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DEVELOPING OF NEW TECHNOLOGY FOR REPAIRS OF BRANCH CONNECTION DEFECTS

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ABSTRACT
The article presents testing of the new type of split sleeve for repairing of branch connection defects on gas pipelines. Such type of defects mostly required replacing of the damaged area. Developed new type of split sleeve consisting of three segments might thus lead to reduction of the costs and bring an opportunity to repair leaking defects without interruption of the media supply. Proposed solution should also increase strength of pipeline against the additional loading. Low-cycle bending test was carried out to analyze behavior of the structure during additional load to branch connection.
Keywords: branch connection repair, split sleeve, gas pipelines

1. INTRODUCTION
Defects of the branch connections are mainly situated in the area of fillet weld between header and branch pipe. It is necessary to repair such defects but only a few of the commonly used repairing technologies can be applied due to complicated geometry of branch connection, especially when angle between header and branch pipe is different from $\varphi = 90°$. New type of split sleeve was designed recently [1], which ensure repairing of the damaged area even when gas is leaking from the pipeline. Permanent repairing techniques should also ensure corresponding or better resistance to loading as undamaged branch connection.

In many practical applications, metal structures are subjected to cyclic loads, which occasionally may be strong enough to induce repeated yielding of the material [2]. Gas transmission pipelines are often loaded by internal pressure fluctuations and external loading can be also present due to insufficient soil concretion, ground movement or presence of frequent road near the pipeline. Branch connections can also maintain loads induced by the armatures placed on the branch pipe near the connection causing bending moment. Such loading leads to severe stress cycles that may induce low-cycle fatigue damage, the degree of which is influenced by stress concentrations (due to geometrical and material discontinuities, surface roughness, macro and micro inclusions and defects), the type of loading (strain- or stress-controlled and degree of non-proportionality) and the presence of residual stresses (from manufacturing processes, prior large deformations and welding) [3].

The aim of presented article is to analyze stresses induced in the junction of branch connection by external force with low-frequency. Unreinforced branch connection was tested together with the one with applied split sleeve for repairs of branch connection defects.

2. METHODOLOGY OF EXPERIMENTAL WORK

Cyclic bending tests were performed on two branch connections made of S355J2H steel. First was the unreinforced branch connection sample with outer diameter of Ø159 mm and Ø60.3 mm for header pipe and branch pipe, respectively. Thickness of header pipe was 4.5 mm and the branch pipe was 4.0 mm thick. Angle between the pipes was 60°. Pipes were joined together by fillet weld with weld throat of 7.1 mm. Dimensions of the second branch connection was the same as for the first case and new type of split sleeve was applied to it. Spilt sleeve (Fig. 1) used to the branch connection repairs consist of cylindrical part and sphere-like part (split into two segments). Segments of the sleeve were joined together by butt welds and after welding of the butt welds, whole sleeve was welded to the branch connection by fillet girth welds (average size of weld throat 7.3 mm). Each weld was made by manual metal arc welding process. Whereas internal space of sleeve will be during operational time exposed to leaking gas during the assembling process [13], design of the sleeve has to ensure sealing up of the internal space and places of welding. Sealing up of the internal space of split sleeve was designed by application of silicone-based sealants fixed to so-called "sealant carriers". Sealant carriers copy every splitting surface of sleeve, as well as the holes in the places of connection of the sleeve and pipeline. Wall thickness of the split sleeve welded to the branch connection was 16 mm.

