Theoretical And Experimental Analysis Of Corroded Pipe Strength

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Abstract

Process industries have vast networks of pipelines. Those pipelines are prone to external and internal corrosion. Usually environmental conditions and other operating factors cause corrosion. Although there are various ways to protect corrosion but it is inevitable. It may lead to uniform material loss of the wall thickness or pitting, which corresponds to the local wall thickness reduction or general form of cavitations. Corrosion cavity can appear as simplified or in other general form as shown in Fig. 1. These corrosion defects can appear externally as well as internally. Corrosion reduces strength of pipe leading to risk on production, facilities and even human life. To avoid failures due to corrosion and ensure safe and continued operation, corrosion has to be detected and measured. The strength of these corroded areas has to be determined to ensure safety of pipeline, facilities and human life. In this paper different theoretical method are mentioned which are used to evaluate pressure carrying capacity corroded pipe. And also brief information is added about experimental validation of analytical methods. It is very important to carry out periodic assessment and inspection of the pipeline by assessing remaining strength of corroded pipe.

Introduction

Corrosion reduces strength of pipe leading to risk on production, facilities and even human life. To avoid failures due to corrosion and ensure safe and continued operation, corrosion has to be detected and measured. The strength of these corroded areas has to be determined to ensure safety of pipeline, facilities and human life. It is very important to carry out periodic assessment and inspection of the pipeline by assessing remaining strength of corroded pipe. Currently, industry widely uses various codes (Empirical Relations) to estimate the strength of corroded pipe which is little time consuming and conservative. However, strength of corroded pipe can be evaluated using analytical, numerical and experimental methods.

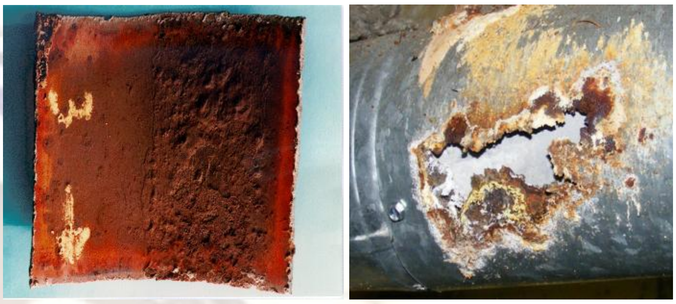

Fig. 1: Typical Corrosion in Pipe

Typically following corrosion assessment methods are used to estimate the burst pressure of corroded pipe:

Analytical Method-

The basis for the well known ASME B31G was developed in the late 1960's and early 1970's in a project sponsored by AGA-NGI8, where a semi-empirical fracture mechanics formula for calculating the remaining strength of a metal loss defect was made .

The original formula was modified and became known as B31G, and there allowable maximum hoop stress and more conservative for thicker walled pipelines.

$$p_{b,\mathrm{intact}} = \frac{2t}{D-t}\sigma_u$$

Where P_b = Burst pressure of corroded pipe.

D = Nominal diameter of pipe.

t = Wall thickness of pipe.

σ_u = Ultimate strength .

The ASME B31G criterion is developed based on full scale tests of pressured to failure corroded pipes. It allows determination of the remaining strength of the corroded pipes and estimating of the maximum allowable operating pressure (MAOP). However, the B31G criterion contains some simplifications. Another shortage, is the possibility of only proving the pipe integrity under internal pressure, other stresses are not taken in to account. There is also restriction in assessable defects, namely the corroded area depth can not be greater than 80% of the wall thickness and not less than 10%.This method is based on the measurement of the longitudinal extent of the corroded area as shown in Figure 2. It considers the depth and longitudinal extent of corrosion, but ignores its circumferential extent. Although analytical methods are popular and widely used, there are pressure detecting equipments to carry out periodic assessment of strength of corroded pipe. However, FEA based approach is not very popular to evaluate strength of corroded pipe.

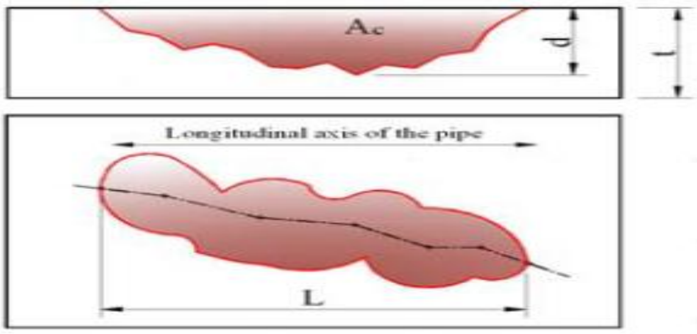

Fig. 2: Corrosion Parameters used in Analytical Methods [6]

Methodology

As discussed in above section there are analytical, numerical, experimental and statistical methods available to estimate strength of corroded pipe. From literature it is observed that some of the currently in use corrosion assessment methods are over conservative. When pipeline operators use these codes for their fitness for service analysis, they are probably subjected either to unnecessary maintenance or to premature replacement of pipelines. Some of the methods are less conservative corrosion assessment method based and might lead to failure of pipes due to incorrect prediction of corroded pipe pressures. Hence following objectives are outlined and proposed in this work:

- To study and evaluate advantages and limitations of existing analytical methods for strength assessment of corroded pipes.
- To estimate corroded pipe strength using commercial FEA tool ANSYS
- Experimental validation of analytical and FEA results
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Analytical and FE analysis results are validated using laboratory experimental set-up for corroded pipes.

