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THE CALCULATION OF DISTORSION IN A GAS PIPELINE IN THE OVERCROSSING AREA

1. INTRODUCTION

The proper execution, exploitation and maintenance of pipelines used for the transport of natural gases requires a detailed knowledge both of the phenomena which appear during exploitation, as well as of the causes which led to them.

The goal of the current paper is to analyse the behaviour and the loading mode of the pipeline for the transport of methane gas in the crossing area.

After executing the pipeline section from the river crossing area, a raising of the pipeline from the support pillars has been noticed. The analysis of the deformation mode of the pipeline section, of the efforts and stresses has been carried out using the analytical calculation method.

2. DETERMINATION OF THE EFFORTS AND OF THE STRESSES

The pipeline was assimilated with a strength structure whose geometrical shape is given by the way in which the river crossing has been realised, as presented in Figure 1.

The calculus of efforts, stresses and strains occuring in the pipeline is made by taking into account following loads: p – the gas pressure in the interior of the pipeline; g_c – the calculation weight of the pipeline, at its calculation have been taken into account the weight of the pipeline material and of the gas, the effect of the wind; t – the temperature difference.

Because the pipeline has raised itself from the support pillars at the moment when it was subjected to the work pressure p, the effect of the forces at the slabs has not been taken into account.

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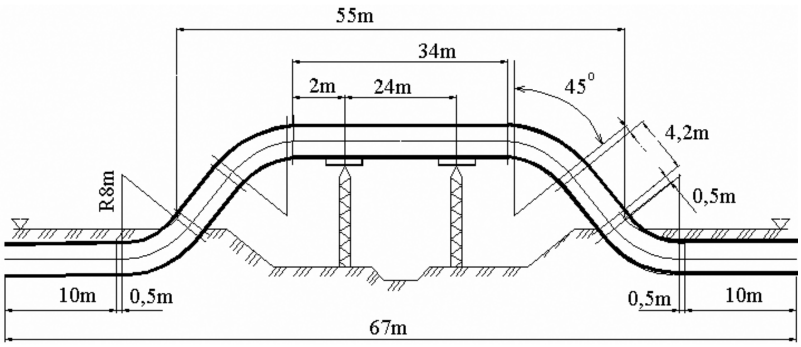

Fig. 1. The overcrossing area

At the extremities of the overcrossing area, the pipeline is buried in the soil and pressed so that a good fastening of the pipeline is achieved. The buried and pressed area of the pipeline has been assimilated to a fastened type of joint.

The determination of efforts, stresses and strains has been carried out taking into account the loads in Figures 2 and 3, as well as the effect of the temperature difference.