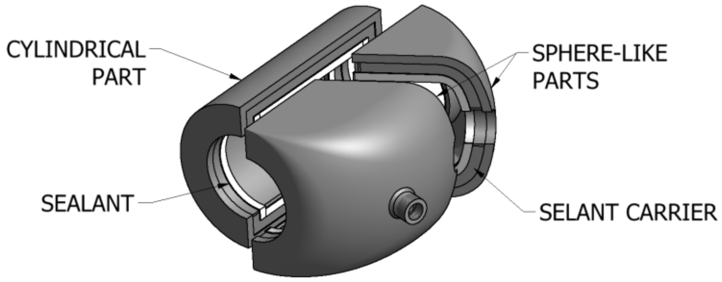
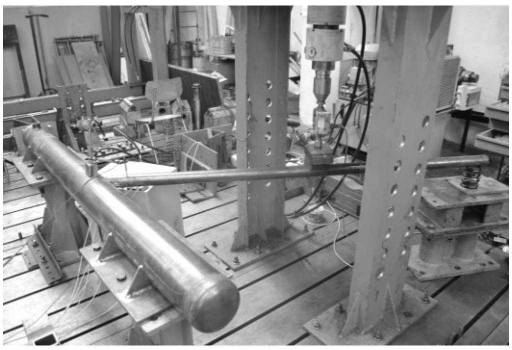
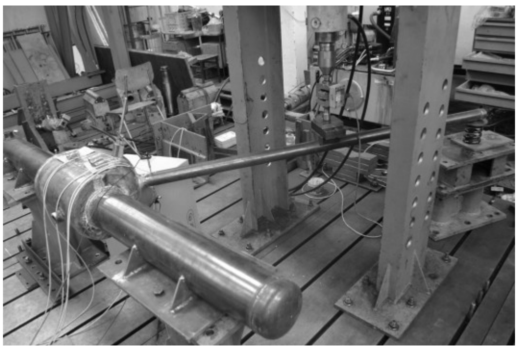


Figure 1. 3D model of split sleeve for branch connection repairs

Bending force was applied by electro-hydraulic machine RSVH with force detector LC-IE-20kN-EK acting in a distance of 1000 mm from the weld joint between header pipe (split sleeve) and branch pipe. Free end of the branch pipe was supported by the spring due to high deformation of the pipe at the end resulting to very low frequency of force during test. Specimens were fixed by the 8 bolts at the ends of the header pipe, 4 bolts at each end. For this purpose, experimental samples were equipped by the steel plates welded to the header through four ribs. Arrangement of the experimental tests is shown in Fig. 2.



a)



b)

Figure 2. Experimental test arrangement for branch connection without reinforcement (a) and with split sleeve (b)

Stresses of the samples were measured by 6 unidirectional strain gauges type 6/120 LY11 placed in the area of fillet weld during testing process of unreinforced split sleeve (Fig. 3a). For the branch connection with split sleeve only 4 strain gauges were used (Fig. 3b), as it was found out that stresses measured by strain gauges 3 and 4 at the first sample were negligible. Applied force was changed to maintain required maximal stress in at least one of the strain gauges and cycled from the minimal to maximal stress value. Maximal stress value was chosen from the material Yield stress in such way that stress should be in the range of allowable stresses for S355J2H steel. Required value of the stress (Tab. 1) was increased after the sample maintain loading during the N = 2.10^5 cycles. Increasing of the force was applied until formation of the crack in the sample was observed.

a) *b)*

Figure 3. Position of strain gauges: a) strain gauges (SG) on the unreinforced branch connection (SG number 5 and 6 are on the bottom symmetrically with SG 1 and 2); b) strain gauges on the sample with split sleeve (SG 4 is placed symmetrically with SG 3)

Table 1. Required stresses and number of testing cycles during testing

Testing level	**Required stress σ_r [MPa]**	**Required number of cycles N**
1	140	2.10^5
2	180	2.10^5
3	220	2.10^5
4	260	2.10^5
5	300	2.10^5
6	340	2.10^5
7	gradually increasing stress	to destruction

