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Permanent Repairs of High-Pressure Gas Pipelines Using the Innovative Cold Sleeves Method (STO®)

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Background

The company Eustream as the biggest transporter of natural gas from the Russian Federation to Western Europe pays an extreme attention to maintaining its key technologies as well as pipeline systems. This segment has been its long-term focus of attention not only in terms of following up on global trends of systems designed for repairs of typical pipeline damages (e.g. corrosion defects, welds, incorrectly applied coatings, land slides etc.,) and their consequent use in practice, but also in terms of development and testing of pipeline systems repairs. A typical example of such repairs tool, continually developed over the past 15 years, is a cold sleeve, which has been applied successfully on the Slovak product pipelines (Eustream transmission network, Bratstvo gas pipeline system, Transpetrol a.s.).

Aim

The hermetic coating application to pipeline in terms of full operating pressure without transport limitation of transported medium in the order to increase the pipeline strength which is affected by non-permissible type of defect as corrosion or the other type of material loss or unfused root of pipeline circumferential weld.

Methods

The cold sleeve (STO) is a cold (glued) joint between the pipe, which is being repaired, and the steel shell of the sleeve produced without any thermal effect using an adhesive polymer with penetration capabilities. Its principle lies in fabrication of a hermetic shell aiming at increasing the load capacity of the pipe affected by the impermissible defect. The space between the pipe and sleeve shell is being filled in by a special composite material (Fig. 1).

