Analysis of Pipe Size Influence on Pipeline Displacement with Plain Dent Based on FE Calculation

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Abstract

According to the report of the United States transportation department, mechanical damage is one of the most important reasons for the pipeline accident .The most typical form of mechanical damage is indentation. Dent defect is one of the important factors affecting pipeline fatigue life, and it will greatly reduce the fatigue life of the pipeline in service. Meanwhile the dent displacement will be changed with the operation pressure fluctuations of the in-service pipeline, resulting in a circular bending stress, which directly affect the pipeline fatigue life. For typical plain dent on pipeline, the finite element models were established under different circumstances. A large number of the calculation results were sorted and inducted. On this basis, the results were analyzed by univariate. Non-linear regression analysis was utilized to fit the results, some specific expressions of the relationship between the dented pipeline displacements and the diameter and wall thickness of pipeline are obtained after much calculation and analog.

Keywords: *Pipeline Diameter, Wall Thickness, Plain Dent, Displacement, Finite Element*

1. Introduction

According to the report of the United States transportation department, mechanical damage is one of the most important reasons for the pipeline accident. The most typical form of mechanical damage is indentation (or simply dent).The Figure 1 is dent cross-section shape.

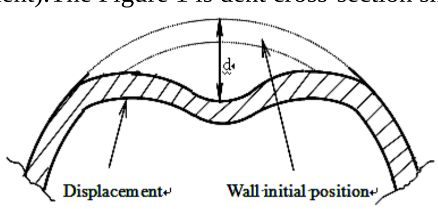

Fig. 1 The dent cross-section shape.

Under the effect of internal pressure, the dented pipe can have certain recovery, which will increase with the increase of internal pressure [1]. Dent recovery can be described by the recovery ratio, which is the ratio of the ultimate dent depth that undergoes the dent recovery and the original dent depth after the external disturbance is removed [2] .The dent recovery ratio is the very important parameter to influence the fatigue life of the dented pipeline [3,4,5].

There is a direct correlation between the dent recovery and the maximum displacement when the dented pipeline suffered the operating pressure. In order to accurately judge the fatigue life of the dented pipeline, based on finite element calculation results, the maximal displacement of the dented pipeline is studied in single-factor and multi-factor analysis by regression method [6,7].

2. Dent Defect Classification and Modeling

According to the analysis of the data accumulated at the scene, the dent on pipeline can be classified by three typical types: type I, type II and type III (see figure 2) [8,9]. The finite element analysis is carried out for type III (plain dent) in this paper.

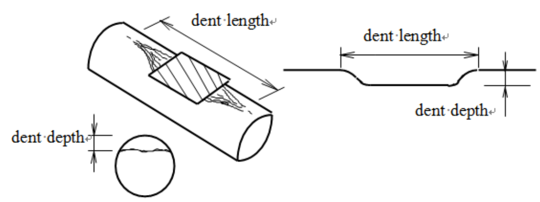

Fig. 2 The shape of plain dent.

The finite element software is utilized to establish the dented pipeline model under different circumstances. According to the real stress state and geometry shape of the pipe under internal pressure, a half of pipe is chosen for analysis by the axisymmetric principle, which includes all the model of dent defect.

It is apparent that different boundary conditions will have different impacts on the deformation even for the same

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load cases. However, compared to the dimension of pipelines, the dent in a pipe is so small that it could always be treated as a local deformation problem. Therefore, in order to not limit the generality of the research and eliminate the impact of the boundary conditions, the length of the pipe was taken as long as possible in the FE model (6 times the outer radius of pipe was used). In addition, according to the actual situation, fixed boundary conditions were applied on both ends of the pipe.

In fact, most of dent defects is caused in construction stage, and the external disturbance would be removed after dent defects was formed, so the FEM model only considered the formed dent. In addition, the influence of external load was not considered, and only the inner pressure was considered.

The 4-node shell element SHELL 63 was used to mesh the solid model. Different meshing density was used to simulate the dent, and according to some factors such as analytical process, calculation accuracy and calculation time and so on, a best meshing density was chose.

Pipeline material is used API X-60. The model of the original dent is result from a flat compressing pipeline along the longitudinal pipe. Pipe diameter is D. Pipe wall thickness is t. The longitudinal dent length of FE model is L. Dent length is the distance between intactness cross-section that is adjacent on both sides of the dent. The dent depth of FE model is d. Dent depth is the maximum displacement of the pipe wall thickness on the place of dent. The internal pressure of FE model is P. In addition, the finite element model conformed to some existing papers that study the similar problems.

The figure 3 and figure 4 are respectively the finite element mesh and displacement of the dented pipeline when P is 3.105Mpa, the ratio of pipe diameter and wall thickness D/t is 30 and the ratio of dent depth and pipe diameter is 0.08.

