency of wind gusts and amount of precipitation the damage probabilities of the pipeline linear section and wellhead equipment due to various factors have been determined.

1. Introduction
The complexity of studying materials fatigue and determining the residual life of the equipment is substantiated by a large number of factors that affect life characteristics such as climatic conditions in which the equipment is operated, in particular.

At the stage of declining production, gas pressure is significantly reduced and does not have a substantial impact on aging and degradation of equipment materials; basic damage occurs due to climatic factors. This is especially true for the deposits located in the Subpolar climatic zone characterized by cold and long winters, high rainfall, strong winds, high humidity and low annual average air temperature. Such climatic conditions increase static and cyclic loads on the equipment. However, as a rule, these features are practically not taken into account when performing planned diagnostics and determining the residual life of the equipment.

Therefore, the purpose of this work is to study the impact of climatic factors on the processes of accumulation of steel structure operational damages. The article presents the results of studies of the impact of climatic factors, as well as changes in internal gas pressure on the pipe steel structure and properties and the probability of destruction of the pipeline linear section and wellhead equipment.

2. Data and methodology
To estimate the fatigue damage of the wellhead equipment and the pipeline linear sections diagnostic measures have been performed and dispatching data on daily pressure fluctuations in the pipelines, the ambient temperature variations, the frequency of wind gusts and the amount of winter precipitation during 20 years of operation have been analyzed.
The pipeline operating pressure drop from 12 MPa to 4 MPa reduces the impact of technological factors on material degradation. However, temperature fluctuations from -53 °C to +32 °C at a humidity of about 75%, wind gusts up to 40 m/s and snow loads are significant damaging factors.

A visual inspection control (VIC), ultrasonic thickness measurement, magnetic powder and ultrasonic flaw detection have been performed on the linear section of the active pipelines and wellhead equipment, hardness readings have been taken and, in addition, the coercive force has been measured on the pipelines. For a comparative analysis features of macro- and microstructure have been studied, hardness and coercive force have been measured, ultrasonic thickness measurement has been carried out and resilient modulus has been defined on the samples made of pipe spools.

3. Results and discussions

3.1 Flaw detection, mechanical and magnetic properties

By the flaw detection results cracks at the point of wellhead equipment attachment to the well casing have been found. The average reduction of the pipeline linear section wall thickness is 0.5 mm with a coefficient of variation of 0.3.

To estimate the mechanical properties of the metal and welded joints as well as changes in their properties during operation hardness of the main pipeline elements has been measured and impact bending tests have been carried out. Hardness values are HV_{10} = 157-179 with a coefficient of variation of 0.06. The resilient modulus values are KCV_{+20} = 120 J/cm² and KCV_{-60} = 60 J/cm² with a coefficient of variation of 0.05. The mechanical properties fully comply with the requirements for 10G2С and 09G2С pipe steels.

Measurements of the coercive force (Hc) have revealed no inhomogeneity of magnetic properties in the base metal. In the weld seam heat-affected areas there is a specific increase in the value of Hc. The base metal Hc mean value is 592 A/m; in the heat-affected areas it is 712 A/m with a coefficient of variation of 0.12.

3.2 Microstructural analysis

The pipe metal microstructure is ferrite – pearlite with the perlite content of 20-25% and ferrite grain of 10-30 microns. The pipes outer and inner surfaces are characterized by the occurrence of a large number of small corrosion pits with a diameter and depth from several micrometers to 0.2 – 0.3 mm, and larger pits with sizes up to 1 mm. No variations in the metal structure and corrosion cracking in the pit cavities have been detected (figure 1).

When predicting the development of corrosion damage it is necessary to note the positive impact of climatic conditions of the Subpolar zone. Chemical corrosion processes are slowed down at low temperatures and in the absence of aggressive environments associated with industrial emissions in the atmosphere. In addition, the occurrence of a continuous cover of moss, which has bactericidal properties, prevents a development of bacterial corrosion of the pipeline outer surface.
3.3 Estimation of fatigue damages

To estimate the fatigue damage, the dispatching data on daily pressure fluctuations in the gas well flow lines and ambient temperature during 20 years have been analyzed. The flow line pressure is from 3 to 5 MPa taking into account daily and seasonal fluctuations (winter – summer).