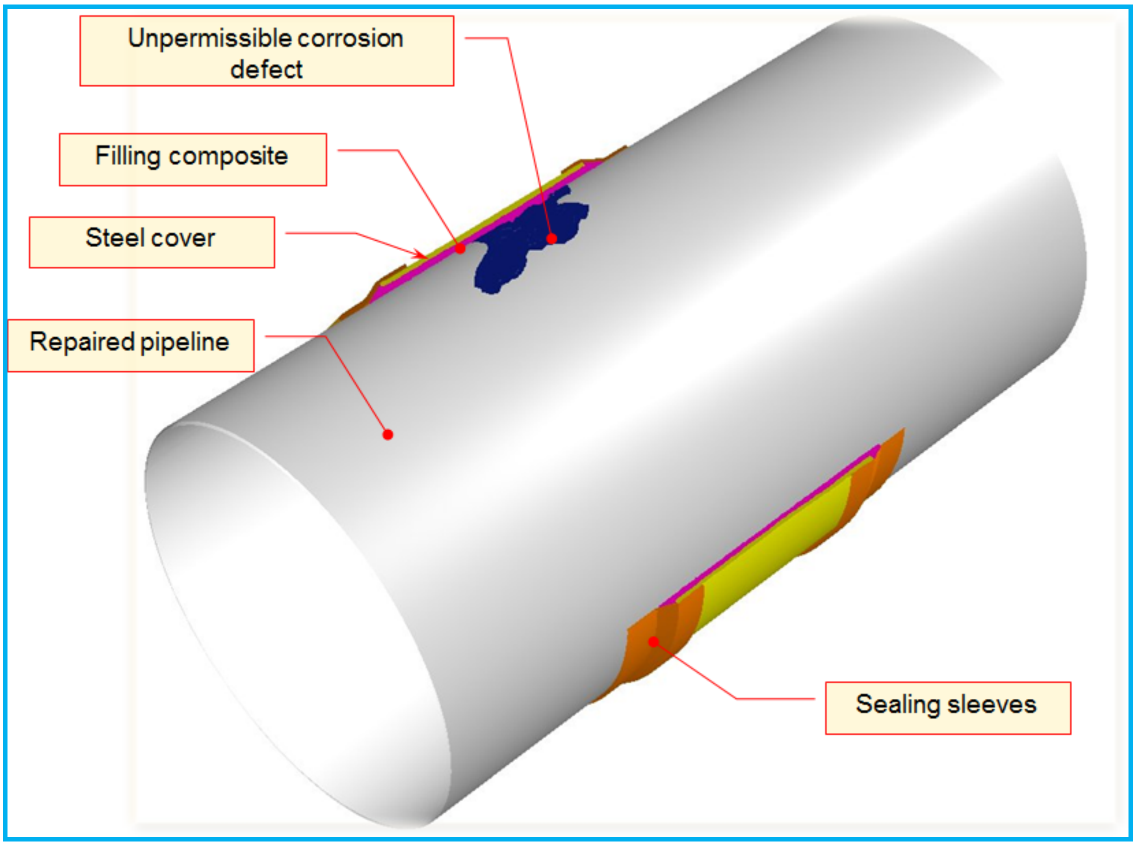

Fig. 1 Cold sleeve

An undisputable advantage of this high-pressure pipelines repair method is the fact that the repair can be carried out under full operating pressure, i.e. without any limitation to medium transmission. The method can be used for repair of all kinds of corrosion or material losses up to the yield point Re of the repaired material. The length of the repaired pipe is not limited since sleeves can be arranged continually one after the other.

In respect to safety of high-pressure pipeline operation the current version of the cold sleeve has been characterized by the following limitations:

- STO can be used as a permanent repair only for corrosion defects,
- STO is not suitable for use as a permanent repair for anomalous welds, since the filling material after polymerization becomes fragile and in case of pressure changes under certain conditions the filling is cracking, or possibly separates / detaches from the basic material,
- high price of the filling material as well as demanding maintenance of the filling device.

When compared with the operation situation, during depressurizing the gas pipeline shrinks and due to the fact that the cold sleeve shell keeps its dimensions acquired during installation, there generates internal tension in the adhesive layer between the polymer and metal of the gas pipeline, as well as the STO shell. This results in detachment of the filling material as well as in integrity disruption of the glued joint – filling material (composite) – pipe (Fig. 2).

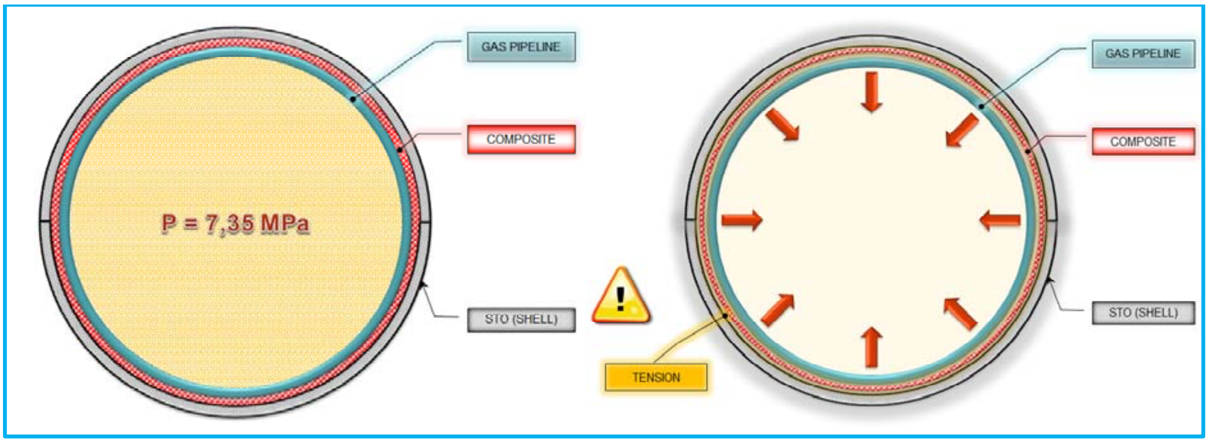

Fig. 2 Effect of the pipe depressurizing

Specification of the Anomalous Weld

For the sake of better understanding one has to state the following:

Over the whole period of defect identification in welds construed during the Eustream Gas Pipeline Network (former "Transit gas pipeline") construction there has been detected a great number of defects of the type of an incomplete root penetration maximally up to the depth of 1 mm. This defect has never occurred on both edges of the weld root, neither was it identified along the whole weld circumference. For purposes of safe proving of new filling material suitability of the innovated STO technology we have opted for a conservative approach, which means that the strength analysis included an anomalous weld in respect of which the incomplete penetration was defined at both edges of the root up to the depth of 1 mm as well as along the whole weld periphery (Fig. 3).

