Formulation of Requirements for Gas Main Pipes Featuring High Stress Cracking Resistance

(A.B. Arabey, Gazprom, Russia)

Stress corrosion cracking (SCC) or stress corrosion in pipe metals has gained importance over the last 10 to 15 years as a key risk factor for gas mains disruption.

Gazprom carries out comprehensive R&D activities and takes organizational measures to tackle the SCC challenge. Leading experts from national industry-specific academic and educational institutions are engaged in the process.

Gazprom pursues the following SCC control strategy: prevention of its early signs, detection and monitoring of minor damages, repair of critical cracks or a pipeline in general.

Production of pipes with high stress cracking resistance is considered a promising way of SCC prevention.

Thus, Gazprom is conducting research aimed to determine metal properties and pipe production techniques that could be useful in fighting against stress corrosion.

An important tool in investigating the SCC process and mechanism is the correct selection of the testing methods allowing for laboratory simulation of the gas pipeline operation procedure as applied to pipe metal samples and for the lengthy SCC process acceleration with no disturbance to it.

Development of the testing methods that could adequately simulate the SCC process is an individual challenge that hasn't been met yet.

During our research we attempted to test metals under stresses similar in intensity and nature to those of the strain-stress state of a gas pipeline under operation. Electrolyte patterns with a composition close to that of actual soil electrolytes were used as an active medium. The research focused on approaches that considerably reduce the period of a sample exposure until a SCC colony is formed. Several methodological approaches to testing have been compared to select optimal laboratory testing conditions.

The following considerations were taken into account in developing the methodological approaches:

- strain-stress state of tested samples should maximally imitate actual conditions of the pipe metal stress – it should have a biaxial orientation. This enables to rule out the disadvantages of widely-used testing methods involving only a monoaxial extension. The main disadvantage is the absence

of the main SCC feature – formation and expansion of SCC colonies during a testing process;
- the SCC process under actual operating conditions covers a long period of time (up to 30 years) that prevents its study in the real-time format. In this context the laboratory testing methods should involve the measures accelerating the SCC process with no disturbance to it.

The problem of ensuring the distribution level and geometry of loads specific for gas mains impacts during operation was resolved through the right selection of a sample form – we used a 50x50 centimeter cross-shaped section of a pipe under study. The section retained the cylindrical shape (Figure 1). A unit containing an electrolyte pattern with a composition close to that of actual soil electrolytes was fixed in its geometric center.

To accelerate the testing process we employed the method of cyclic loading of samples frequently used for such purposes. The method cyclogram is presented in Figure 2. Meanwhile, it is worth mentioning that actual conditions of gas mains operation (unlike oil pipelines) do not provide for any significant cyclic impacts on an installation.

We performed a series of 20 tests and managed to simulate a vivid example of the SCC process in a relatively short period of time: 5 hours – 10 days (depending on the intensity and nature of cyclic loads and, undoubtedly, resistance of the material to cyclic loads). As a result, a colony of multiple short cracks appeared.

To evaluate the correspondence of testing to the actual SCC process at a gas main we carried out fractographic investigations of fracture surfaces at crack edges using raster electronic microscopy.

The investigations revealed that cyclic loads on pipe steel samples provoke fatigue cracks, which is confirmed by specific jogs on the surface of crack edges (Figure 3). At the same time, long-term studies of the fracture surface in the samples found in accident sites or in pipes with SCC defects detected during scheduled in-line inspections did not show any fatigue damages.

The fracture specifics point to the fact that the testing didn’t achieve their primary purpose, i.e. reproduction of the SCC process observed during gas pipeline operation.

In this way, application of cyclic stress modes in testing is not appropriate for analysis of factors causing generation and development of SCC cracks in pipe metal. It is necessary to adjust the method by reducing the period of samples exposure through other measures.

In this respect it will be expedient to study during testing the relations between the specific features of cyclic impacts (amplitude and frequency, cycle symmetry factor) on the samples in order to define the level of their threshold values that are still unable to trigger the fatigue destruction.

Laboratory studies of the SCC process with Ph ~7 are foremost hindered by the insufficiency of data on the mechanism of the event being studied.

Thus, for instance, researches haven't been made yet on the phenomenon of zero SCC in pipe metal of oil mains that are similar to gas mains by design, load schemes and conditions of pipes exposure to the surrounding environment.

This may indicate that researchers are disregarding some factors involved in the SCC process at gas mains and provoked by specific relations between the conveyed medium and the pipeline design.

