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Mechanical Stresses in Aerial Crossing Piping Lines with Nonconformities

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Abstract

Analysis of stresses and strains in aerial crossings of natural gas pipeline often involves a reevaluation of the geometry and their connections as a result of the pipe laying and interaction with the ground. In this paper are presented the results of the structural analysis of a pipe DN500 lines in self-supporting crossing aerial pipe for which were found both deviations from the drawing of execution as movements of the ground after laying down. Evaluation of stresses has been carried out on the real geometry – obtained in situ – using finite element method (FEM) for different load cases. The results obtained reveal that the displacements of self-supporting crossing aerial pipe inducing by potential and possible movements of the ground can be sources of dangerous pipe application and as such, it is necessary an intervention that would lead to bank consolidation or strengthening of pipe, or both.

Key words: *piping line, aerial crossing, FEM*

Introduction

Often in the case of aerial crossing piping lines (in the majority of cases, pipelines for the transport of natural gas) deviations occur from the crossing aerial piping project as a result of cooperation pipe-soil, ground movement and intervention or repair works (maintenance). It is therefore necessary to a reassessment of the stresses and deformations in piping of crossing aerial based on their actual geometry.

Such a situation is encountered in the case of pipe DN500, wire W1, shown in the isometric diagram of Figure 1, that has been the subject of an intervention within the meaning of the replacements the line pipe (fig. 2) with “lyre” aerial crossing piping line (fig. 3). The right portion of the points S1 and S8 has been replaced with aerial crossing S1-S2-S3-S4-S5-S6-S7-S8 (fig. 3), made up of curves S1-S2, S3-S4, S5-S6 and S7-S8 and straight lines S2-S3, S4-S5 and S6-S7.

Following the execution of the work and at some time after it were found the deviations from the original project. As a result of measurements performed in situ were found into the following:

- The straight line (top most) of aerial crossing W1 is located shifted toward the vertical plane with about 180 mm;
- Also, straight pipe (top most S4-S5) of W1 pipe line is not horizontal;
- At one end there have been movements of the pipe, visible on a bend pipe of the S1-S2 of the entry in the ground of aerial crossing.

Starting from the current situation, the calculation of stresses will be made in several hypotheses to capture as faithfully real situations described above.

Initial Calculation Data

As follows from the drawing as shown in Figure 1, the analysis pipeline has in aerial crossing the outer diameter $D_e = 508$ mm, and the thickness of the wall $\delta = 7{,}1$ mm on straight line and $\delta = 11$ mm on bends. Pipe material is L360NB (X52) with proof strength $R_{t0,5} = 360$ MPa. Based on this value may calculate the allowable strength pipe material relationship with [4, 5]:

$$\sigma_a = \varphi F_b F_t R_{t0,5} \tag{1}$$

in which:

φ is the quality of welded pipe tubing; for BW welding $\varphi = 0{,}8$;

F_b – design factor which takes into account the location of the zone class analyzed; It considers that the aerial crossing is part of the location class 1B (which corresponds to areas of land opened up us with pastures or hayfields, with orchards and farms or households or with sparse housing), in which case $F_b = 0{,}72$;

F_t – design factor which takes into account the maximum operating temperature of the pipe; if the temperature of the wall duct in operating situation is under 120°, $F_t = 1$;

It follows that the admissible strength of the pipe material $\sigma_a = 207$ MPa.

