Influence of Pitting Corrosion on Burst Pressure Value

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Abstract. *The article is focused on the safety assessment of pressure pipelines with corrosion defects and the influence of individual defect distance on burst pressures. The practical part presents the modelling of a pipeline with corrosion defects. Burst pressures were determined for each model with changing corrosion defect parameters and mutual interaction between the actual defects. The paper outlines the results of the numerical simulation by a finite element modeling software. The main aim of the work is to highlight the fact that the currently employed standard procedure used to assess the impact of corrosion defects on pipes is not precise enough and does not fully correspond with the results of the simulations presented here. The simulation results suggest, that the currently used safety factors need to be increased, in order to include the geometric effects of corrosion defects.*

Keywords: Pressure Pipeline, Corrosion Defect, Burst Pressure, Safety

1. Introduction

The main causes of pipeline failure are external disturbances and corrosion [1]. Therefore, novel methods are necessary to evaluate and determine the severity of the fault detected in the pipe. Pipelines will always contain defects at some point during their operational life, thus it will also require a judgment call, whether or not it is necessary to carry out maintenance [2]. Major accidents on pipelines were caused by a combination of several factors, in most cases, however, a corrosion defect was the underlying cause (Hrašovník 2014, Janków Przygodzki 2013, Slanec 2008, Stone Kosihy 2000). This article deals with defects caused by corrosion and assesses its impact on the stress state conditions and the security of the entire operation [3]. In this method, the computation of the burst pressure is based on the tension strength of the material. DNV-RP-F101 also considers a quadrangular defect profile and the depth of the maximum length of the actual defect. Its use is suitable for modern ductile materials. The maximum possible depth of the defect is 0.85 times the residual wall thickness [6].

Simulation of the effect of distance pitting in the direction of the pipe axis

The pipeline section was modeled in the ANSYS finite element modeling software using the Solid 187 element [5].

The models developed here not only vary the length of the corrosion defect but also its depth. Three representative values of depth were selected, namely h_d = 4.6 mm, 6.8 mm and 9 mm. These values correspond to the third, half and two-thirds of the thickness of the undamaged pipeline. First, we investigated the value of the internal pressure at which the notches in the roots reach the peak stress corresponding to the breaking strength of 675.9 MPa material. The results of this simulation are shown in Table 1.

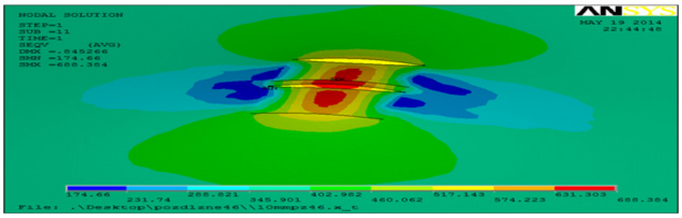


Fig. 2. Simulation of pipe defects with depths of 4.6mm in 10mm distance at which the defects interact

Simulation of the effect of distance pitting around the perimeter of the pipe

The simulation is changed by analyzing the effect of pitting distance running around the perimeter of the pipe, otherwise the simulation conditions are similar to the previous one.

2. Results

Simulation of the effect of distance pitting in the direction of the pipe axis

Table 1. Loading pressure required to achieve the burst pressure for corrosion defects in the axial direction of the pipe

Depth of defects h_{d1} =4.6 mm			Depth of defects h_{d2} =6,8 mm		Depth of defects h_{d3} =9 mm	
Distance of corrosion defects l_d [mm]	Loading pressure p_1 [MPa]	Peak stress σ_{max1} [Mpa]	Loading pressure p_2 [MPa]	Peak stress σ_{max2} [Mpa]	Loading pressure p_3 [MPa]	Peak stress σ_{max3} [Mpa]
110	9.9	678.7	9.1	674.7	7.7	674.9
115	10	680	9.18	674.5	7.9	677.2
120	10	674.1	9.4	675.1	8.15	674.3
125	10	675	9.47	680.2	8	677.5
130	10.1	679.9	9.6	676.2	8.2	675.3
135	10.2	674.5	9.57	679.5	8.25	673.7
140	10.2	676.3	9.6	679	8.4	672.9
150	10.3	678.9	9.64	674.2	8.45	679.1

Table 1 shows that the value of loading pressure required to achieve the expected burst pressure decreases with respect to the increasing depth of corrosion damage. The change in the loading pressure required to achieve the burst pressure for one deep defect but with variable distance of the corrosion defects is not as significant.

Simulation of the effect of pitting distance around the perimeter of the pipe

Table 2. Loading pressure required to achieve the burst pressure for corrosion defects distributed over the circumference of the pipe