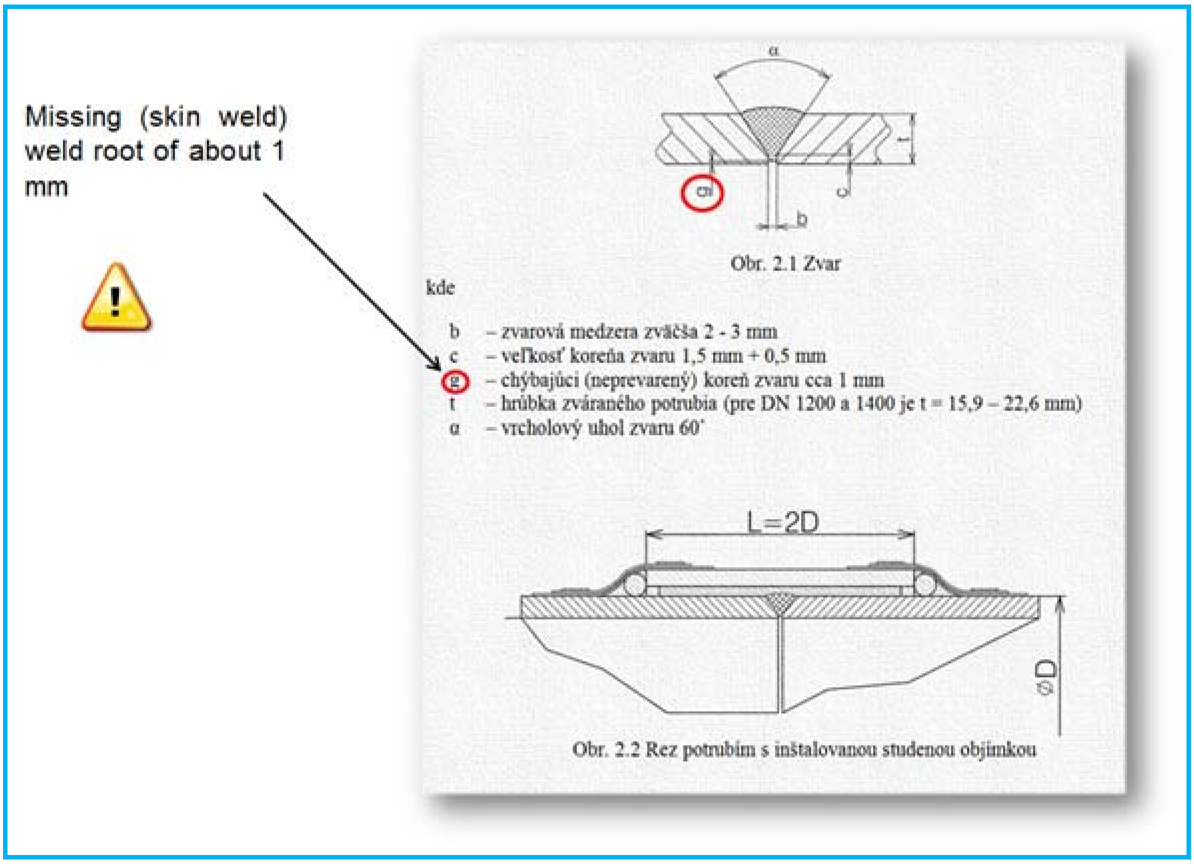

Fig. 3 Anomalous weld specification

Due to the above reasons, just as well as due to the new ambitious objective to eliminate limitations and to extend applications of the cold sleeve it was decided to continue in developing the new STO by way of implementation of a research and development task. The task has been named " Verification of the new filling material for STO as a permanent repair of the high-pressure gas pipelines according to TC.R.90.01.06 (Development of a new technology, Annex 1, chapter 3, Art. 1.2, letter B)".