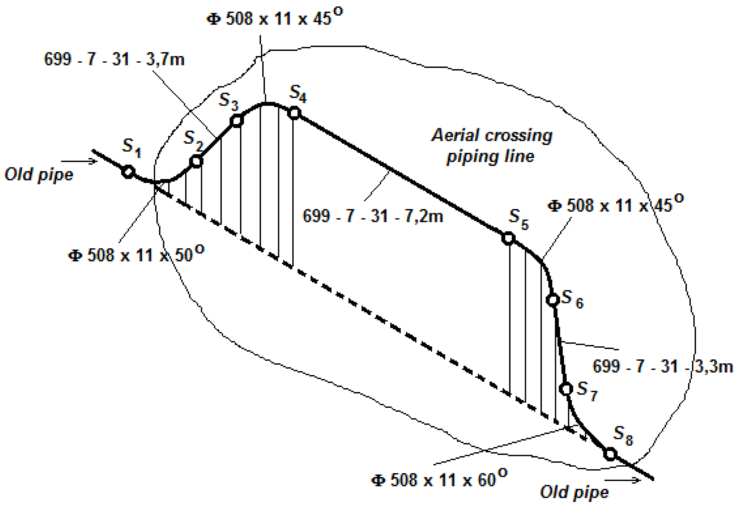

Fig. 1. Isometric representation of aerial crossing – W1 wire.

Fig. 2. Old aerial crossing piping line.

Fig. 3. New aerial crossing piping line – W1 line.

Static Model

Starting from isometric diagram shown in Figure 1, the static model of the pipeline in the aerial crossing is shown in Figure 4. The upper aerial crossing was considered to be offset with 180 mm in the horizontal plane what is tantamount to a rotation of the vertical plane of aerial crossing to an angle of approximately 3º.

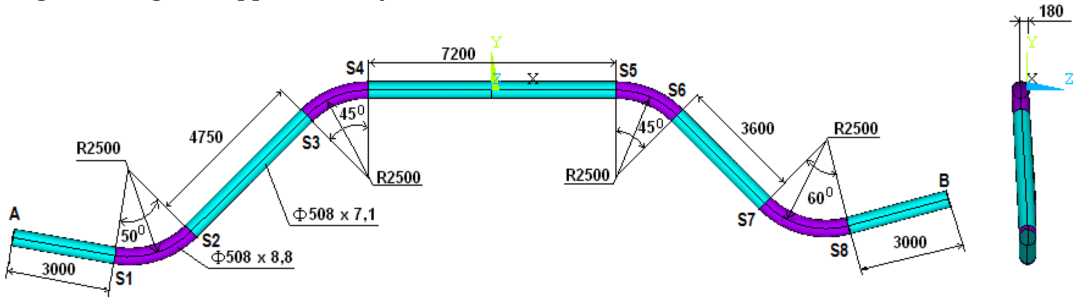

Fig. 4. The static model of the pipeline.

Determination of mechanical stresses from wall pipe of aerial crossing was achieved with a suitable calculation using the finite elements method (FEM). For this purpose, the wall pipe was divided into quadrilateral finite element type Shell.

Boundary Conditions

We have considered several variants of the abutments to the soil, as follows:

a) In points A and B, the connection to the existing pipe (from the ground, on the model of figure 4) it was considered gripping type. Also on the straight portions of the A-S1 and B-S8, due to contact between the pipe and the soil, got stuck on the vertical movements of the semi-cylindrical. In addition, it is considered that any curves S1-S2 and S7-S8 vertical displacements have not because these curves are almost completely buried in the ground. This boundary condition it symbolizes the LS1 and is presented in Figure 5.

b) In points A and B, the connection to the existing pipe (from the ground, on the model of figure 4) it was considered gripping type. Also on the straight portions of the A-S1 and B-S8, due to contact between the pipe and the soil, got stuck on the vertical movements of the semi-cylindrical. This boundary condition it symbolizes the LS2 and is presented in Figure 6.

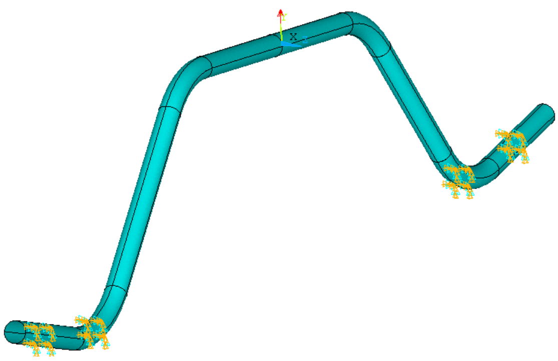

Fig. 5. LS1 boundary conditions of aerial crossing.

