TESTING OF NEW TYPE OF SPLIT SLEEVE FOR PIPELINE REPAIRS BY INTERNAL PRESSURE

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SUMMARY

Repairing technologies for pipelines still require attention due to large extent of distribution network containing different construction parts including elbows, branch connections and others. Repairing of the defects in the branch connection area without interruption of the gas supply is very difficult. Such defects mostly require replacing of the damaged part with interruption of media supply or construction of the bypass around the branch connection. The first method is sometimes difficult to realize and the second is relatively expensive due of necessity of hot-tapping (creating of the hole into the pipeline and welding without the interruption of media supply). In this article, new repairing technology with application of special split sleeve is presented. Computation of required wall thickness is described together with testing based on internal pressure.

1. INTRODUCTION

The various types of integrity break can be discovered on pipelines during the service time of high-pressure gas distribution network. Statistically, the most common cause of pipeline failure until the 2013 was external interference (28 %), followed by corrosion (26 %), construction defects/material failure (16 %), ground movement (16 %), hot-tap made by error (6 %) and the rest were other and unknown causes (8 %) [1]. Very dangerous are defects that have sharp geometrical shape and which act like local stress concentrators [2].

Numerous kinds of repair techniques of the gas pipelines are now available including the cut out and replacement of the pipeline, construction of the bypass along the damaged area, grinding, weld deposition, metallic or composite sleeves, etc. [3]. Although the repairing techniques for straight parts of pipelines are quite well established, only a few of them are applicable for branch connections defects (for ex. defects in the area of fillet weld between header and branch pipe (Fig. 1)). Defects of the branch connections can be mostly repaired only by the replacing of damaged area of the pipeline, which requires interruption of media supply or bypass construction. Both technologies are expensive and there is still a necessity of designing new (or improved) repairing technologies. Some of the possible technology of repairs is application of the split sleeves that may be in some cases and with appropriate construction used to various defects, even with gas (or another media) leakage.

Figure 1. *Split sleeve for branch connection repairs*

Recently a new type of split sleeve for such defects repairs has been designed [4,5]. Split sleeve (Fig. 2) consist of the cylinder part and sphere-like part (split into two segments), which has to ensure safely installation of the sleeve to the repaired branch connection. Parts of the prepared split sleeve are during the repairing process placed to the area with defect and welded together by butt welds (Fig. 3). To the header and branch pipe is sleeve welded by full encirclement fillet welds after the completion of the butt welds. Whereas internal space of sleeve will be exposed to leaking gas during the assembling process, it is necessary to ensure sealing up of the internal space and places of welding. Sealing up of the internal space of split sleeve is designed with using sealants fixed to so-called "sealant carriers". Sealant carriers copy every separation surface of sleeve, as well as the holes in the places of connection of the sleeve and pipeline.

Figure 2. *Split sleeve for branch connection repairs*

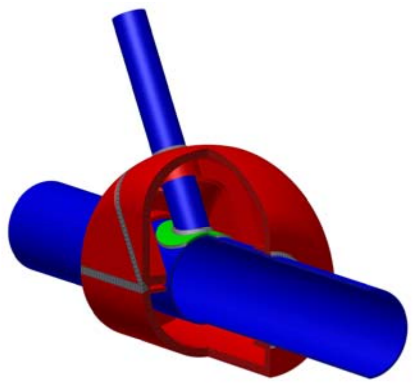


Figure 3. *Branch connection with split sleeve*

One of the most important requirements for the application of the sleeve as a permanent repair is the maximum allowable operating pressure (MAOP) of the sleeve. In this article, determination of the required sleeve wall thickness and pressure testing of the manufactured split sleeve are presented.

2. FINITE ELEMENT COMPUTATION OF SPLIT SLEEVE WALL THICKNESS

Split sleeves for pipelines repairing can be in general considered as thin-walled pressure vessels. Since walls of the sleeve offer little resistance to bending, it can be assumed that the internal forces exerted on a given portion of the wall are tangent to the surface of the sleeve (vessel). The resulting stresses on an element of the wall will thus be contained in a plane tangent to the surface of the vessel [6]. Computation of the stresses in the cylindrical and/or spherical pressure vessel is simple, but determination of stresses in the complicated geometry of the split sleeve for branch connection repairs is more difficult. In such cases, it is possible to use finite element (FE) analysis [7,8].