Taking into account the actual methods [1-3], calculations of the pipeline elements destruction probability have been performed and a comparative analysis of the calculated and actual loading conditions has been carried out.

The calculated value of the stress amplitude in the pipe wall is 10 MPa, taking into account corrosion damage; and at the area of welded joints it is 20 MPa, taking into account stress concentration. Thus, the damaging effect of internal pressure fluctuations provides less than 0.1% of a welded joint damage probability with a design life of 40 years and 150 cycles of pressure variation from 3 to 5 MPa per year. The actual frequency of loading is not more than 10 cycles per year, i.e. the calculated damage probability is many times higher than the expected one for actual operating conditions.

Next, the effect of thermal expansion on the stresses in the curved elements of the pipeline (branch line) has been studied. Due to thermal expansion, elastic and plastic deformations can occur in the branch lines. Therefore, it is necessary to estimate the extreme cases of loading, i.e. in the area of elastic and plastic deformations.

Elastic deformation means that the branch lines operate in the area of elastic stresses. For calculations we take 60 cycles of stress fluctuations per year due to thermal expansion, which will be 2.4 thousand cycles within 40 years of operation. At stress amplitude of 200 MPa, after the performance period of $7 \times 10^3$ cycles, the damage probability equals 0.1%.

Plastic deformation means that the branch lines operate near the yield point, in the area of plastic deformations. For calculations we also take 60 cycles of stress fluctuations per year due to thermal...
expansion, which will be 2.4 thousand cycles within 40 years of operation. At stress amplitude of 1.1-1.2 yield stress after the performance period of $4 \times 10^3$ cycles, the damage probability will be 5% [4]. Under the considered loading condition, the damage probability of the expansion pipe does not exceed 5% within 40 years of operation.

The obtained results of damage probability are comparable with the Gazprom standard data for the raw gas pipelines built before 1995, with cyclic thermal stresses in the areas of branch lines most contributing to the possibility of pipeline destruction.

The analysis of the damaging effect of internal pressure fluctuations and wind gusts up to 40 m/s for the wellhead equipment characterized by high wind resistance has been made. Internal pressure fluctuations cause damage in the very wellhead equipment, and wind gusts damage the point of wellhead equipment attachment to the well casing. It has been established that wind gusts acting during 20 years of operation are the main damaging factor, and internal pressure fluctuations do not cause an accumulation of crucial damage. According to the diagnosis results, only in two wells out of fifty cracks at the point of wellhead equipment attachment have been found, which coincides with the calculations.

4. Conclusion

The results of the studies have shown that the damage probability of the pipeline linear section due to internal pressure fluctuations is not more than $10^{-4}$ per kilometer a year, and due to wind and snow loads, this figure increases to $2 \times 10^{-3}$ per kilometer a year. The major contribution to the pipeline damage possibility is made by cyclic temperature stresses in the area of branch lines; in this case the damage probability is $5 \times 10^{-3}$ for each branch.

The damage probability of the wellhead equipment due to variations of the internal gas pressure does not exceed the value of $10^{-4}$, and the influence of wind gusts up to 40 m/s increases this value to $10^{-3}$, with the most dangerous area of transition from the wellhead equipment to casing.

Thus, according to the calculated and diagnostic data, it can be concluded that the climatic factors significantly affect damage probability of the facility under test.

5. Summary

The accomplished studies are based on the analysis of the Subpolar zone climatic factors damaging effect on gas field infrastructure elements, taking into account operational loads, which makes it possible to more accurately estimate the damage probability and the period of further operation.

As a follow-up to this work, it is important to change the approach to reconstruction, repair of the existing and design of new facilities: installation of wellhead equipment, taking into account the direction and frequency of wind gusts, the possibility of ground location of pipelines without trestle construction.

References

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