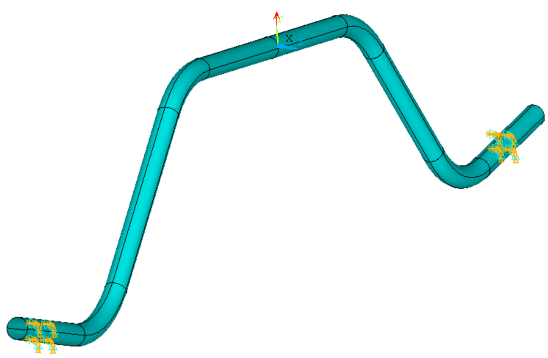

Fig. 6. LS2 boundary conditions of aerial crossing.

c) In points A and B, the connection to the existing pipe (from the ground, on the model of figure 4) it was considered gripping type. Vertical movements of the inferior semi-cylindrical were blocked only at one end (on the S7-S8-B in figure 4). This situation symbolizes the LS3 engine.

Loading Cases

a) SI1 – maximum operating pressure of pipe, $p_{MOP} = 4$ MPa;
b) SI2 – the weight of the material from which the pipeline made; were considered the density of steel $\rho = 8 \cdot 10^{-9}$ Ns^2/mm^4 and acceleration of gravity $g = 9810$ N/mm^2; pipe weight is calculated automatically by the program of calculation used.
c) SI3 – the action of the wind; the action of the wind it was considered as a distributed load along the length of the aerial crossing exposed on wind. Its intensity is determined by the relationship [1, 2]:

$$p_v = k_v g_v L_v \quad (2)$$

in which: k_v it is a coefficient of form of the element that is subject to the action of the wind; for circular sections (annular sections) k_v =1,25; g_v is dynamic pressure of wind; it was considered a hurricane-type winds with a speed of 120 km/h, which corresponds to a dynamic pressure $g_v = 0,6817 \cdot 10^{-3}$ N/mm^2; L_v is the width of section of pipe which is exposed to the wind; $L_v = 508$ mm; Results a distributed intensity load due to the wind, $p_v = 0,4328$ N/mm. It was considered that for the purposes of the action, which would increase the inclination towards vertical supra-crossing (in reverse Z axis in figure 4).
d) SI4 – soil settlement under the pipe. It was considered a 12 mm displacement on the vertical of the S1 section of pipe.

Analysis Cases

Starting from the situations presented in the paragraph 3 and loading combinations listed in paragraph 4, there were many combinations possible (CA) and have retained the most relevant, presented synthetically in Table 1.

Results

Mechanical tension analysis was performed using the ANSYS program. Because, from a practical point of view, the maximum stresses are important, in table 1have been noted the values calculated on the basis of the criterion von Mises. In Figure 7 is shown a map of von Mises stresses in CA2 case.

Conclusions

a) The maximum level of tension due to its own weight $\sigma_{max} = 17,6$ MPa it is generally low (tab.1). It has made a calculation of the structure when the aerial crossing is perfect vertical (has no inclination of 180 mm) and the maximum stresses, ghive by tare weight, does not differ significantly from those presented in table 1. It follows that this inclination of the pipe does not introduce significant requests in the system;
b) Corresponding insured CA2 analysis the maximum stresses are greater than in the case of CA1, $\sigma_{max} = 128$ MPa. This increase is due to the contribution of the internal operating pressure 4 MPa;

Table 1. Combination of analysis cases.

Analysis cases (CA)	**Boundary conditions**			**Loading cases**				σ_{max} **MPa**
	LS1	LS2	LS3	LC1	LC2	LC3	LC4	
CA1	x			x				17,58
CA2	x				x			128,1
CA3		x			x			127,1
CA4	x					x		133,9
CA5			x				x	263,2

