Study of the Evaluation Methods for Dents

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Abstract. As a kind of geometric defects, dents are permanent plastic deformations, which pose a threat to pipeline safety. In order to better prioritize and effectively repair the dent defect in pipelines, the depth based criteria and strain based criteria are both used in the assessment of severity of dents. The most complete dent profiles are provided by a multi-channel geometry tool with a magnetic flux leakage tool or ultrasonic inspection tool. Compared the depth criteria and the strain depth criteria, the strain criteria is a better method to evaluate the severity of dent defect.

Keywords: Dent, Depth based criteria, Strain based criteria, Assessment.

1. Introduction

Dents are formally defined as a depression, which produces a gross disturbance in the curvature of the pipe wall, caused by contact with a foreign body [1].They are permanent plastic deformations of the circular cross-section, which belong to mechanical damage. As a kind of geometric defects, dents can be caused in any section of pipeline's service life. Especially in the pipeline construction period, Extrusions or collisions are hard to avoid. In the operation period, falling objects as well as excavation equipment are able to cause dents. The dent defect always leads to stress and strain concentrations, which may pose great threat to the safe operation of oil and gas pipelines. As a consequence, dent assessment should be utilized to judge their significance and rank dents in order of severity; what's more, recommendations should be needed for the badly damaged pipe section.

2. In-Line Inspection of Dent Defect

In-Line Inspection method is common in mechanical damage detection. It can detect the damages of pipeline under the condition that the pipe systems operate normally. Compared to excavation detection, in-line inspection not only does not need to suspend transportation but can detect the defect which are likely to fail afterwards. The detection tools are installed with the pigs and placed in the pipe, which detect and report the characteristic and dimensions of pipe defect along with oil or gas flow. Magnetic flux leakage tools and geometry caliper tools are the commonest tools used in Pipeline integrity assessment.

Magnetic flux leakage tools detect defects by application of a magnetic field in either the longitudinal or circumferential direction. As with the tools moves along the pipe wall, powerful permanent magnets magnetize the surrounding metal via wire brushes that contact the internal wall. The tool sensors record the change in the magnetic field. When pigs move over dent defects, the movement of sensors records the disturbance in curvature in the pipe wall. Magnetic flux leakage tools are sensitive to the change of geometry and mechanical properties. Through signal analysis can give information about the longitudinal and circumferential extent of dents .However, it cannot offer the exact depth and actual dent profile.

Ultrasonic inspection tools are sensitive to even small deformations. The separation of the carrier from the internal wall lead to variations in the sound path of the recorded into measurable changes in the values of the recorded stand-off distances [3]. It cannot offer the exact depth and actual dent profile as well. What's more, the tools' detection capability can be influenced when sharp contour changes because of potential loss of signal in those locations.

Geometry caliper tools can detect dents or other anomalies such as ovalities, buckles and so on. It can provide the information about location, orientation, length, width, depth and even the detail dent profile. But whether the dents are associated with mental loss or weld seam is unknown.

Every inspection technology has its shortcomings, that is to say, one inspection technology alone cannot provide all the information required to make dent assessment. The most complete information can be gained by a multi-channel geometry tool with a magnetic flux leakage tool or ultrasonic inspection tool.

3. Dent Assessment Method

Dent assessment aims to screening the dent defect which has great threat to pipeline safety or the probability of pipeline failure is quite high. The information used in dent assessment is usually obtained by high-resolution geometry tools and other supporting information. The following sections describe two methods to assess dent severity. The assessment results allow the pipeline operators to prioritize their dig lists

3.1 Depth based criteria

Dent depth is one of the most important parameters of a dent which is defined as the distance between undamaged cross section and damaged cross section. A lot of the available guidance traditionally uses a measurement of dent depth to determine its severity. Table1 shows the international code guidance relevant to the assessment of dents in pipeline [3-7].

Table 1 Published guidance on the assessment of dents in pipeline based on depth criteria

Published criterion	Plain dent	Dents at welds
CSA Z662-03(2007)	When OD<101.6mm,then d<6mm;when OD> 101.6mm,then d< 6%OD	When OD<329.9mm,then d<6mm;when OD>329.9mm mm,then d<2%OD
AS 2885.3(2010)	d< 6%OD	Need repair immediately
API 579(2007)	d< 7%OD	—
API PUBL 1156(1999)	Liguid pipe:d< 6%OD	Dents at brittle welds are not allowed;the depth of dents at ductile welds is lower than 2%OD.
API 1160(2001)	When OD<304.80mm,then d<6.35mm;when OD> 304.80mm,then d< 2%OD	Need repair immediately
PDAM(2002)	Unconstrained dents:d< 7%OD; constrained dents:d< 10%OD	Need repair immediately
49 CFR 195(2007)	Liquid pipe:1.when the depth is higher than 6%OD, repair is needed immediately 2. when the OD is bigger than 304.80mm and the depth is higher than 3%OD,or when the OD is bigger than 304.80mm and the depth is higher than 6.35mm, repair is needed in two months. 3.when the depth is higher than 2%OD, repair is needed in half a year.	Need repair immediately