The expected objective and concurrently required result was to:

- propose a filling material with the required properties (adhesive and cohesive strength, viscosity, ductility, processability time, chemical resistance, el. breakdown strength etc.),
- achieve that the innovated repair system by the STO method is recognized as permanent repair also for anomalous welds of the high-pressure gas pipeline.

The task was assigned to employees of the centralized maintenance in Senica. Upon a thorough analysis of weaknesses of the currently used STO technology they proposed a procedure divided to the following stages:

I. stage

I.1 To define the qualities of the new filling material

For the new filling material there have been defined basic parameters as follows:

- compressive, tensile and shear strength,
- adhesive strength,
- flexibility module,
- hardness, ductility
- viscosity, penetration ability
- chemical resistance
- application time (pot life).

I.2 mechanical testing

Upon selecting the most suitable material and its modification by the manufacturer there were produced testing samples (Fig. 4) for:

- adhesion tests,
- cohesion tests,
- corrosion tests.

Fig. 4 Testing samples for mechanical and corrosion tests

In Fig. 5 one can see a broad force dispersion necessary for detachment for a normal load of the filling and maximal force at the tensile test of the filling material. Results of these tests show statistical behavior of the testing samples with big dispersion of maximal force. For example the maximal force necessary for tearing of the sample moves within <200, 500> [N]. It is caused mainly by chemical composition, surface as well as internal inhomogeneity of the material, way of polymer processing as well as sample manufacturing.

It is very important to note that also in case of mechanical testing results evaluation, due to the safety of high-pressure gas pipelines operation, there was selected the conservative approach and the values that were entered in the strength analysis were the lowest ascertained values of the mechanical testing.

Another level of the conservative approach was the fact that the strength analysis also considered the axial loading of the whole system. (Axial loading FO produced by the gas operating pressure in the closed pipe. This load is calculated as FO = P . S, wherein P represents the operating pressure and S the internal circular area of the pipe.)