Simulation software ANSYS was applied to computation of the stresses in the wall of the sleeve, and according to results, wall thickness was determined.

Numerical simulation was performed on the model representing a half of the sleeve with the symmetry plane crossing the axis of the branch connection. Prototype of the sleeve was designed for branch connection with outer diameter of Ø159 mm for header pipe and Ø60,3 mm for branch pipe. Angle between the pipes was 60°.

As a material of the sleeve, S355 grade steel was applied. Nonlinear material elastic-plastic model for S355 grade steel was used to obtain more realistic results of FE analysis (Fig. 4).

Several values of thickness and dimensions of sealant carriers were applied during thickness determination. Initial thickness was chosen according to wall thickness of practically used cylindrical split sleeves to 10 mm. Such thickness resulted in very high stresses in FE analysis (over 1000 MPa) and thickness had to be increased up to 16 mm. Initial models also did not contain sealant carriers. It was also consider that usage of the sealant carriers might be useful and next models also contained sealant carriers with thickness of 5 mm and length of 50 mm.

Such thickness was also insufficient but length was not have very important role and could be reduced. Final dimensions of the sealant carriers was 8x35 mm.

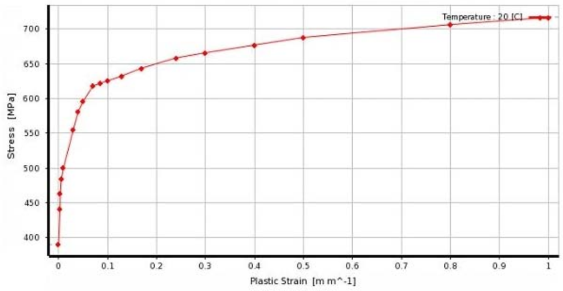


Figure 4. *Stress-strain diagram of S355 grade steel used in FE analysis*

The 3D models prepared in Autodesk Inventor software was meshed in ANSYS by automatic meshing function. Triangular and quadrilateral elements for 3D analysis was used to prepare the mesh due to increasing of the wall thickness up to 16 mm, and to consider presence of the stresses in the wall thickness.

Boundary conditions of the computation are shown in Fig. 5. Connection B, C and D was fixed and plane A is symmetry plane of the model. Pressure with value of the 6,3 MPa was applied to each internal face of sleeve.

Distribution of the equivalent stresses for the final dimensions of the sleeve and internal pressure 6,3 MPa are shown in the Fig. 6 and Fig. 7. Computation results showed that thickness of split sleeve 16 mm is sufficient. It was also demonstrated that sealant carriers serve not only to isolate internal space of sleeve during welding but also as the reinforcement of the sleeve against pressure.

