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Influence of main pipelines continuous exploitation on their physical and chemical properties

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Abstract
The processes taking place in the metal pipe during prolonged use can affect both the standard mechanical properties, and the custom, estimated by a specially developed technique. In this regard, for the assessment of metal pipes after their prolonged use is necessary to study the complex physical and mechanical properties to assess the resistance to the destruction of the metal in the environment closest to the operating conditions.

Keywords: *fatigue, hydrogenation, stress concentrators, weld seam, gas pipeline, static load, low-frequency loads.*

Introduction

Crack formation is known to be the localized process and it depends on local variations in metal structure [2]. In this respect the researches on local variations in metal structure should be carried out to specify the influence of continuous exploitation on resistance to breakage of pipes. The researches on the evaluation of metal inclination to strain age-hardening, resistance to origination and developing of cracks, crack growth resistance characteristics, delayed brittle fracture in conditions of strain, corrosion medium and hydrogen should be carried out as well. Determination of steel inclination to brittle fracture while decrease of temperature during tests is no of less importance. This fracture depends on the interacting process of impurity atoms with defects of crystalline structure and it is one of the criteria of steel evaluation that is fracture sensitive [3,4].

While continuous exploitation except strains, the pipe metal may be subjected to corrosion medium. It is believed that the major cause of fracture while metal contact with corrosion medium is the localized metal corrosion leading to the reduction of throat area and formation of a crack. Another cause contributing to crack formation while exploitation is metal hydrogenization. The crack in this case may be formed while keeping under strain below the flow limit as a result of delayed fracture developing. It should be marked that inner microstrains, connected with localized metal cold work and crystalline transformations, contribute to the delayed fracture developing [5].

For overall estimation of structural strength and development of pipe reliability criteria series of tests should be carried meeting the structural condition of metal, stages of crack origination and developing, influence of corrosion medium and hydrogen [6].

Some results of analysis of pipes samples of 19 main pipelines from the localities with different environmental conditions are given. Their percentage sharing is given in the figure 1, which shows that similar in chemical composition steels 17GS, 17G1S and 19G make 81% of the total number of analyzed steels. That is why the main statistical analysis was carried out with these steels, named hereafter as steels of 17GS type.

The total amount of analyzed pipes is 106 samples. 86 samples of them are carrier pipes, 9 – pipes of emergency reserve, 7 – emergency pipes, 3 – pipes of extra branches, 1 – pipe of current output and also corresponding amount of welded seams, among which there predominated plant longitudinal seams. There were defects in all site welds and in 8 plant longitudinal seams.

All the pipes were operated in different force conditions. The most severe pipe operating conditions were at the start of segments. Arrangement of pipe samples along the route was as follows: from the beginning of linear sections – 28, from the middle – 17, from the end- 22 samples.