In this context we have recently arranged the study of acoustic events resulting from interaction between the gas flow and the pipe wall. Their aim is to evaluate the role of acoustic pipeline impacts provoked by gas transmission in the SCC process. Later on, the achieved results will be used in adjusting the testing methods for SCC resistance of metals.

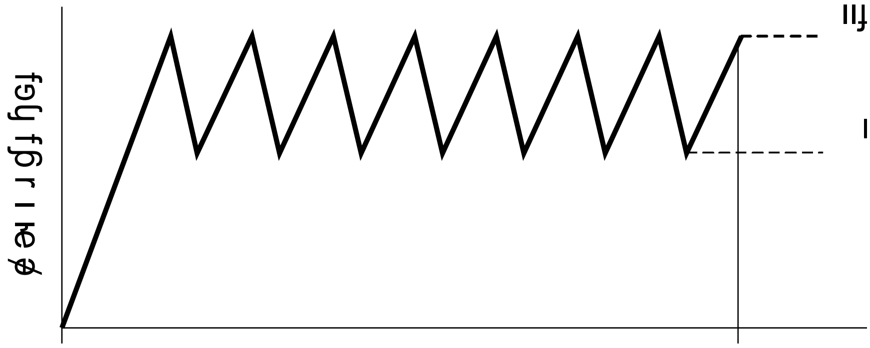
Application of this method will reveal a system of factors initiating SCC in gas pipeline metal and identify their critical parameters:

- chemical composition of pipe steel and its production technologies stipulating its proneness to SCC;
- pipe bending and welding parameters determining the level and nature of residual mechanical stress distribution across the pipe body;
- threshold mechanical stress for the SCC process startup;
- soil and soil electrolyte parameters.

The research will unveil the requirements for flat steel products, pipe bending and welding as well as pipe surface quality, that enable higher SCC resistance of pipes.

It is clear that the challenge of metal stress cracking in the neutral environment (Ph~7) is dependent on the development of the testing methods for SCC resistance of pipe steels.

Figure 1 – SCC test sample with corrosion unit to simulate separation of insulation cover on pipes



100 % of yield point

70 % of yield point

Stress

Time

60 minutes

Figure 2 – Graph of stress variations during SCC tests

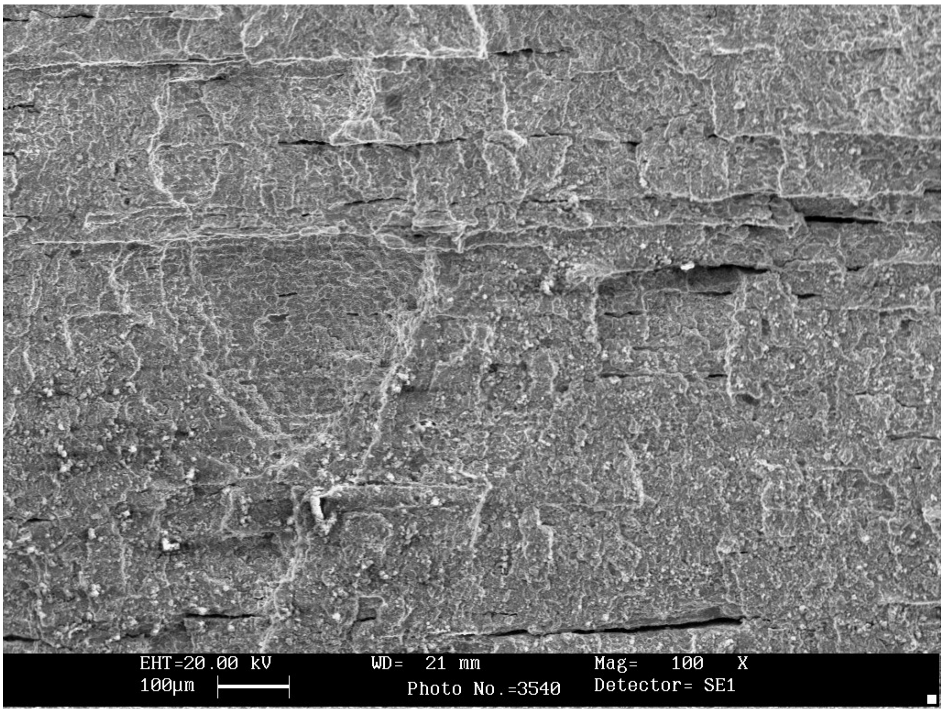


Figure 3 – Fracture along a big crack generated during SCC tests. Fracture shape is specific for cyclic destruction. Pipe surface is on top. X100. BSE.