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Numerical study of a cracked pipeline under internal pressure

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ABSTRACT

In the industrial sectors, pipelines have been used as the most economical and safe means of transporting oil and gas (Pipelines). However, the number of accidents has increased considerably as their use has increased. As a result of the operating load and the pressure used, the thickness of the tube must be increased and the mechanical characteristics improved. This approach was applied to predict the growth of crack effect in samples of two pipelines at given thicknesses and pressures. We created cracks with deferential dimensions in both API X80 steel pipelines, with an application of deferential internal pressures. For the simulations, we used the code ANSYS.

1. INTRODUCTION

The efficiency of pipeline transport systems, widely used in the oil and gas industries, depends, to a large extent, on the increase in diameters and working pressures while reducing wall thickness to lower the cost per unit of transport [1, 2]. API pipe steels have been widely used to transport oil and gas from the most remote corners of the world [3, 4]. API grades such as X-65 and X-80 were frequently used to manufacture large oil tanks and pipeline tanks to transport large volumes of oil and natural gas [4, 5, 6].

Cylindrical bodies either of steel or other material have great application in the field of mechanics such as oil and gas pipelines (Pipelines). Under the influence of internal stresses, pressures or temperature changes, these bodies can undergo significant deformations and sometimes damage and bursting [7].

Due to geographical, geological, economic and even political diversity, the erosion of oil and gas pipelines is undoubtedly a specific phenomenon [8].

The problem is very often the presence of a crack, a geometric discontinuity present in the critical areas of the structure, which tends to spread as the stresses are applied. This can lead to the ruin of the structure. It is understood that the presence of this defect constitutes a source of geometric non-linearity which is added to the phenomena mentioned above. But the fracture mechanics presuppose the presence of an initial defect, from which the crack will be able to start. This defect can be a hole, an inclusion in the material, an imperfection due to the manufacturing process, which generates local over-stresses [9].

Our study is based on the change in the dimensions and position of the crack (whether internal or external), with a variation of the internal pressure in two tubes having two different thicknesses.

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1.1. *Study material properties (API X80)*

Table 1. Mechanical properties of ISO 3183 X80M steel [10, 11]

Properties	MPa	Ksi
Yield strength (YS)	568	82
Tensile strength (TS)	686	100
YS/TS (%)	83	
% Elongation	44	
Average micro-hardness (HV0.2)	235	

Table 2. Geometry of the three tubes

	External diameter	Internal diameter	Thickness
Pipeline 1	722 mm	762 mm	20 mm
Pipeline 2	722 mm	747 mm	12.5 mm
Pipeline 3	722 mm	742 mm	10 mm

We will simulate the three pipelines (the length of the three pipelines is 1000 mm) to keep the results as reference.

2. *PIPELINES WITHOUT CRACK*

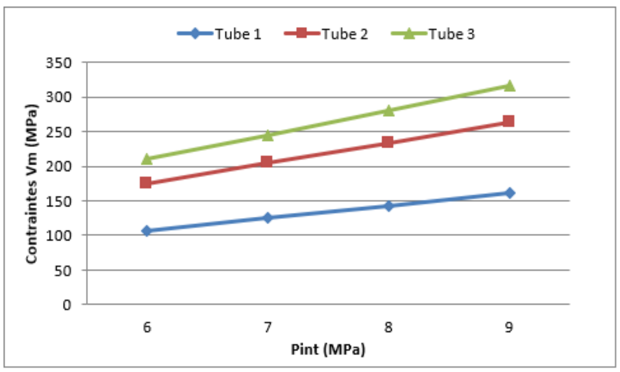


Fig. 1. Von Mises stresses of the three tubes not cracked

From the results obtained, we can say that the stress of Von Mises is proportional to the internal pressure applied.

2.1. *Stress concentration coefficient (Kt) of the three tubes*

$Kt = \sigma / \sigma max$ [12, 13]

$\sigma = PR/t$

$Kt = PR/ t\sigma max$

P: internal pressure; R: internal radius; t: tube thickness σ: nominal stress; σ_{max}: maximum stress.

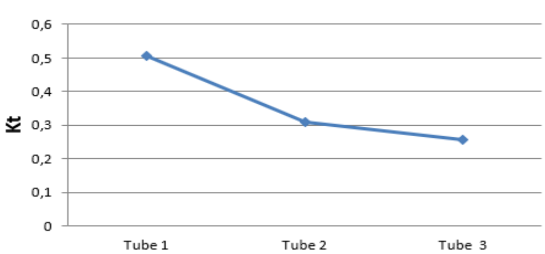


Fig. 2. Stress concentration coefficient Kt

The stress concentration coefficient is high for the first tube.

