PROMISING LINES FOR STUDYING STRENGTH AND LONGEVITY OF HYDROCARBONS TRANSPORTATION PIPELINES

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A currently actual task is to extend the period of operation of the existing pipelines within the existing standard requirements to strength and longevity (service life), to resolve the problems of integrated technical diagnosis and repair/recovery activities in the damage areas outside the allowable fault rate standards to extend the safe operation life with a fixed maintenance schedule.

The following assumptions apply under the regulations that justify strength, longevity and reliability:

– the temporal technological heredity of the base metal production, plate/pipe making processes by manufacturers is not taken into account explicitly;

– the mechanical properties of pipe construction steels are assumed to be remaining unchanged during the pipe transportation, pipeline construction and operation processes;

– safety margins are considered to be constant for all life cycle phases;

– pipe/pipeline deterioration is connected first of all with a decreasing of wall thickness because of corrosion (general and local) and erosion.

The above factors must be taken into account to ensure safe operation.

Taking into account deterioration and ageing of pipe steels

The promising lines of design and experimental analysis of pipelines' strength should include a direct quantitative accounting of temporal deterioration and ageing of pipe steels at various temperatures, cycle numbers leading to a corruption of the basic design characteristics of yield stress and ultimate stress.

The processes of deterioration and ageing of pipeline steels in the conditions of plates and pipes making, transportation, construction, pipeline testing and operation must be reflected.

The existing knowledge of the temporal ageing and deterioration of carbon/low-alloy steels is reduced to the following basic provisions (Figure):

– natural ageing (curve 1) of steels in the initial state ($e = \sigma = 0$) at the ambient temperature is characterized by a slow growth of yield stress, and a reduction of the yield stress to ultimate stress ratio;

– heat ageing (curve 2) of steels in the initial state ($e = \sigma = 0$) at higher temperatures t_1 and t_2 ($t_1 > t_0$; $t_2 > t_1$) is leading to an accelerated growth of yield stress values at the initial phases of exposure, with their further reduction (overageing of steels);

– deformation ageing (curve 3) of steels in a cold-worked state for $e > 0$ gives a less change in the yield stress than the natural change, even at the ambient temperature;

– dynamic ageing (curve 4) for higher temperatures in a plastically deformed state ($e > 0$) in the conditions of stress effect ($\sigma > 0$) may be first accompanied by a minor growth, then a drop of yield stress and ultimate stress values, with a reduction of the extent of hardening of pipe steels in the plastic area.

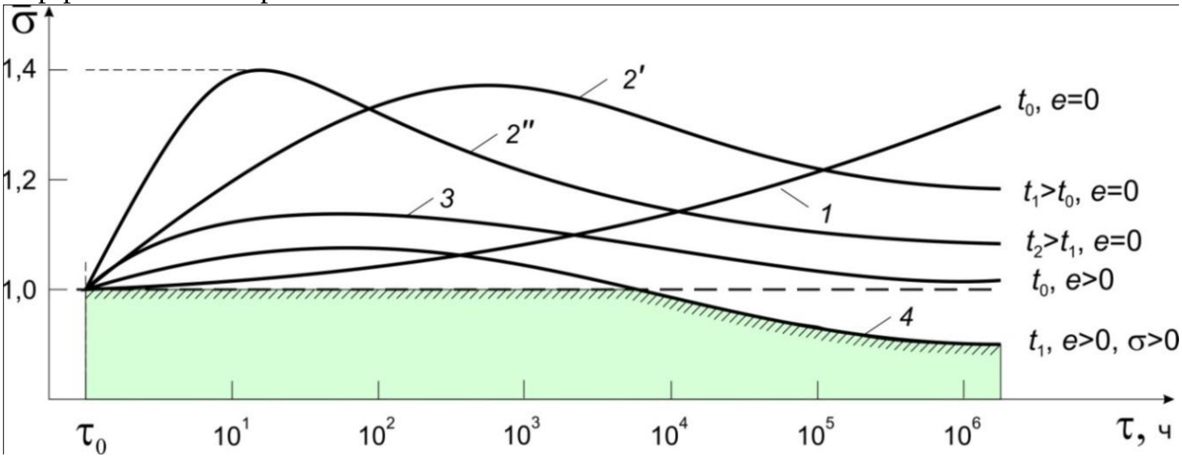

Figure. Pipe steel ageing process diagram

In all cases of ageing (curves 1 – 4), the yield stress to ultimate stress ratio is growing.

The following must be taken into account in the adjusted and standard calculations of pipelines' strength:

– an alteration of ultimate stress and yield stress values, which is not interrupted in all ageing and deterioration modes;

– mechanical properties deterioration effects, i.e. a reduction of the relative yield stress;

– a reduction of plasticity and fracture toughness accompany the ageing and deterioration process.

Safety margins appear to be depending on ageing and deterioration of pipe steels and depending on time, temperature, cyclicity and stress-strain behavior. This fact not reflected explicitly in the domestic and foreign regulations must be taken into account in future elaboration of pipeline strength standards.

Taking into account a damage of pipes' surface layers

The cases of pipeline damage are largely connected with the most intense damages of pipes' surface layers (because of corrosion, erosion, mechanical impact). Relevant tests are required for an experimental assessment of the surface damage effect.

The problems of crack resistance and survivability, when cracks of a technological and operational origin occur and are growing, are and will be particularly important in the pipelines strength analysis.

The standard approach of Transneft Research Institute has an important development element, where the assessment of strength and longevity of pipelines with cracks not only covers nominal stresses, but also local deformation in the concentration zones. A local stress-strain behavior at the crack point is determined on the basis of solving a boundary-value problem using numeric methods, with determining maximum stresses and strains. In such case, an effective stress-concentration factor for the crack zone is determined, which factor is depending on the material's structural parameter that is determined experimentally, when testing samples with cracks.

One more, and the most widely used, method for assessment of pipelines strength is to assess safety margins using equations and criteria of the linear and non-linear fracture mechanics. This approach determines through calculation the stress intensity factors. In case of a plastic deformation, strain intensity factors should be used instead of stress intensity factors.

Conclusions

The standard calculation of pipelines' strength on the basis of the allowable stress and ultimate limit states that is widely used for several decades both in the domestic and foreign practice is based on a quantitative determining safety margins for yield stress and ultimate stress is still actual.

A new scientific basis for the design analysis and justification of safety margins, with a quantitative accounting of all basic operational, technological and structural factors, including the effects of ageing, deterioration of pipe steels and pipes, generation and development of hazardous damage and faults (including those caused by corrosion/erosion), is being established on the basis of in-depth and wide-scale design and experimental work performed by the academic and leading industrial institutes.

The scientific researches and development of standards by Transneft Research Institute LLC have accumulated a considerable experimental material that allows, on the basis of actual mechanical characteristics of steels, a reasonable minimizing the excessive safety margins for both the existing pipeline systems and those under construction and future ones.

References

1. Radionova S., Lisin U., Makhutov N., Revel-Muroz P., Neganov D., Zorin N. *Nauchno-tekhnicheskie, social'no-ehkonomicheskie i pravovye aspekty nadezhnosti transporta nefti i nefteproduktov*. [Sci-tech, social, economic and legal aspects of the oil and oil products transportation safety]. Science and technology of the oil and oil products pipeline transportation. 2016, №6. – pp. 20 – 31
2. Makhutov N.A. *Development of Techniques for Mechanical Tests in Mechanical Engineering*. Inorganic Materials. 2014. Vol. 50, No 15, pp. 1516-1520