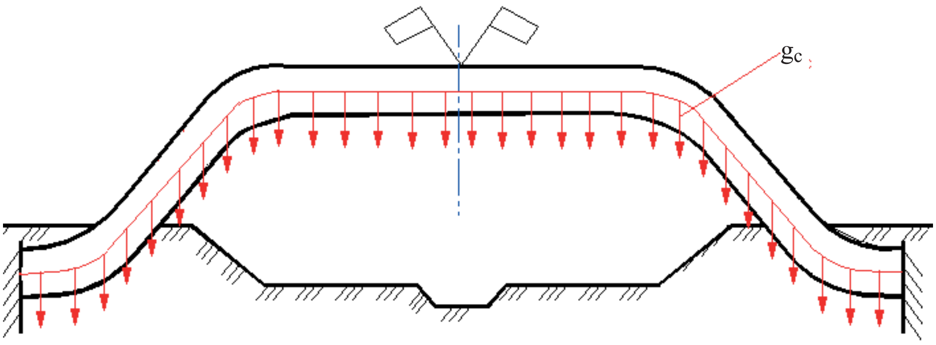

Fig. 2. The way in which the pipeline's own weight g_c appears

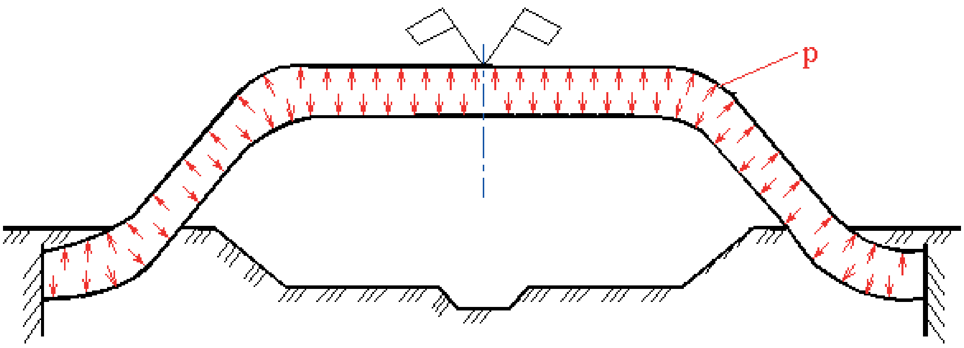

Fig. 3. The way in which the inner presuure *p* appears

The action of pressure p of the gas inside the pipeline produces supplementary efforts in the area of the bendings, which affect the entire strength structure.

Given the geometrical and loading symmetries, for the basic system has been considered one half of the structure, as shown in Figure 4a and b.

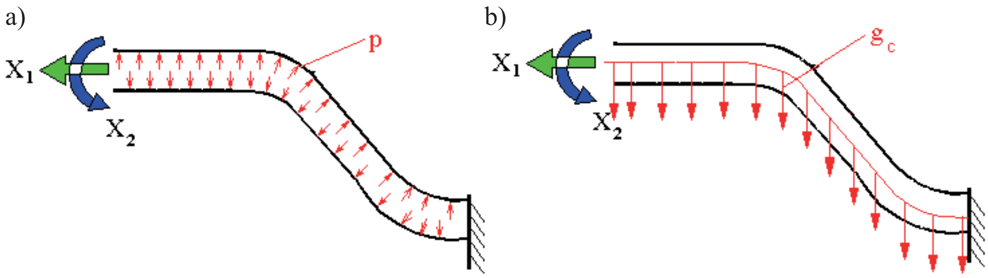

Fig. 4. The basic system

The supplementary equation system needed for the determination of the unknown factors X_1 and X_2 is obtained from the conditions regarding the displacements in the symmetry axis of the crossing. In this cross-section, the displacement in the direction of the longitudinal axis and the rotation have to be zero.

In this case we will have

$$\begin{bmatrix} \delta_{11} & \delta_{12} \\ \delta_{21} & \delta_{22} \end{bmatrix} \cdot \begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix} + \begin{Bmatrix} \delta_{10} + \delta_{10,t} \\ \delta_{20} + \delta_{20,t} \end{Bmatrix} = 0 \tag{1}$$

where:

- X_1, X_2 – the efforts which appear along the blocked directions,
- δ_{10}, δ_{20} – displacements in the direction of the two unknown factors, produced by the loads produced by the inner pressure and by the pipeline weight,
- $\delta_{10,1}, \delta_{20,2}$ – the displacements produced by the temperature difference,
- $\delta_{11}, \delta_{22}, \delta_{12}$ $(\delta_{12} = \delta_{21})$ – the displacements in the direction of the two unknown factors produced by fictive unit loads.

Since the inner area of the pipeline above the median line is larger than the inner area which lies under the median axis, in the area of the bending a force F is produced, according to Figure 5, which can be considered as uniformous distributed p_F, according to Figure 6, along the median curve of radius R.

In this case we have

$$p_F = p \cdot \frac{\pi \cdot D_i^2}{4\alpha \cdot R} \sqrt{2(1 - \cos\alpha)} \tag{2}$$

where D_i – the inner diameter of the pipeline.

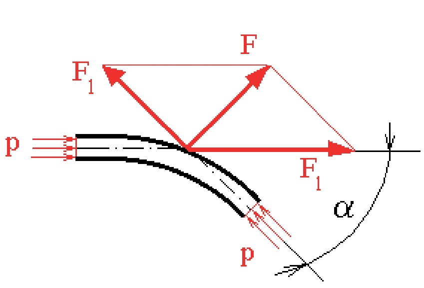

Fig. 5. The force in the bending area

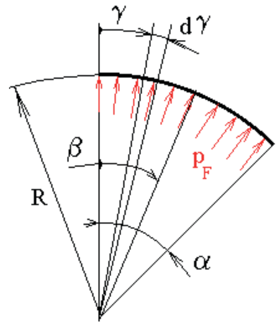

Fig. 6. The distributed force in the area of the bending

After solving the equation system (1) and determining the unknown factors X_1 and X_2, the efforts solicitating the pipeline are determined with following relationships:

$$N = N_0 + n^{x_1} \cdot X_1 + n^{x_2} \cdot X_2$$

$$T = T_0 + t^{x_1} \cdot X_1 + t^{x_2} \cdot X_2 \qquad (3)$$

$$M = M_0 + m^{x_1} \cdot X_1 + m^{x_2} \cdot X_2$$

where:

N_0, T_0, M_0 – the efforts produced by the inner pressure and by the pipeline weight,
n, t, m – the efforts produced by the fictive loads $X_1 = 1$ and $X_2 = 1$.