Numerical Approach (FEA Approach)- Steps-

a. Creating the model: - The model is drawn in 1-D, 2-D or 3-D space in the appropriate units (meter, mm, inch etc.). The model may be created in the pre-processor, or it can be imported from another CAD packages via a neutral format (IGES, STEP, ACIS, Para solid, DXF, etc.).
b. Defining the element type: - This may be 1-D, 2-D or 3-D & specific to the analysis type being carried out no. of elements are available for analysis like 8-node-42, 8-node-82 (plane 82),6-node-2(plane 2) etc.
c. Applying a mesh: - Mesh generation is a process of dividing the structure continuum into a number of discrete parts or finite elements.If the mesh is finer ,the results are also better but the analysis time is longer. Therefore, a compromise between accuracy & solution speed is usually made.
d. Assigning material properties: - Material properties Young's modulus & Poisson's ratio are defined. Also other properties like coefficient of expansion, coefficient of friction, thermal conductivity, damping effect, specific heat etc. are defined if required.
e. Apply loads: - Some types of load are usually applied to the analysis model.

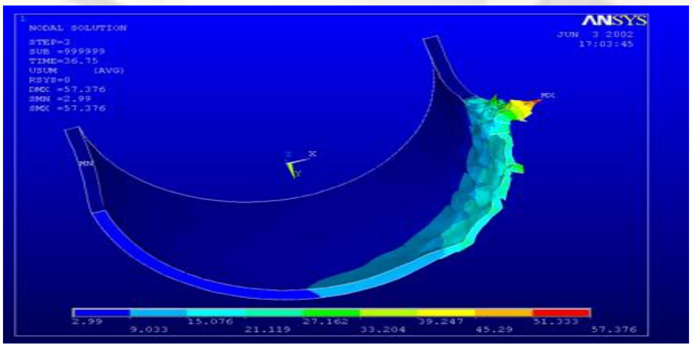
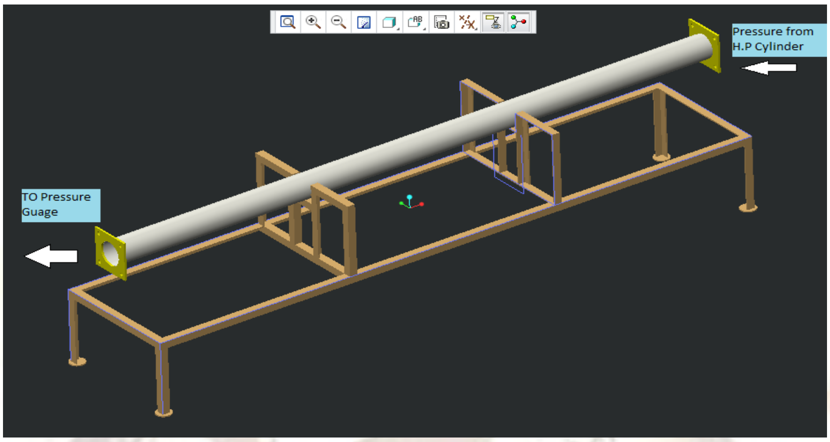


Fig. Typical deformation stages of corroded pipe for a burst analysis[4]

Experimental Approach

Constructional Details-

Experimental set up consists of pipes with and without corrosion having different nominal diameters. These pipes will be connected to the U-tube manometer for pressure measurement (or Pressure transducer can be used) . A flow control valve arrangement will be used to have close monitoring over flow of fluid. These experiments can be conducted in fluid mechanics laboratory.



Experimental Setup

Sample results

Three successful burst tests with different defect depths were completed to study the failure behavior of artificial corrosion defects in pipelines.
The geometry and experimental failure pressures of the three pipes tested are summarized in Table.2.

Test ID	Pipe Dimension (mm)			Defect Dimension (mm)			Experimental Failure Pressure (MPa)
	L	D	t	L (2c)	Width (mm)	Depth (a) (%WT)	
C1	1800	508	5.7	200	30	22	12.8
C2	1800	508	5.7	200	30	45	9.59
C3	1800	508	5.7	200	30	61	6.00

Table 2. Geometry and Test Results [8]

Fig. 3 .Corroded pipe after burst test [8]

Conclusion

With this study strength of corroded pipe can be investigated and time required to replace the pipes can be approximated. And because of FE analysis approach one can easily analyze the ultimate strength of corroded pipe having complex corrosion profile area so that danger due to bursting of pipe can be eliminated which gives various advantages in the various fields of engineering.

References

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