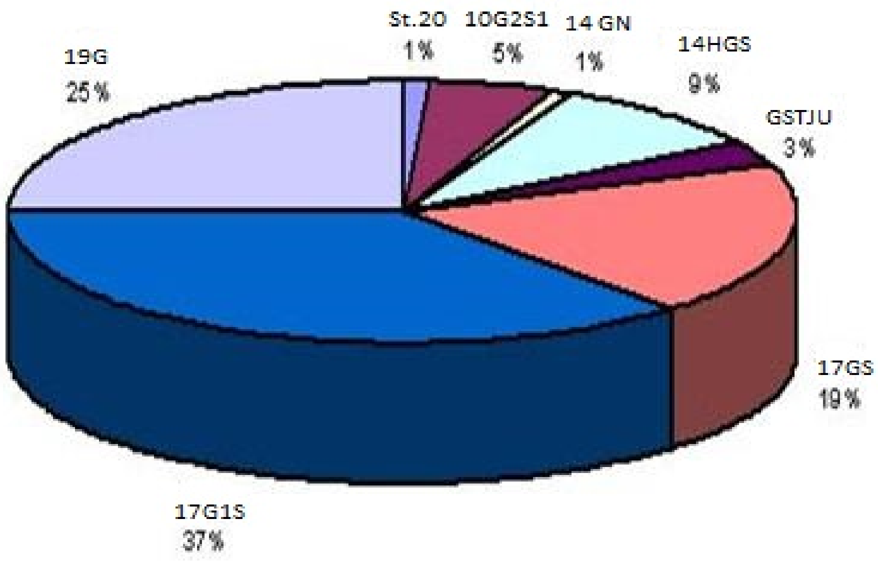

Figure 1 Percentage sharing of pipes steels samples according to the grades.

For evaluating mechanical properties the samples of pipes and welded seams were taken that are from 17GS steel, they collected from active pipelines, emergency spools and emergency reserve. The pipes were 425-1220 mm dia and 7-15.2 mm wall thickness. Working service was from 4 to 60 years. As initial condition the properties of pipes of emergency reserve from the similar steel grade and current metal was taken.

According to the results obtained, hardness, flow limit and malleability are almost unchanged, depending on operating time.

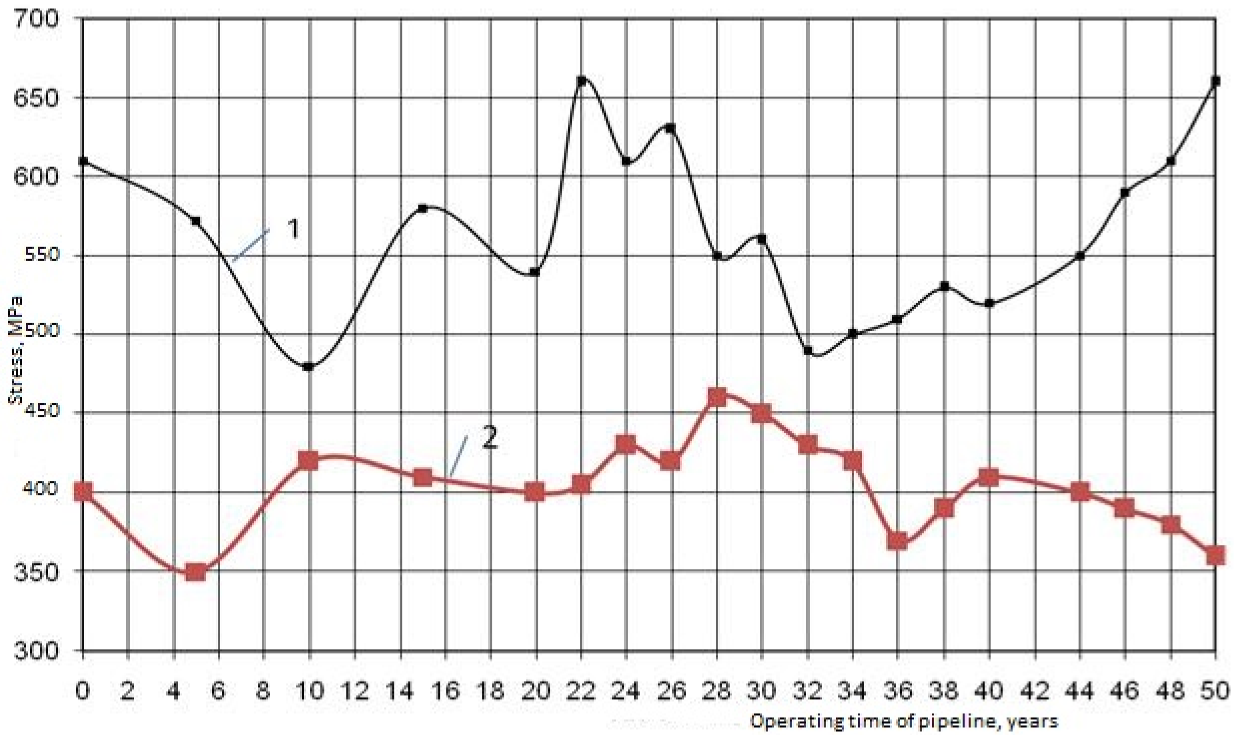

Figure 2 Characteristics curve of stress changes during the long period of pipeline operation. 1 -stress limit σ_r, 2 – flow limit $\sigma_{0,2}$.

