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EXPERIMENTAL SIMULATION OF A TRANSMISSION GAS PIPELINE DESTRUCTION; APPLICATION OF THE ANSI/ASME STANDARDS.

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ABSTRACT: Linking up to the foregoing paper titled "Numerical simulation of a transmission gas pipeline destruction" ([Numerical ...]) this paper deals with the experimental assessment of the cause of a DN 900 transmission gas pipeline breakdown onset and the ANSI/ASME standard application. Using retrieved parts of the damaged pipes for the identification of the responsible defect, an identical fault was machined on an intact pipe taken from the accident vicinity. Such a prepared testing body was equipped, while using large deformation strain gauges, for a hydrostatic burst test.

1 Introduction

As was explained in the foregoing contribution [Numerical ...], examined was the problem of a rupture on a DN900 transmission pipeline, having nominal thickness of 12 mm, made of St 52.3 steel, spirally welded, pipes. For this purpose, prepared was a testing body made of an intact pipe taken from the vicinity of the pipeline rupture site on the surface of which a model defect was machined, serving for a hydrostatic test comprised of several presurizing cycles including burst test.

With respect to the complexity of the defect topography, it was decided that large deformation strain gauges to be placed in significant localities where both positive and negative extremes should appear according to preliminary FEM computations and thus confirm their quality. Complex of all the results of the presented theoretical and experimental analyses helped the authors to confirm even more the reliability of their theoretical approach to the limit state assessment having been developed so far.

2 Experiment executed on the testing body

The model surface defect (to be utilized for the pipeline breakdown assessment) was designed on the basis of investigated actual defect geometry, remaining thicknesses and material characteristics of the ruptured DN900 pipeline. Fig.1 shows the model defect contour across which dashed lines mark positions of six planary sections: one in longitudinal and five in circumferential directions, the profiles of which are shown in Fig.2.

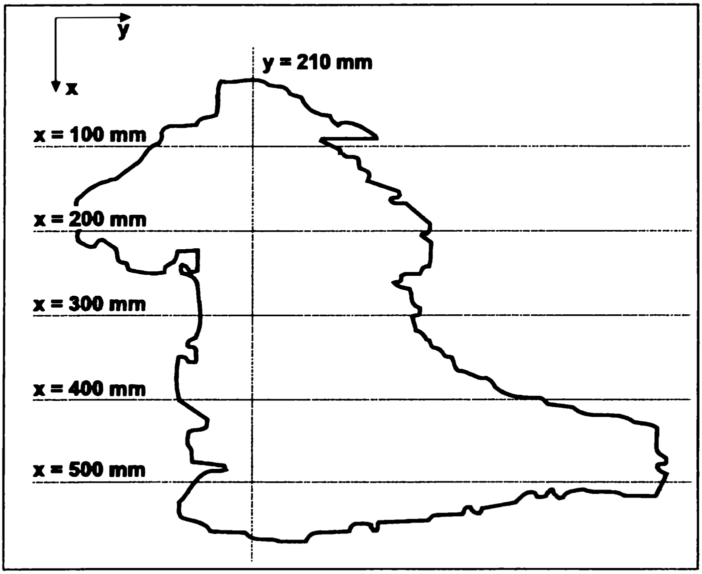


Fig. 1: Contour of model defect with sectional positions.

In the middle of the defect contour, a field was machined whereof having the thinnest pipe wall (being 4 mm) in the defect. This model surface defect was machined on a model body consisted of an intact pipe taken from the accident vicinity, and, subsequently, equipped for strain measurement. After the preliminary FEM computation determining theoretically the strain extremes, strain gauge crosses were placed onto these localities (Fig.3(a)). A general view of the testing body can be seen on the photo in the Fig.3(b). The experiment consisted in hydrostatic tests including preliminary testing cycles and the burst test proper which ended in the model body rupture at a pressure of 8.1 MPa. In the course of these tests, the model defect strain distributions were recorded using the strain gauges for large strain measurements the plots of which are shown in the conclusion.

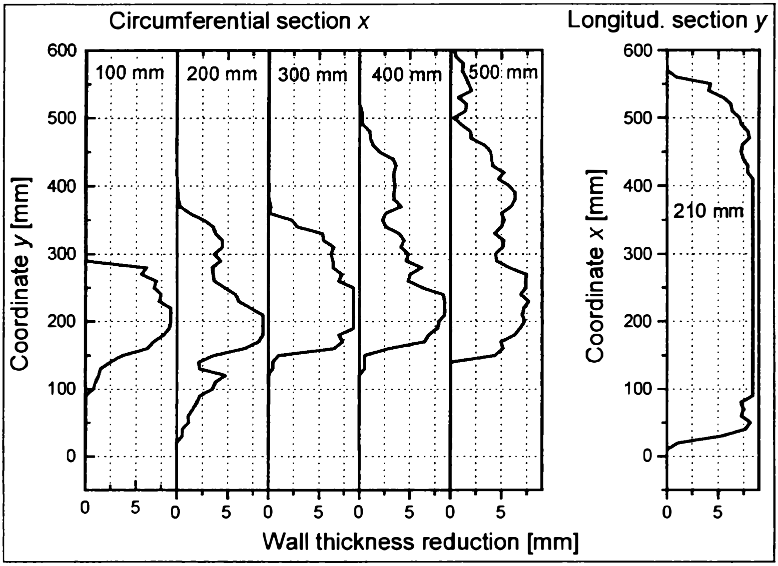
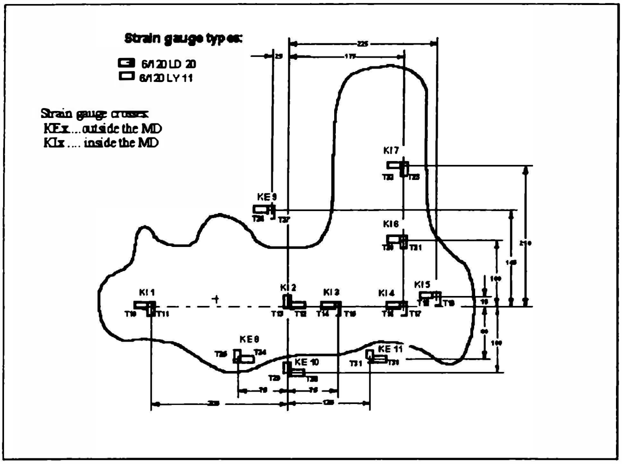