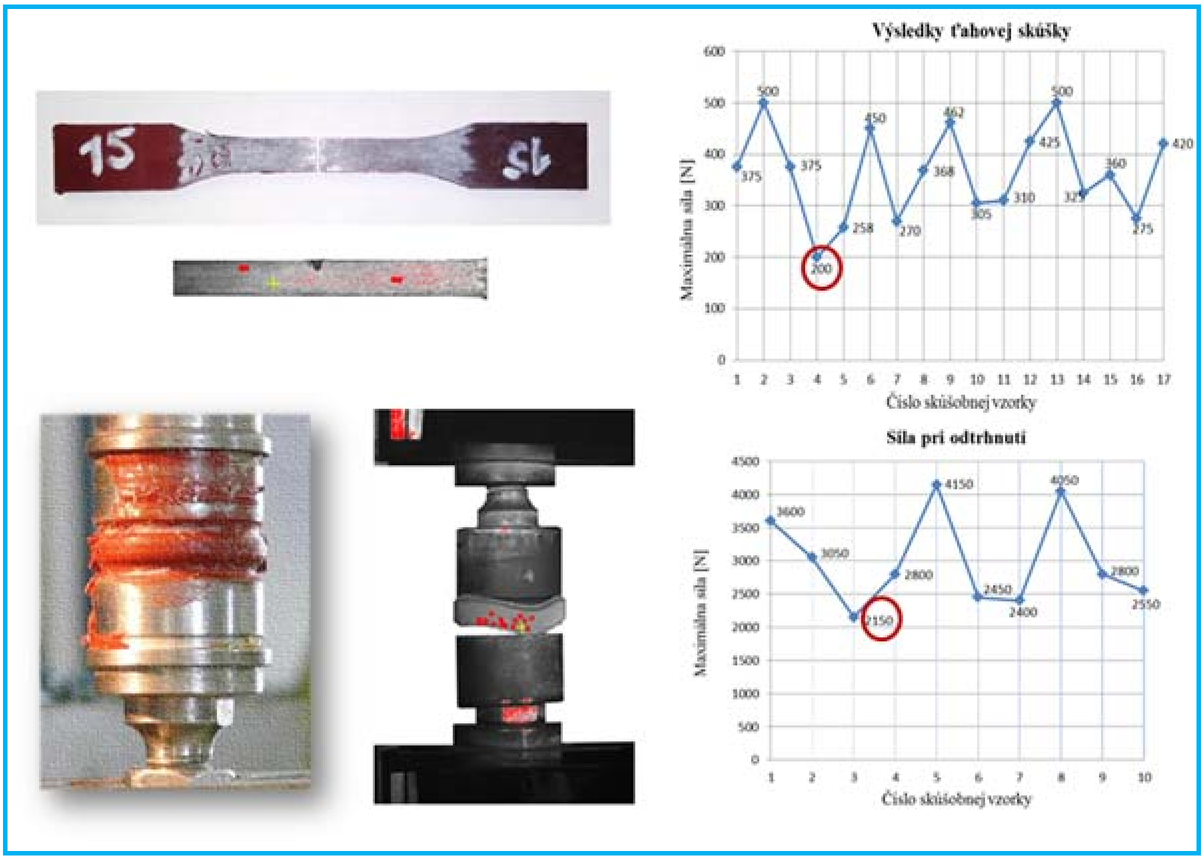

Fig. 5 Mechanical tests evaluation

I.3 technological testing

Upon evaluation of the results of the mechanical tests there followed technological tests (Fig.6) that were implemented in the laboratory conditions of the centralized maintenance in Senica (with the aim to reach real conditions as close as possible) (Fig. 6). The technological tests included:

- leakage test,
- model test,
- measuring of radial stress on the external surface of the STO shell as well as the pipe under repair,
- final visual check.

Fig. 6 Technological tests

II. stage

Upon successful completion of the material as well as technological testing the results of the tests were submitted to two independent authorities.

Results

- from the strength calculations of the finite elements method, in consideration of the ultimate load-carrying capacity there derives that the least favorable alternative is the one with the biggest diameter of the pipe and the smallest wall thickness (Ø 1 420 mm with the wall thickness 15,6 mm) also in consideration of the axial force,

- the pipe as well as the sleeve are stressed in the elastic area under the yield point of the utilized steel types,
- results of the detachment (separation) simulation imply that the cohesion of the plastic filling and the sleeve or pipe will not be disrupted even in case of the most critical stress,
- from the point of view of the plastic filling separation, the repair of the anomalous weld by the cold sleeve is safe.

The overall assessment of the technical solution of the given task was requested from the Technical Inspection that eventually confirmed that the solution was successful by issuing the Certificate (Fig. 7).


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Fig. 7 The independent authority

Conclusions

- The repair of the high-pressure gas pipelines by the innovated cold sleeve method (STO®) can be implemented under full operating pressure without any limitation to transmission capacities,
- the repair can be applied to all kinds of corrosion defects or material losses up to the yield point of the material , while the length of the pipe which is being repaired is not limited,
- the repair can be applied also to anomalous welds with a defect of the type of an incomplete root penetration,
- cost saving for the repair represents more than 40 %,
- elimination of problems with instability, quality and filling of the old filling material, as well as with the maintenance of the filling device.

As derives from the above, by the new STO the company Eustream acquired an exceptional original repair tool for repairing of a broad spectrum of defects of the high-pressure gas pipelines practically of any possible dimension. Due to its extraordinary qualities, especially the possibility of repairing the weld defects, as well as extensive corrosion defects, upon its patenting (the process is currently successfully under way, a note of the author) it will be possible to use this repair tool also on the pipeline systems of other European gas companies.

References

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