Damage to Natural Gas Distribution Steel Pipelines caused by Rigid Bodies resulting from the Excavation of Laying Trenches

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ABSTRACT

The present paper focuses on analyzing the occurrence of defects such as dents and local deformations by laboratory simulations of a real case of a defect detected on a natural gas distribution pipeline lain at a depth of approximately 0.6 m. The defect is caused by a river stone which due to the compression forces, damages the pipe to the point of cracking. In the laboratory, the simulation was carried out on a steel pipe insulated with extruded polyethylene which was acted upon by a mandrel made of duralumin. The purpose of the tests is to determine the maximum values at which the pipe material fractures. It was found that the fracture of the pipes when there are rigid bodies in the protective layer of sand is accelerated by the sand existing between them and the pipe and by the change in the properties of the steel the pipes are made of when they are kept in water.

Keywords-pipelines; natural gas distribution; forces; fracture

I. INTRODUCTION

Distribution pipes are usually installed underground at a depth at least equal to the local frost depth. If we consider dividing the territory of Romania into areas according to the frost depth (STAS 6057-77), the frost depth in the Municipality of Sibiu where the research was conducted ranges between 900 and 1000 mm [1]. The underground distribution pipes are made of steel or high-density polyethylene [2]. The distribution pipeline routes are, as far as possible, straight, going along streets or thoroughfares. It is not allowed to install pipes under or along tram lines, railways, or channels that communicate with neighbouring buildings without special preparation. It is prohibited to pass the distribution pipelines under buildings or through their annexes [3].

The surface of the pipelines intended for the distribution of natural gas and its equipment can show a series of defects and imperfections, which affect the operational safety. The residual mechanical strength and the operational safety of the gas distribution pipelines are essentially influenced by the presence of defects. In this sense, this paper analyzes how the natural gas distribution pipelines made of steel and insulated with extruded polyethylene can be damaged by the existence of rigid bodies resulting from the route excavation and unintentional contact with the surface of the pipes, especially on their upper side, where we consider the exerted mechanical force to be the greatest. These defects can be considered imperfections or geometric defects and represent deviations in size and shape that significantly change the configuration of the pipe's cross-section, leading up to the fracture of the material: dents and local deformations are traces of impacts or interaction with external forces [4, 5]. In this study, we simulate a real case identified on the distribution pipes located in our region which created malfunction in exploitation for the gas provider (Figure 1).

II. TEST PREPARATION

Starting from the defect shown in Figure 1 detected on the distribution network of pipelines in the Municipality of Sibiu, which occurred due to the existence of a river stone on the upper surface of the pipe, most likely resulting from the excavation of the laying trench and the inadequate depth of the pipe network of approximately 0.6 m, we tried as much as possible to simulate this phenomenon in the laboratory. Thus, we processed a mandrel model to simulate the river stone, more precisely rounded at the end and with approximately the same dimensions as the defect, having an end in the form of a hemisphere with a radius of approximately 10 mm. The local printing by compression was carried out by this special mandrel made of hard aluminum (Figure 2), so that it had the necessary hardness to apply the forces in the order of 10^4 N [6].

Fig. 1. Defects as local deformations detected on the pipelines.

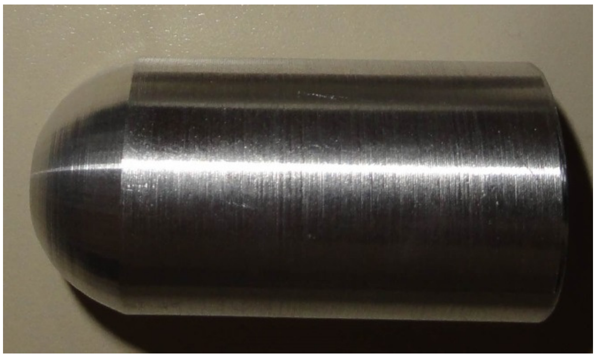

Fig. 2. Mandrel made of hard aluminium.

For the experiment, we substituted the section of the pipe where the defect was detected with L245 steel pipe segments, having Ø 60.3 mm diameter and 3.6 mm wall thickness, insulated with class B PEHD high-density polyethylene, with an applied thickness of 1.8 mm. The tests were carried out on three sets of pipes with a length of 600 mm: one set was kept in its original state, the second was kept in rainwater for 72 hr, and the third was kept in loam sand for 72 hr (Figure 3).