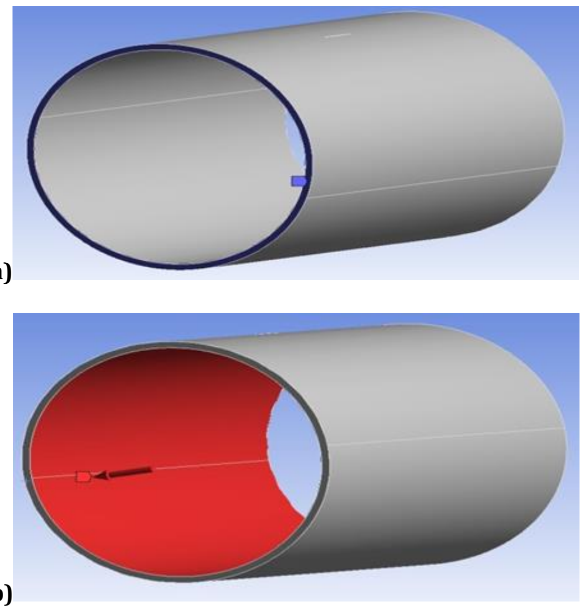
We will consider the first two tubes to which we initiate an external crack having a width and a depth, while varying the internal pressure applied.

3. TUBES WITH EXTERNAL CRACK

3.1. Variation of depth

In this part we applied a crack to the outer wall of the same dimensions (length a = 100 mm and width L = 1 mm) to the two tubes, and we apply the same pressures (6, 7, 8 and 9 MPa). The depth varies. Figure 4 shows the fixation of the tube under internal pressure.

a)



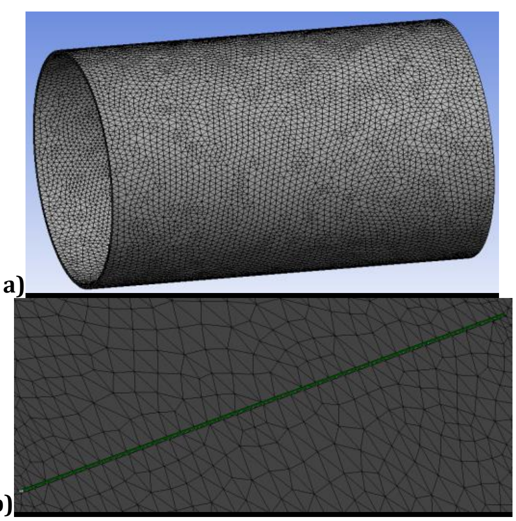
b)

Fig. 3. Fixing and application of internal pressure: a) Fixing of the tubes; b) Application of internal pressure

Simulation of the tubes

The following figure shows the tube mesh and the refined crack mesh (Figure 4).

a)



b)

Fig. 4. Meshing of the pipelines: a) Tube mesh; b) Fine mesh of the crack

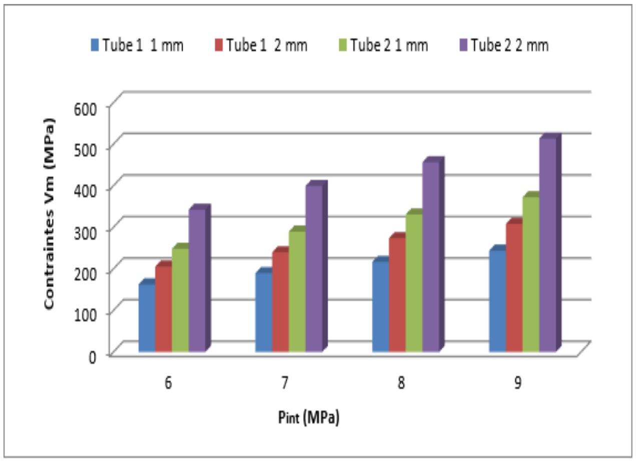


Fig. 5. Stresses of Von Mises as a function of crack pressure and depth

The effect of the crack depth is important in the case of the second tube.

3.2. Variation of the width of the crack

We will just vary the width of the crack.

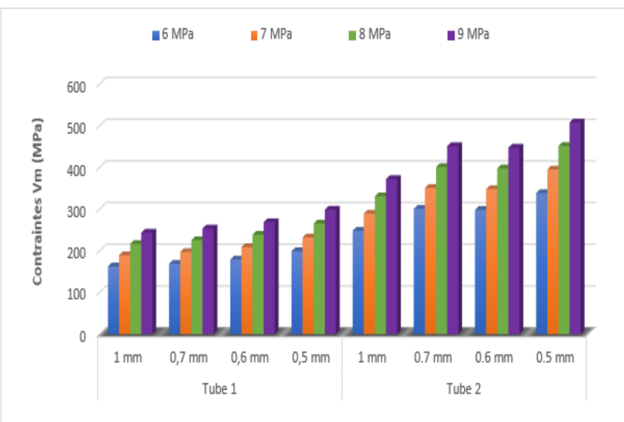


Fig. 6. Stresses as a function of crack pressure and width

The stresses are close to the elastic limit for a width of 0.5 mm for tube 2.