3.2 Strain based criteria

ASME B31.8 (2007) recognized that the evaluation of dents shall also consider the strain values in the dent. It provided the method to calculate strains in a dent in appendix R [8]. The maximum values of three strain components in a dent are calculated using the following equations:

Bending strain in the longitudinal direction

$$\varepsilon_x^b = -\frac{t}{2R_x} \quad (1)$$

Bending strain in the circumferential direction

$$\varepsilon_y^b = \frac{t}{2}\left(\frac{1}{R} - \frac{1}{R_y}\right) \quad (2)$$

Membrane strain in the longitudinal direction

$$\varepsilon_x^m = \frac{1}{2}\left(\frac{d}{L}\right)^2 \quad (3)$$

In these equations is the radius of curvature of the unreformed pipe surface, which is half of the OD. The parameter t is the wall thickness, and L is the dent length in longitudinal direction. Dimensions R_x and R_y are the external surface radii of curvature and are measured in the transverse and longitudinal planes through the dent, respectively. The dent may only partially flatten the pipe such that the curvature of the pipe surface in the transverse plane is in the same direction as the original surface curvature, in which case R_y is a positive quantity. If the dent is reentrant, meaning the curvature of the pipe surface in the transverse plane is actually reversed, R_y is a negative quantity. Determine the radius of curvature, R_x, in a longitudinal plane through the dent. The term R_x as used herein will generally always be a negative quantity. (figure 2)

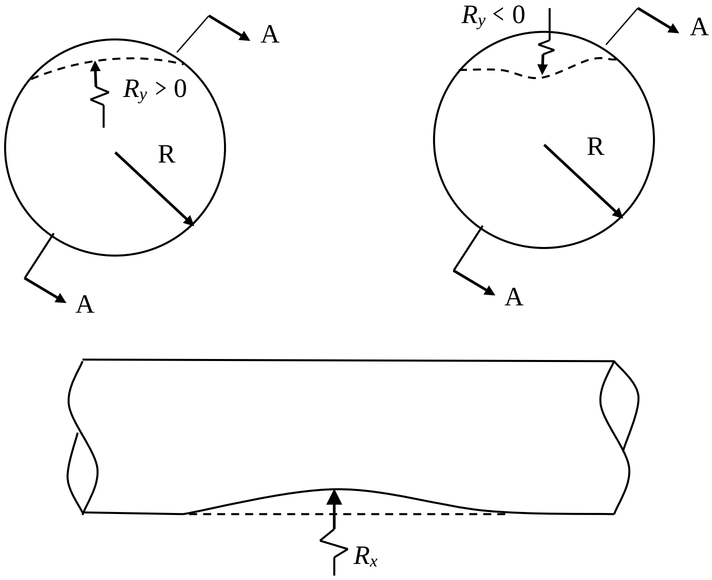

Fig.1 Method for Estimating Strain in Dents

Effective strains on pipe's inner and outer surfaces

$$\varepsilon_i = \sqrt{(\varepsilon_y^b)^2 - \varepsilon_y^b(\varepsilon_x^b + \varepsilon_x^m) + (\varepsilon_x^m + \varepsilon_x^b)^2} \quad (4)$$

$$\varepsilon_o = \sqrt{(\varepsilon_y^b)^2 + \varepsilon_y^b(\varepsilon_x^m - \varepsilon_x^b) + (\varepsilon_x^m - \varepsilon_x^b)^2} \quad (5)$$

According to ASME B 31.8, if the larger of the two values, ε_i and ε_o, is smaller than the limiting strain value of 6%, the dent is considered acceptable.

4. Case analysis

In-line inspection tools detect some dent profiles of a pipe. The pipe is a 660mm OD gas pipeline, which the thickness is about 9mm. According to the detection data, depth based criteria and strain based method are both used to assess the dent severity. The comparison is shown in Table 2.

The depth based criteria suggests that the dent of which depth is up to 6% OD is unsafe. However, the strain based criteria suggests the strain should be lower than 6%. As can be seen in Table 2, it is not reasonable to take the depth of the dent as the only parameter to assess the severity. The dents of

NO.5 and NO.6 are about 4mm deep, but the strains are both over 6%. The depth criteria cannot tell the severity of deformation reasonably. Even the depth of the dents does not exceed 6%OD or 6mm, the strains may be higher than 6%.

Table 2 Comparison of two methods

Dent number	Depth(mm)	d/D(%)	Strain(%)
1	5.8	0.9	1.5
2	6.6	1.0	1.6
3	15.8	2.4	4.5
4	19.9	3.0	4.7
5	25.2	3.8	6.8
6	25.6	3.9	7.5

5. Conclusion

One inspection technology alone cannot provide all the information required to make dent assessment. The most complete information can be gained by a multi-channel geometry tool with a magnetic flux leakage tool or ultrasonic inspection tool.

The depth criteria may misestimate the severity of deformation. Even the depth of the dents does not exceed 6%OD or 6mm, the strains may be higher than 6%. Therefore, the evaluation of pipeline dents should be based on strain criteria.

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