Averaging of values was carried out in accordance with the number of analyzed pipes for each working service. For pipe metal the value of ultimate resistance to separation σ_r in the interval of experimental dispersion 480-670 N/mm^2 are close to standards for the given steel grade (at least 520 N/mm^2) and are remained on this level during operating time.

The similar results are also observed for the flow limit $\sigma_{0,2}$, where within the limits of dispersion it remains near-constant. Pipe metal ductility - percentage extension δ and reduction in area ψ - almost does not change during all the period of operation and is on the level of GOST claims and Technical specifications(at least 24 % for δ, standarts for ψ are absent). Percentage extension changes within the limits 22-31.5 % and reduction in area within the limits 50-64 %. Therefore, 60 years of exploatation have not led to noticeable reduction of ductility index.

The analysis of mechanical properties of welded seams showed that similar to pipe metal there is no any dependence of properties on the operating time. The value σ_r changes within 462-640 N/mm^2 limit, $\sigma_{0,2}$,- within 338-474 N/mm^2 . It almost coinside with corresponding characteristics of the pipe parent metal while close dispersion of properties. Ductility indexes of welded seams are lower, than of parent metal. So, δ changes within 15-26 % limit, ψ - within 36-61 % limit. Dispersion of these parameters a little greater, than of parent metal, that is connected with welded seams defects, which show themselves while testing.