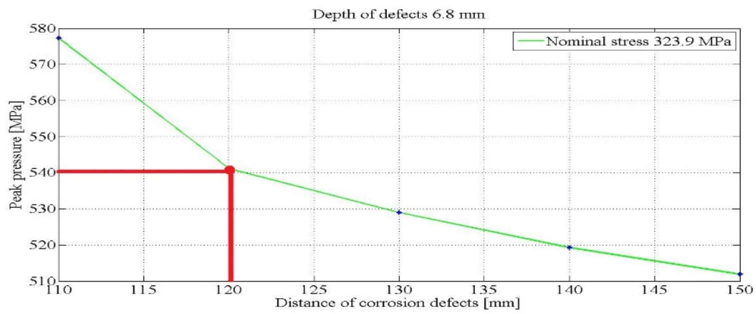
Depth of defects h_{d1} =4,6mm			Depth of defects h_{d2} =6,8mm		Depth of defects h_{d3} =9mm	
Distance of corrosion defects l_d [mm]	Loading pressure p_1 [MPa]	Peak stress σ_{max1} [Mpa]	Loading pressure p_2 [MPa]	Peak stress σ_{max2} [Mpa]	Loading pressure p_3 [MPa]	Peak stress σ_{max3} [Mpa]
110	11.2	673.2	10.2	677.1	674.9	9.6
115	11.2	680.1	10.2	674.8	677.2	9.6
120	11.2	677.4	10.2	678.1	674.3	9.55
125	11.2	674.9	10.2	679.9	677.5	9.5
130	11.2	677.3	10.2	678.4	675.3	9.6
135	11.2	675.8	10.2	674.5	673.7	9.6
140	11.2	678.6	10.2	677.0	672.9	9.55
150	11.2	676.9	10.15	677.2	679.1	9.55

As we can see from Table 2, the pressure required to achieve burst pressure that would correspond to the actual material strength does not vary substantially with the depth and distance of the corrosion defects. One possible reason is the geometry of the corrosion defects themselves. Since by varying the position of the defects in the axial direction of the pipe were defects together with sharp edges. There was thus a situation that even with the smallest distance is corrosion defects of varying depth and distance does not affect. This finding is a nice proof that the interactions between defects are highly dependent on the geometry.

3. Discussion

For a pipe with the dimensions of 1200 x 13.6 mm, for which the nominal stress (unaffected by corrosive defects) is known, the peak stress affected by the corrosive defects can be estimated by the presented analysis. If the internal pressure of the pipeline is 8 MPa, and we suppose that a nominal stress of 323.9 MPa and defects with identical geometry are present (e.g. depth of 6.8 mm), and if the distance of these defects is 120 mm then we may estimate a peak stress caused by the corrosion defects as 542 MPa. If one is aware of this information, then may calculate the actual safety factor as the ratio of the maximum stress in the roots of the notches and the actual allowable stress [7]:

$$k_{actual} = \frac{\sigma_{dov}^{actual}}{\sigma_{max}} = \frac{675.9\ \text{MPa}}{542\ \text{MPa}} = 1.23\,.$$



Graph 1. A graph of the peak stress within the defect at a line pressure 8Mpa

4. Conclusions

We may conclude from the presented analysis of burst pressure for pipes with different depths of corrosion defects and various mutual spacing that the real destructive forces can be significantly higher than the pressure calculated in accordance with the procedures outlined by DNV-RP-F101. The established procedures unite corrosion defects on the surface and thus their actual impact underrated. By continuing in this sense, it would be possible to perform more calculations (in this work, there were about 200) with the aim of creating a comprehensible set of guidelines that would allow for the known load distribution of defects and their depth (found e.g. internal inspections) to establish genuine security against destruction and then decide on the maintenance schedule.

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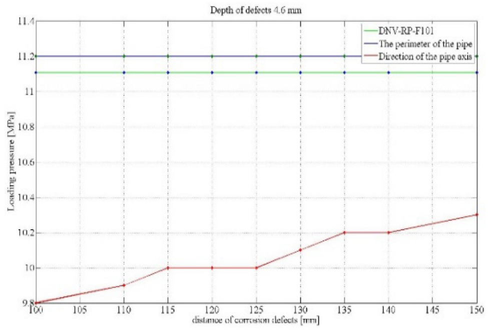
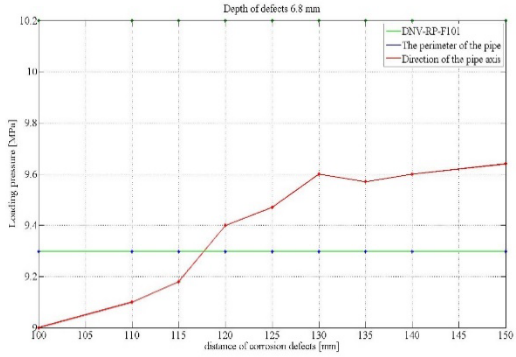
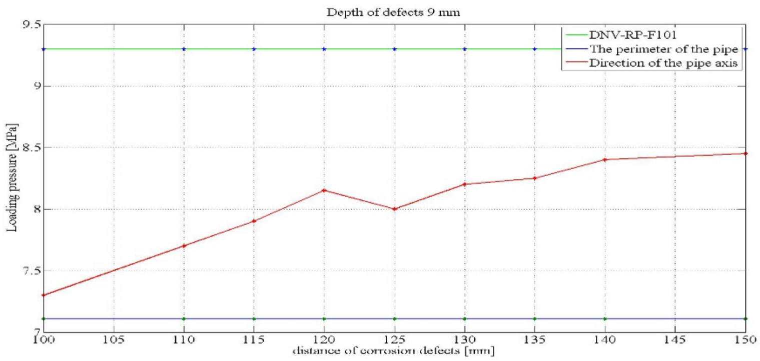
Appendix



Graph 2. Comparison of the load pressure required to achieve the destruction of the pipe for 4.6 mm deep defects



Graph 3. Comparison of the load pressure required to achieve the destruction of the pipe for 6.8 mm deep defects



Graph 4. Comparison of the load pressure required to achieve the destruction of the pipe for defects 9 mm depth

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