For determining the vertical displacement of the upper section of the pipeline, following analytical expression has been used

$$\delta_k = \sum_{i=1}^{n=5} \left[\int \frac{1}{E \cdot I_z} M \cdot m_v^k \cdot ds + \int \frac{1}{E \cdot A} N \cdot n_v^k \cdot ds \right] \qquad (4)$$

where:

$n = 5$ – the 5 sections corresponding to the basic system,
M – the analytical expression of the moment, for the considered section, determined with the relationship (3),
N – the analytical expression of the axial force, for the considered section, determined with the relationship (3),
m_v^k – the analytical expression of the moment, for the considered section for the unit fictive load applied at the distance a from the symmetry axis, according to Figure 7b,
n_v^k – the analytical expression of the axial force, for the considered section for the unit fictive load applied at the distance a from the symmetry axis, according to Figure 7a.

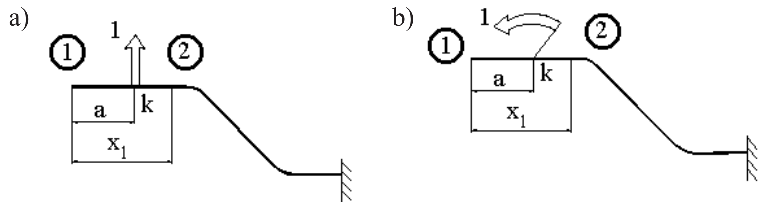

Fig. 7. Applying of the unit loads on the section 1–2

For determining the rotation of the transversal section of the pipeline for the section 1–2, expression (4) is used, where instead of the term m_{φ}^{k} is used. m_{φ}^{k} represents the analytical expression of the moment, for the considered section, when a unit moment is applied at the distance a from the symmetry axis, according to Figure 7b.

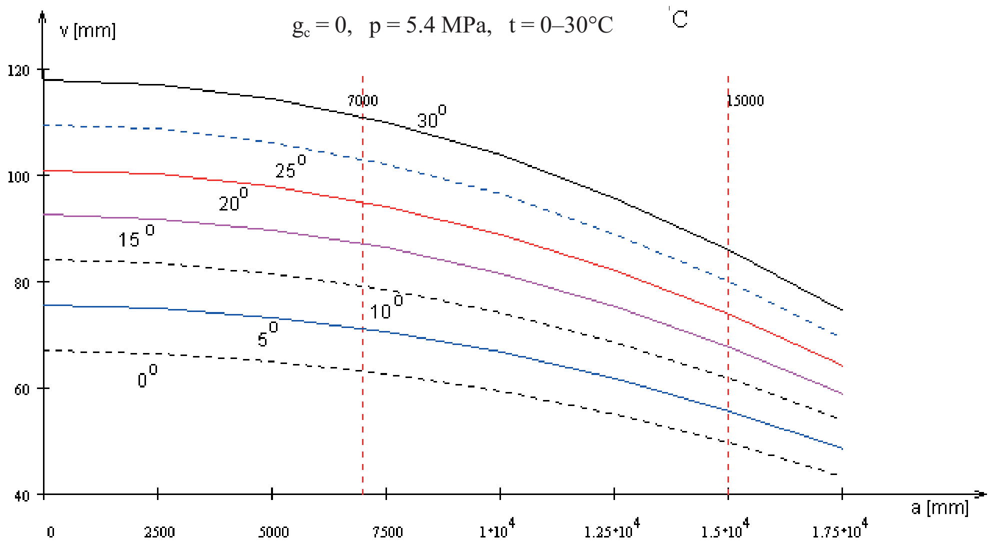

Fig. 8. The deformation of the horizontal section

In Figures 8 and 9 it is presented the way in which the horizontal section is deformed, according to the basic system of the methane gas transport pipeline.

Thus:

– in Figure 8 for the case in which $g_c = 0$, $p = 5.4$ MPa, $t = 0$–30°C;
– in Figure 9 for the case in which $g_c = 5.79$ N/mm, $p = 5.4$ MPa, $t = 0$–30°C.