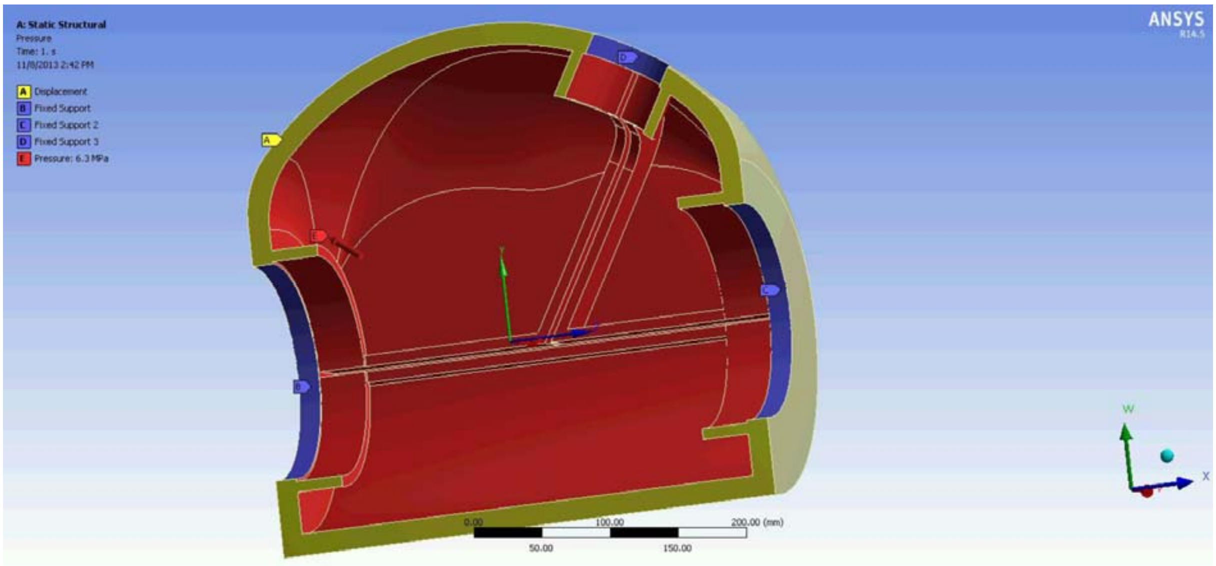


Figure 5. *Boundary conditions in FEM analysis*

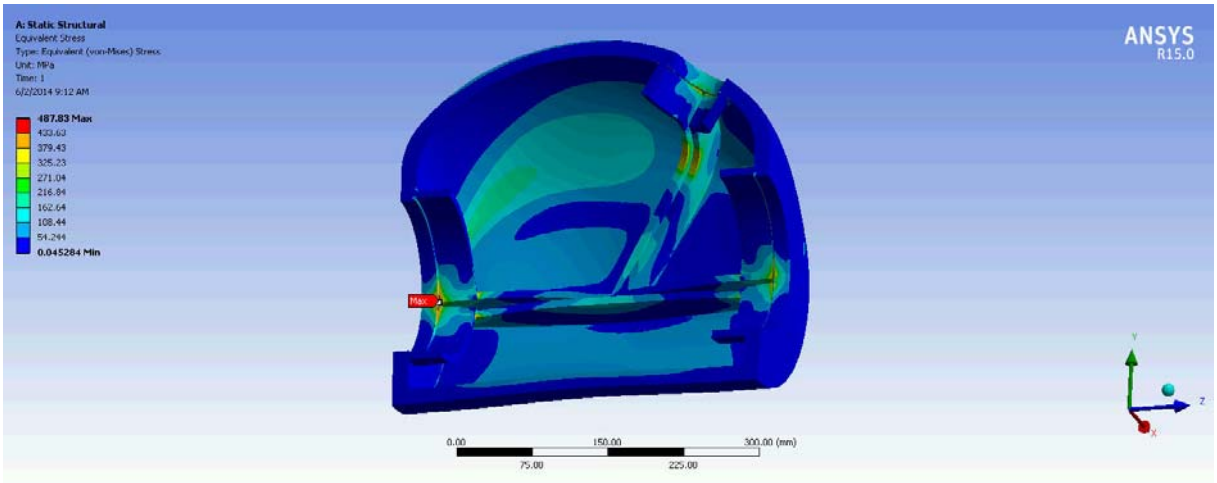


Figure 6. *Equivalent stresses in the split sleeve – inner surface*

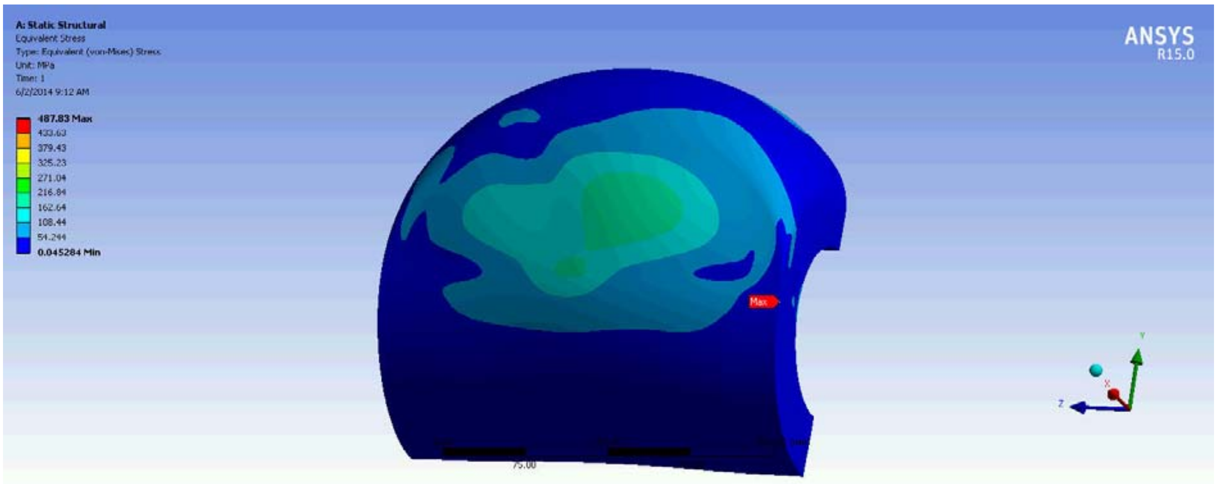


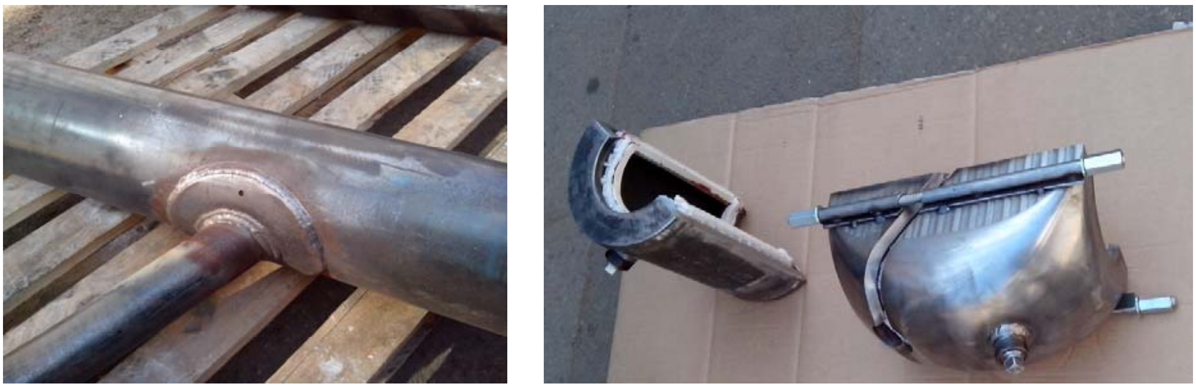
Figure 7. *Equivalent stresses in the split sleeve – outer surface*

3. MANUFACTURING OF THE SPLIT SLEEVE

Branch connection for application of split sleeve was made as a weldment of the pipes with dimensions of 159,0x4,5 mm and 60,3x4,0 mm for header pipe and branch pipe, respectively. Place of connection branch pipe with header is consider as an isolated hole and reinforcement of the hole needs to be assessed. According to EN 13480-3 standard [9], reinforcement with thickness of 4,5 mm and length of 35 mm should be used. For this purpose, steel plate with shape of ellipse (reinforcement pad) was used and welded to the header and branch pipe (Fig. 8a).

Different manufacture processes and also semi-products were applied to parts of the sleeve. Cylindrical part was prepared by welding of end plates to thick-walled pipe (thickness of 16 mm for each part). Both end plates are made of S355J2+N steel and material of the thick-walled pipe was S355J2H steel. Sphere-like part was made by milling of S355JR steel block to required shape and size. Machined part was after that split into two segments. Materials used in this type of construction have ensured weldability without additional conditioning. Manufactured parts of split sleeve are shown in Fig. 8b.