Fig. 2: Model defect sections – see Figure 1

2.1 ANSI/ASME standard application

The theoretical and experimental investigation was completed by the ANSI/ASME standard application. Based on numerous past experiences, a number of the by ANSI/ASME hitherto evaluated data (obtained by means of practically all its derived methodologies, e.g. : the basic and modified B31.G criteria, and the effective surface criterion) have been proved to be considerably conservative. Application of these methodologies for a different type of evaluation (e.g. for the limit pressure prediction), than that of the routine statements proving a potential satisfaction of the ANSI/ASME standard conditions, could seem not to have another practical meaning. But just such theoretically predicted results (which have been verified by the experimentally obtained data) enable extending hitherto existing bases and thus gradually improving the precision of these standard procedures. For the model defect evaluation, a pertinent basic profile of the model defect was to be assessed. For the purpose, a longitudinal section of the model defect was taken as the basic profile, whereof having its total length of 560 mm and the maximum wall thickness reduction of 8.4 mm (i.e. minimum wall thickness tmin = 4 mm); see the last graph in the Figure 2 showing the defect longitudinal section in Y = 210 mm. The evaluation was carried out by the RSTRENG and CSTRENG211 programs, respectively. The CSTRENG211 program – a CTU software product – enables the computational procedures to execute various set-ups and create further variants. All applied standard variants predicted the model defect limit pressure p_{LIM} being lower than the experimentally obtained burst pressure:

1. the basic B31.G ... $p_{LIM} = 4.5$ MPa



(a)

(b)

Fig. 3: Placement of strain gauge crosses in/around the model defect (MD) (a) and general view of testing body (b).

2. the modified criterion "85 % defect profile area" ... $p_{LIM} = 7.21$ MPa
3. the effective area method ... $p_{LIM} = 6.1$ MPa

Surprisingly, the closest result was not delivered by the effective area method (outgoing from a detailed topology of a defect and obtaining its computational depth and effective length on the basis of the algorithm that divides the defect profile into a number of strips, which being summarized step-by-step in different levels of the defect profile depth). Rather, however, by the modified method considering the defect computational area as the 85rectangular area given by the multiplication of the defect length of 560 mm and depth of 8.4 mm (Fig.2). The cause of it consisted in the fact that the model defect profile was not as articulated as it usually is with a typical pitting corrosion, but that the defect profile virtually formed a rectangular (see Fig.2). It is obvious, according to all the three applied criteria, that the allowable working pressure was assessed to be substantially lower and that this model was inapplicable for operation.

3 Conclusion

The break-down cause of a DN900-St 52.3 transmission gas pipeline was to be assessed. This paper presents briefly the experimental work having been carried out for the purpose. The experimental investigation played two important roles:

1. verified the theoretically obtained data representing the stress and strain state of the model defect;

2. served an unsubstitutable step for obtaining the limit values of the pipe carrying capacity (this ensuing from the fact that the undertaken DN900 pipe was the first one of such dimensions and material which the authors had dealt with).

Ad 1) In Fig.4, delivered is an illustration of the dependence of both the circumferential and longitudinal strains upon the model body pressure. The plots show how closely the theoretical deformation assessments, representing by the FM4 (the FEM fine mesh model with t_{min} = 4 mm) and CM4 (the coarse mesh model) applications, correspond with the nature. The graphs were based on the KI 4 strain gauge cross signals, i.e. in the locality where the MD fracture was initialized. Ad 2) Utilizing the obtained testing body burst pressure of 8.1 MPa, assessed was the limit value of the relative plastic area lengths L_{LIM} (the meaning of which is explained in the foregoing paper [Numerical ...]), confirming the competence of our regression analysis outgoing from the earlier obtained results for the DN800/X60 pipes and enabling a future theoretical assessments of the limit pressure of the pipelines made of the DN900/St52.3 pipes [1].

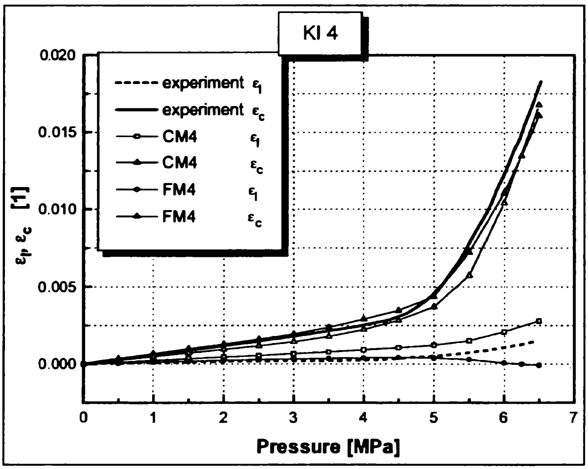


Fig. 4: Comparison of the theoretically and experimentally obtained strain-pressure dependencies.

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