The compression tests were executed in a specialized laboratory equipped with the necessary tools for conducting physical-mechanical tests and analysis and non-distinctive checks (Figure 4), compliant with the European standards [7].

III. TEST EXECUTION

The forces resulting from the compression applied on the upper surface of the pipe section [8] are determined by using the assembly shown in Figure 5.

Fig. 3. Specimens of insulated pipe: (a) kept in water (b) or loam sand (c) for 72 hr.

Fig. 4. Compression testing machine.

IV. TEST RESULTS AND INTERPRETATION

As can be seen, the pipe was subjected to different compressive forces from the testing machine, thus determining the maximum values in the moment of fracture (Figure 6) of the pipe material under the influence of compressive forces [8, 9]. The obtained data are shown in Table I. Regarding these data, it should be taken into account that it is impossible to keep the machine under constant load for more than 2 min and for this reason, the compression time at maximum force value was set at 2 min maximum, enough to read the compression values at the time of the pipe fracture [10, 11].

TABLE I. FRACTURE STRENGTH DEPENDING ON THE ENVIRONMENT.

Pipe material versus storage environment	**Rupture strength [N]**
Steel pipe pre-insulated with extruded polyethylene	66881
Steel pipe pre-insulated with extruded polyethylene and kept in sand for 72 hr	64723
Steel pipe pre-insulated with extruded polyethylene and kept in water for 72 hr	63743

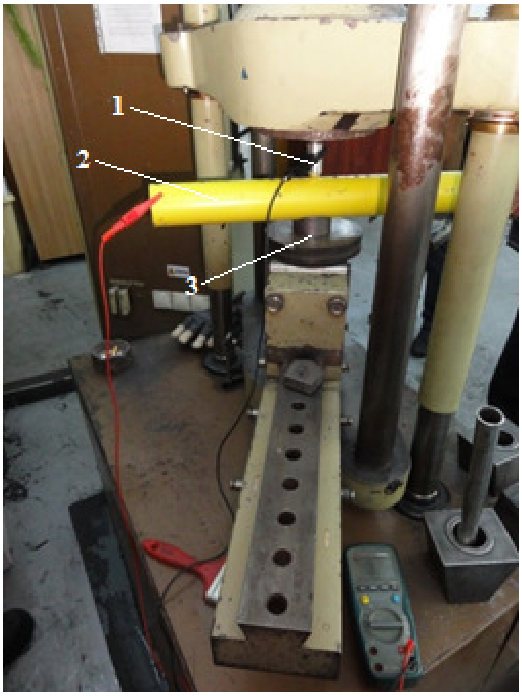

Fig. 5. Detail of the assembly used for determining the fracture strength: (1) hard aluminium mandrel, (2) steel pipe by type L245, (3) special support to fix the pipe.

Fig. 6. Fracture of the pipe material.

V. OBSERVATIONS AND CONCLUSIONS

Analyzing the shown graphs and making a comparison between the different environments of the natural gas distribution networks, we conclude that the rupture strength of the pipe material is superior when the pipelines are kept in the atmospheric environment and decreases significantly when the samples are kept in sand or water. We consider that, in the case of pipes kept in sand, this is due to its granulation and hardness, and when they are kept in water, it is because water changes the properties of the steel the pipe is made of.

We can thus conclude that the fracture of the pipes in the situation when there are rigid bodies in the protective layer of sand is accelerated by the sand existing between them and the pipe and by the change in the properties of the steel the pipes are made of, when they are kept in water (see Figure 7). The next step in our study will be to analyze and simulate this case using the finite element method to determinate the behavior of the pipe subjected to similar loads.

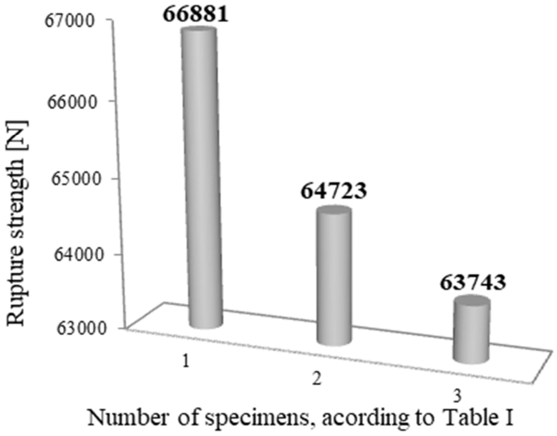

Fig. 7. Rupture strength of the pipe depending on the environment.

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