In Figure 10 we present the way in which the angle of the deformed shape of the horizontal section varies, for the basic system of the methane gas transport pipeline, for the case in which $g_c = 5.79$ N/mm, $p = 5.4$ MPa, $t = 0$–30°C.

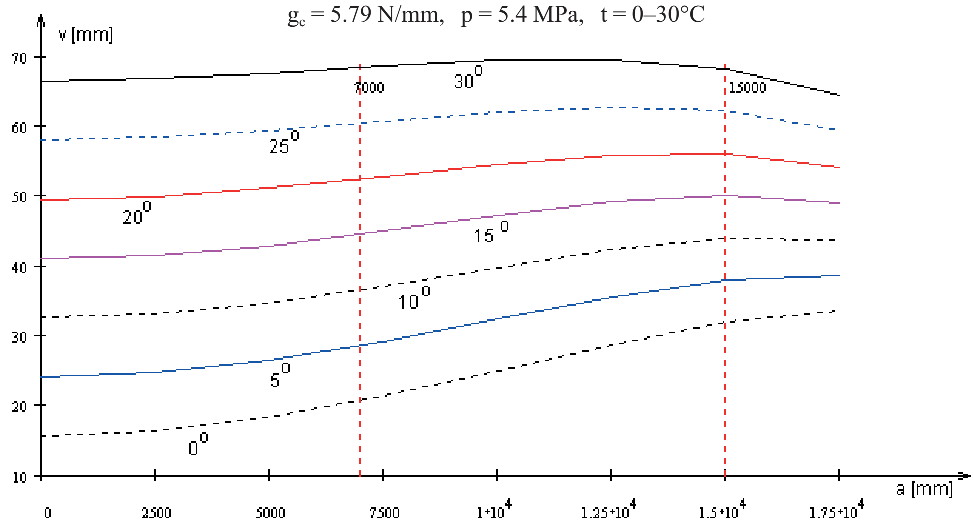

Fig. 9. The deformation of the horizontal section

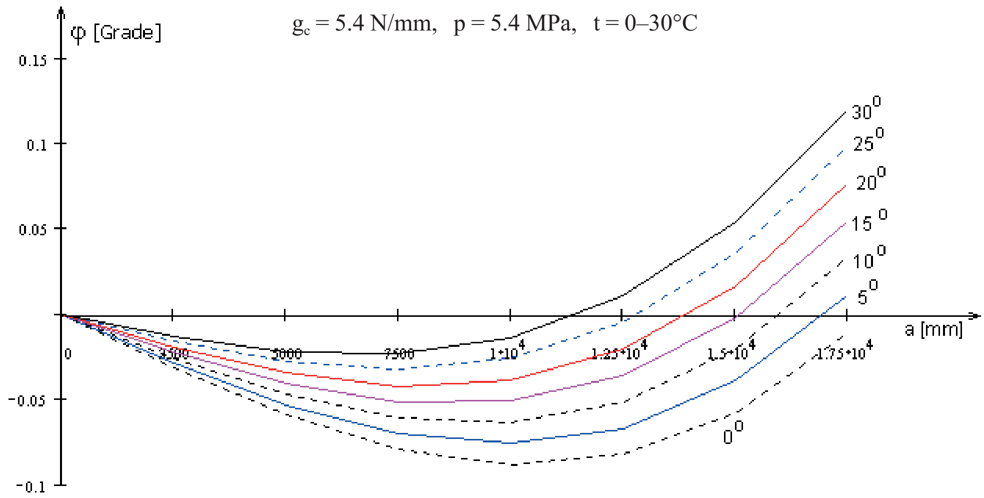

Fig. 10. The rotation of the transversal part of the horizontal section

3. CONCLUSIONS

The analysis of the deformation mode of the methane gas transport pipeline from the area of the Taița river crossing has been carried out taking into account following loads: the pressure inside the pipeline, the own weight of the pipeline; the temperature difference at which the pipeline is heated as compared to the assembling temperature.

From the analysis of the variation graphs of the strains for the horizontal section of the pipeline, a raising of the pipeline in the area of the support pillars could be noticed, with values of δ = 90–118 mm for the case in which the pipeline is loaded only by the inner pressure and values of δ = 64–65 mm when the pipeline is loaded by the inner pressure, by the weight of the pipeline and of the gas. In the case of strains produced by the temperature difference, there can be noted an influence similar to the one produced by the inner pressure. At an increase of the temperature by Δt = 30°, the strain increases by 50% of the strain given by the inner pressure.

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