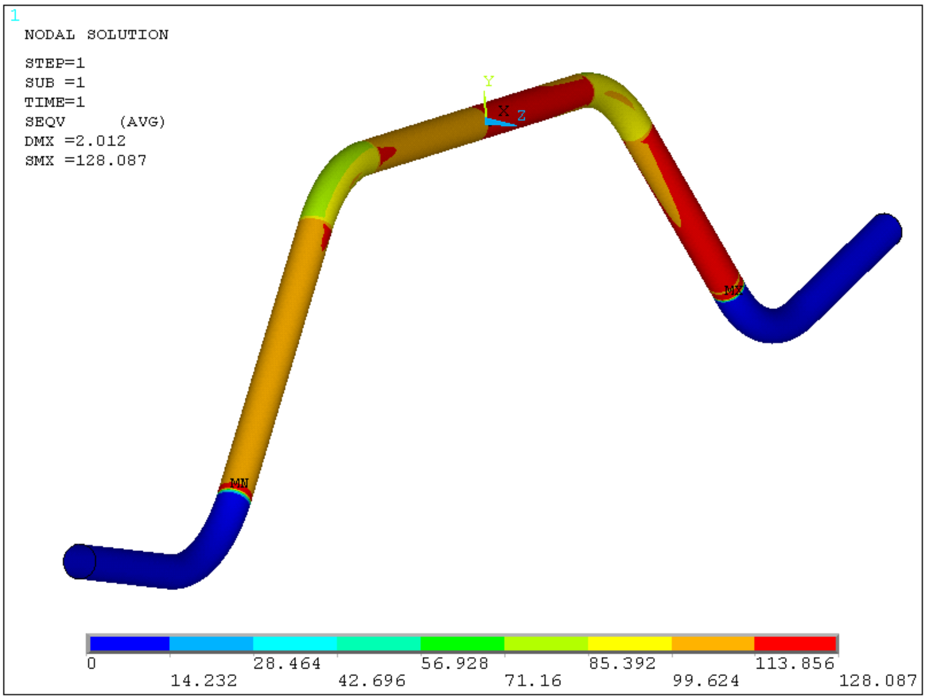

Fig. 7. The map of von Mises stresses in CA2 case.

c) Analyzing the maximum stresses of CA2 and CA3 cases it is noted that the values are comparable, which indicates that the blocking of vertical displacements on A-SI and B-S2 segments, respectively on A-SI and B-S2 segments and on bends S1-S2 and S7-S8 does not change much of the stresses in the pipe elements.
d) The maximum stresses of the first four cases of loading, CA1...CA4, do not exceed the allowable stress value.
e) The influence of wind action is not significant; the increase of the level of stresses in the case of CA3 CA4 is only a few units.
f) The movements of the ground or vertically action of ground on the pipe (but, in general, any direction), inducing severe stresses in wall of the pipe. As follows in table 1, a 12 mm surrender of land in weld zone S1 produce an equivalent stress against 263 MPa, which exceeding the allowable stress level. Admitting that the land is not perfectly rigid (elastic ground), even in conditions of subsidence in area of straight buried (A-S1) – to justify links entered on computing model – yielding land constitutes the most dangerous crossing of supra-solicitation.

References

1. * * * – EN 1991-1-4:2005, *Eurocode 1: Actions on structures* - Part 1-4: *General actions* - *Wind actions*.
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Tensiuni mecanice în tubulatura conductelor magistrale în zona supra-traversărilor cu neconformităţi

Rezumat

Analiza tensiunilor şi deformaţiilor în tubulatura conductelor de transport gaze naturale (magistrale) în zonele supra-traversărilor implică, de multe ori, o reevaluarea a geometriei şi legăturilor acestora ca urmare a lucrărilor de execuţie şi a conlucrării cu terenul.

În lucrare sunt prezentate rezultatele analizei structurale a unei conducte magistrale DN500 în zona unei supra-traversări auto-portante, tip „liră” (fără elemente de susţinere) în cazul căreia s-au constatat, după monta,j atât abateri de la desenul de execuţie cât şi mişcări ale terenului în care aceasta este pozată. Evaluarea tensiunilor s-a efectuat pe geometria reală – obţinută prin relevarea in situ – folosind metoda elementului finit (MEF) pentru diferite cazuri de încărcare. Rezultatele obţinute au evidenţiat că deplasările supra-traversării, produse de eventualele şi posibilele lunecări ale terenului, pot constitui surse periculoase de solicitare a conductei şi, ca atare, se impune o intervenţie care să conducă la consolidarea, fie a conductei, fie a terenului din zona supra-traversării, fie a amândurora.