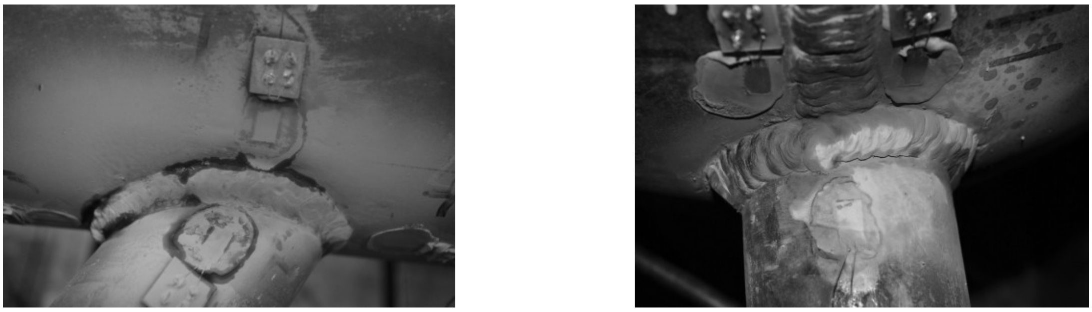
3. RESULTS

Results of the force necessary to obtain required stress value are shown in Tab. 2. Required stress was in the case of unreinforced branch connections measured by the strain gauge placed over the fillet weld on the header pipe (SG 1) and by the strain gauge on the top of branch pipe (SG 3) in sample with split sleeve. It can be seen that lower force was needed in branch connection with split sleeve than in branch connection without reinforcement for each required stress value. In the final testing level of the each sample, force had to be increased to sustain constant stress value before sample destruction. Sample without reinforcement also maintained only four loading levels while sample containing split sleeve maintain seven levels, what refers to evidentially higher strength of the sample with split sleeve.

Table 2. Maximal and minimal loading force during cyclic bend tests of branch connection samples

Testing level	**Required stress σ_r [MPa]**	**Branch connection without reinforcement**		**Branch connection with split sleeve**	
		Maximal force F_{max} [kN]	**Minimal force F_{min} [kN]**	**Maximal force F_{max} [kN]**	**Minimal force F_{min} [kN]**
1	140	3.0	1.0	2.7	0.7
2	180	3.8	1.8	3.3	1.3
3	220	4.7	2.7	3.8	1.8
4	260	6.4 – 13.5	4.4 – 11.5	4.4	2.4
5	300	sample after destruction		4.7	2.7
6	340			5.1	3.1
7	undefined			5.8 – 19.2	3.8 – 11.2

Destruction of the sample without reinforcement occurred at the fourth testing level (required stress 260 MPa) after $6.47.10^5$ cycles. Crack was formed in the fillet weld area in the heat affected zone (HAZ) on the side of header pipe (Fig. 4a). In the sample with application of the split sleeve crack formed also in the fillet weld area. In this case, crack was placed in HAZ of the weld on the side of branch pipe (Fig. 4b). Number of cycles to destruction of the sample was $1.37.10^6$.



a) *b)*

Figure 4. Crack position of the branch connection sample without reinforcement (a) and with split sleeve (b)

4. DISCUSSION

Low-cycle bend testing of the branch connections without reinforcement and with application of the new type of split sleeve resulted in different stress behavior of the samples. In both cases maximal stresses were on the upper side of the sample in the vicinity of fillet weld in the junction of pipes, however in the sample without reinforcement maximal stresses were located on the header pipe and in the sample with split sleeve on the branch pipe. Thickness of the header pipe was only 4.5 mm while split sleeve thickness was 16 mm (4x higher than branch pipe). Significantly higher thickness of the split sleeve thus resulted to strengthening of the junction area and higher stresses in the branch pipe. Strengthening of the junction area by split sleeve was also expressed by higher amount of the testing cycles. Sample with split sleeve maintained more than twice number of cycles than the other sample. Crack position after destruction of the test sample was in the weld HAZ in both cases but different thickness caused that in sample with split sleeve crack was on the side of branch pipe while in the other sample on the side of header pipe.

5. CONCLUSIONS

Stresses evoked by bending moment in the area of weld joint are significantly influenced by application of the split sleeve. Applied split sleeve resulted in lowering of the force to obtain the same required stress, but higher number of cycles were performed before destruction. Experimental measures thus showed significant influence of application repairing by the new type of split sleeve to strengthening of the header and branch pipe junction. New type of split sleeve is an efficient repairing method that except the repairing effect lead to better resistance of branch connection to bending load.

6. REFERENCES

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