After the parts were manufactured, parts of the split sleeve were welded by butt welds by manual metal arc technology (MMA). Whole sleeve was then welded by fillet girth welds to the branch connection.



a) *b)*

Figure 8. *Manufactured branch connection (a) and split sleeve (b) before assembling*

4. PRESSURE TESTS OF SPLIT SLEEVE

Standardized pressure test can be performed according to several standards. For designed sleeve, hydrostatic pressure test was used in terms of EN 12 327 [10] and Slovak technical rule TPP 702 02 [11]. Testing procedure was based on the filling the test section of pipe equipped with the repairing sleeve (Fig. 9a) with water and pumping the pressure up to a value that is higher than maximum allowable operating pressure (MAOP) and holding the pressure for a period of one and a half hours. According to the standards, value of the pressure should be higher than 1,5xMAOP. During the testing period, pressure decrease was measured by pressure gauge (Fig. 9b). Dimensions of the sleeve was designed to MAOP with value of 6,3 MPa and minimal testing pressure was proposed to 10 MPa. During the testing period, no significant decrease of the pressure was detected.

Pressure test to destruction was used to determine weak area of the branch connection with applied split sleeve. During the test, internal pressure was constantly increased to the destruction of the analysed sample. Destruction occurred at the internal gauge pressure 27,3 MPa (273 bar). The crack was situated on the flat surface of the sleeve (Fig. 10).

a) b)

Figure 9. *Pressure test of the split sleeve for branch connection repairs: a) experimental setup; b) detail of pressure gauge with value of the pressure during standardised test*

a) b)

Figure 10. *Position (a) and detail (b) of the crack after pressure test to destruction*

5. DISCUSSION

Numerical computation of the split sleeve for branch connection repair shows importance of the designing phase during the manufacturing process mainly in case of the new repairing solutions and prototypes. Results of equivalent stresses leads to increasing of the wall thickness of the sleeve up to 16 mm (initial value was 10 mm). The reason is relatively complicated shape that was designed to ensure the possibility of sleeve installation and without unwanted increase in the sleeve volume (causing increase in the weight). Higher equivalent stresses than material Yield stress (355 MPa) might be observed in some areas after FE analysis. Such values was present on the sharp edges or in the areas of the sealant carrier connection to the wall of sleeve. This increasing might be influenced by computational method. Equation describing static equilibrium are solved in the nodes of the mesh. After solving process, a post-processing follows, which is strongly dependent on the shape of the elements. Sharp edges might cause that created mesh contains elements, which can during post-processing lead to rapidly increased values of the stress. The main body of the sleeve (Fig. 7) shows presence of the stresses with values below material Yield stress initiated by MAOP. Thickness with value of 16 mm and sealant carriers with dimension of 8x35 mm are thus sufficient to withstand MAOP of the pipeline with value of 6,3 MPa.

Two pressure tests were proposed to the manufactured prototype construction. First test was designed to verify the proposed dimensions. Standardized testing procedure selected to this purpose shows sufficient resistance during the loading of the sample by internal gauge pressure with value of 10 MPa. In addition, correctness of the manufacturing technique of the pipes and split sleeve was also verified as there was not detected leakage of the water. Second testing procedure was selected in order to obtain information about the weak places of the construction. Constantly increased internal gauge pressure leads to destruction and formation of the crack on the flat surface of the sleeve. This place (Fig. 10) is in good agreement with the maximum equivalent stresses of the sleeve main body in finite element computation (Fig. 7). Maximum measured gauge pressure (27,3 MPa) also pointed out a possibility of application of the sleeve with lower wall thickness in practical applications.

6. CONCLUSIONS

New type of the split sleeve for branch connection repairing can bring decrease in the repairing costs compared to repairs by replacing of the damaged area with interruption of the gas supply or with bypass construction. Several conclusions can be stated from the computation of the wall thickness and pressure tests of the designed sleeve as follows:

1) Minimum required thickness and sealant carriers' dimensions for selected pipe dimensions are according to finite element computation 16 mm and 8x35 mm, respectively.
2) Designed construction and welding process satisfies conditions required by the standard EN 12 327 and Slovak technical rule TPP 702 02.
3) The weakest place of the construction is flat surface of the sleeve where the maximum stresses of the main sleeve body were computed and also crack after destruction pressure test was present.

Acknowledgement

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