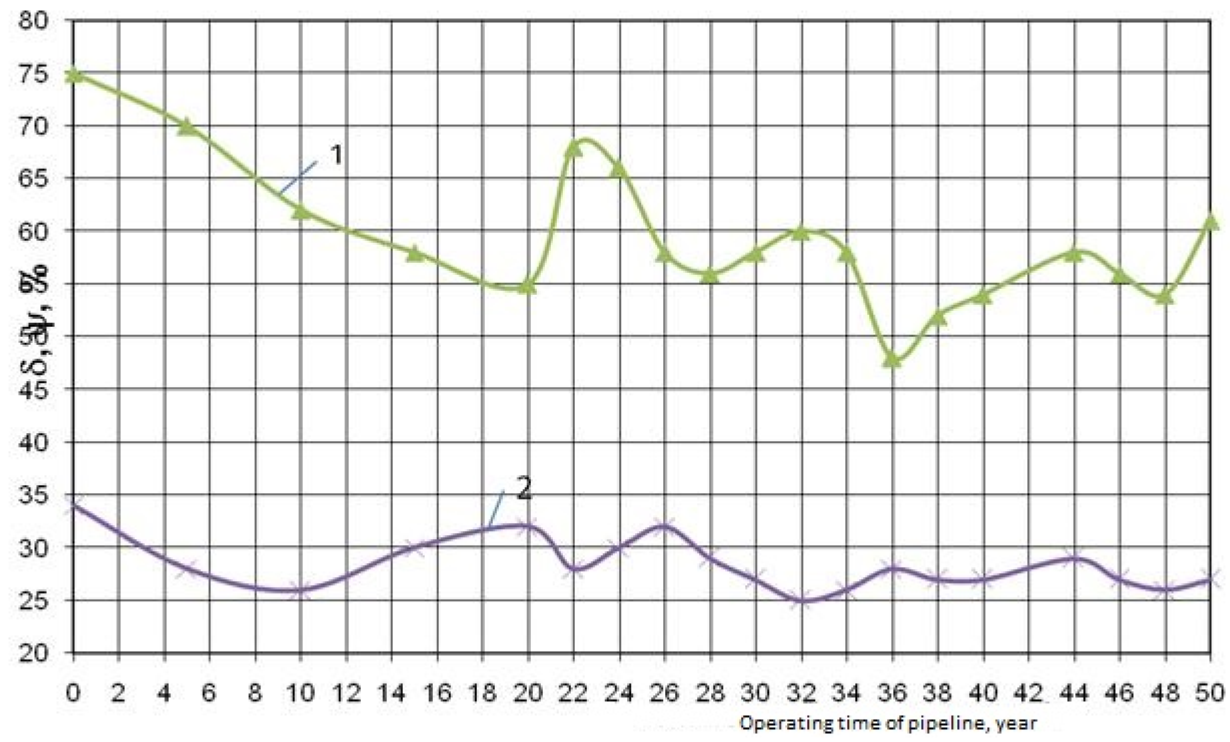

Figure 3 Change of mechanical properties of operated pipelines: 1 - relative reduction φ 2- absolute elongation δ.

The standard mechanical properties – strength, flow limit and ductility – are almost not sensitive to structural changes in metal pipes while operating. For revealing the properties that are sensitive to structural changes, the other types of testing were executed, including tests on the samples with sharp stress concentrator and beforehand created crack and also evaluating of the work of crack formation and developing.

In such a way, the change of structural condition in metal pipe during operation took place, which leads to brittle fracture resistance reduction. One may suppose that one of the main reasons of increasing the inclination of metal to coldbrittleness and reduction to crack formation resistance is strain age-hardening, connected with interstitial atoms cooperation (carbon and nitrogen) with dislocations [2].

The change of structural condition of metal during long-time operation of pipelines may be connected not only with aging process, but also with flaws upbuilding process as a result of stress impact, corrosion medium and hydrogen. Corrosion processes cause the change in surface condition of pipe metal, leading to defects formation, such as corrosive opens, corrosion pits, pitting corrosion, etc [6].

Hydrogenization of metal contributes to formation of inner flaws such as microcracks in the areas of localized microstress impact [6]. It should be mentioned that hydrogenization of metal may run as a result of developing of electrochemical corrosion process. Hydrogenization process may be improved by cathodic protection.

Flaws upbuilding process, such as microcracks and failures during static or quasistatic stress below the maximum destructive force and steel yield point as well, is usually nominated as delayed fracture. Testing on the tendency to delayed fracture while simultaneous stress, corrosion medium and hydrogen impact, imitate the process of damage in real exploitation conditions while electrochemical corrosion process. This type of testing is the most strict and can be useful for evaluating the susceptibility to cracking of pipe metal, operating severe conditions (high-pressure, corrosive medium, etc).

For examining of pipe steels testing technique on the delayed material fracture in conditions of simultaneous stress, corrosive medium, hydrogen and mechanical stress impact, which imitate the real conditions of construction exploitation with forces concentrator was developed. For this the standard samples (10x10x55) mm with sharp notch after static bending test for determination of common yield force in the notch are put into the tank with standard solution of sulfuric acid of 0.1 density and addition of thiourea. Hereafter these samples are loaded on the "Instron" machine beyond the yield point, and then electric tension with 10mA/cm^2 current density is turned on. In such a way there arises hydrogenezation of metal while of corrosive medium and mechanical stress impact.

Conclusions

Delayed fracture runs in three stages that can be fixed while changing a certain property: electrical resistance, mechanical compliance etc. The first stage is incubation time, the stage of crack origination, the second – developing of stable crack, the third is rapid rupture. Delayed fracture testing is executed under different stages of applied load. The lower the value of applied load, the more time till damage. Herewith the durability of incubation time usually longer than the period of stable cracks developing, especially under great stress. Under low tensions the durability of nucleation and developing stages are comparable. Consequently for evaluating the reliability of pipeline operation in conditions of possible contact with corrosive medium the most important is determination of crack nucleation and developing resistance, not rapid as during impact tests, but slow. That is why the level of impact toughness does not reflect crack resistance in pipelines.

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