4. INTERNAL CRACK

4.1. Variation the crack depth

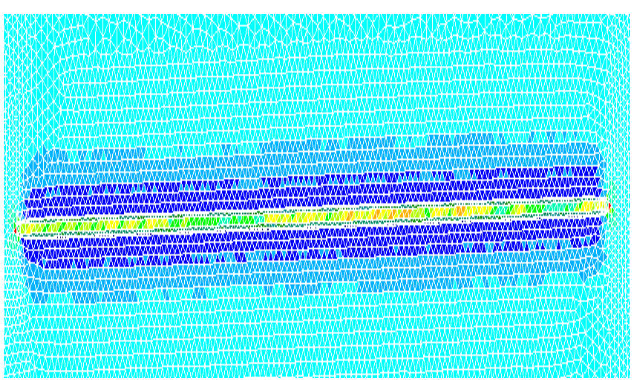


Fig. 7. Cracked zone

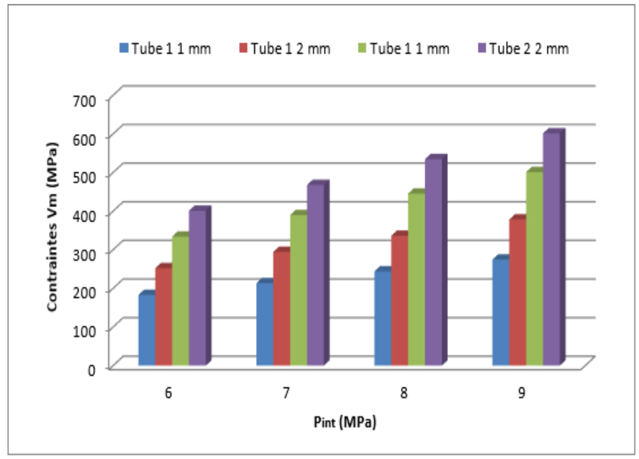


Fig. 8. Von Mises stresses of both tubes as a function of crack pressure and depth (Internal crack)

The existence of an internal crack has more effect than an external crack.

4.2. Variation of the width of the crack

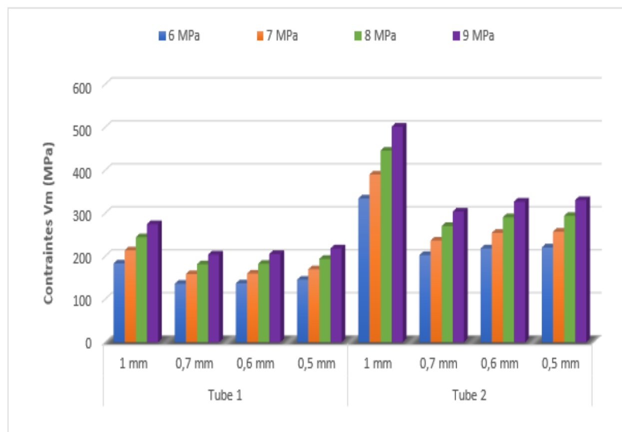


Fig. 9. Von Mises stress results as a function of crack width

These histograms allow us to find that if the width exceeds a value of 1mm the tube 2 risks damage.

5. DISCUSSION OF RESULTS

It can be said that the depth of the initiated crack does not cause rupture of tube 1.

Whereas for the second tube, the 2mm depth of the initiated crack has an adverse effect on the behavior of the tube. This allows us to predict tube damage in a precise interval.

CONCLUSION

A crack is a sudden defect or discontinuity occurring in a material under the influence of internal or external stresses, the substance is separated on a specific surface. As long as the stress forces are not released, this causes a high concentration of stress on the bottom of the crack.

In order to see the effect of an internal or external crack of an internal pressure tube, we considered two tubes of different diameters.

We initiated an internal and an external crack of different dimensions separately in the pressure tube. Von Mises stresses were obtained by varying the width, length and depth of the crack in both cases (tube 1 and tube 2).
For high pressures ranging from 6 Mpa to 9 Mpa, higher thickness tubes should be used.

There was a little effect from the length of the internal crack on the tube, while the effect is negligible for the external crack.

The effect of the depth of the internal crack is greater on the tube. The tube may cause plastic deformation or damage as Von Mises stress exceeds the elastic limit.

The effect of width is apparent for an external crack in the pressure tube.

It can be concluded that the tests we carried out allowed us to deduce that tube 2 works in an elastic field only in the following cases:

The dimensions of the external crack are limited to the following values for pressures ranging from 6 MPa to 9 MPa of width = 0.5 mm and depth = 2 mm.

The dimensions of the internal crack are limited to the following values for pressures varying from 6 MPa to 9 MPa of width = 0.5 mm and depth = 1 mm, or pressures varying from 6 MPa to 8 MPa of width = 0.5 mm and depth = 2 mm.

Tube1 works in an elastic field in all cases of this study.
Generally, the risk of damage is higher in the case of the tube with the thickness of 12.5 mm and with an internal crack close to 2mm for.

The stress concentration zone is located in the vicinity of the crack, the material being elastic while the cracking zone is a plasticized zone. The effect of internal pressure along with the presence of the internal crack on the behavior of the pipeline allows it to propagate through the thickness. The results of the tests performed on the pipeline allowed us to see the effect of the pressure on the size of the plasticized area.

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