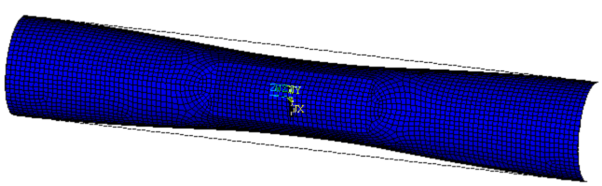

Fig. 3 The finite element meshing map of the part dented pipe.

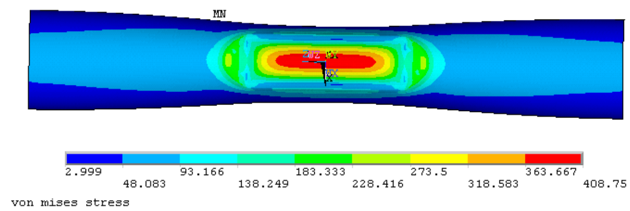

Fig. 4 The displacement of the part dented pipe (mm).

3. The Single Factor Analysis of Displacement

3.1 Pipe Wall Thickness

The figure 5 shows the relationship between the maximum displacement (DMX) and pipe thickness (t) under the different ratio of dent depth and pipe diameter (d/D) when the other parameters is unchanged.

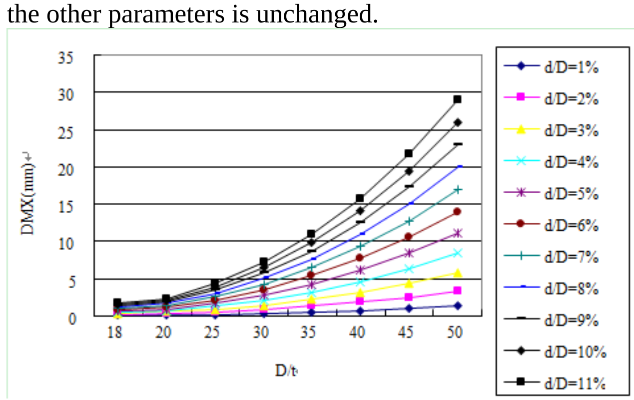

Fig. 5 The relationship of the maximum displacement and the ratio of pipe diameter and wall thickness

The figure 6 shows the relationship between the maximum displacement and pipe thickness when the pipe diameter is equal 1000mm.

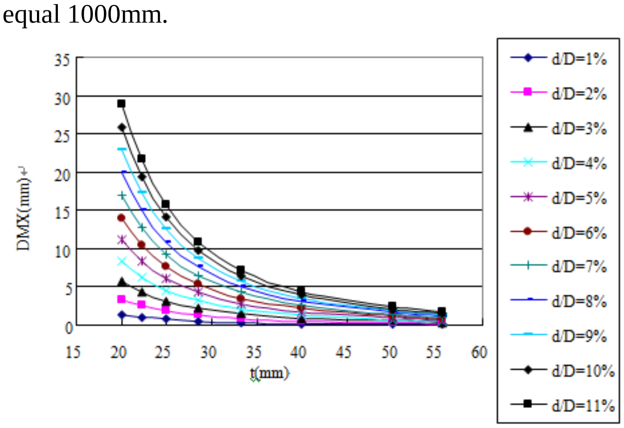

Fig. 6 The relationship of the maximum displacement and pipe wall thickness.

As can be seen from figure 6, at different values of d/D, when pipe diameter is unchanged, the maximum displacement of the dented pipe decreased with the increase of the pipe wall thickness.

After a series of comparison and calculation, the relationship between the maximum displacement and pipe wall thickness can be expressed by power function, which fit it best. The common expression of the power function is as follows:

$$DMX = at^b \tag{1}$$

The table 1 and table 2 list out the coefficient a and b of the expression between the maximum displacement and pipe thickness under the different values of d/D.

Table 1: The values of *a, b* under different *d*

d(mm)	***a***	***b***
10	1388.2	-2.3186
20	6693.5	-2.5387
30	11303	-2.5377
40	23506	-2.6503
50	32999	-2.6676
60	42604	-2.6767
70	53464	-2.6887
80	65432	-2.7018
90	76681	-2.7084
100	89545	-2.7192
110	101772	-2.7261

The correlation coefficient square values of the table 3 are all equal to 1, so the fitting effect is quite good.

Table 2: The values of *a, b* and R^2 under different *d*

d(mm)	***a***	***b***	R^2
(10,20)	4802	-2.5411	0.67
(20,30)	11362	-2.6101	0.84
(30,40)	19566	-2.6452	0.92
(40,50)	28885	-2.6672	0.95
(50,60)	38160	-2.6757	0.97
(60,70)	48083	-2.6837	0.98
(70,80)	58806	-2.6926	0.98
(80,90)	70393	-2.7025	0.98
(90,100)	82616	-2.7123	0.99
(100,110)	95396	-2.722	0.99

As can be seen from table 2, when the dent depth is more than 20mm, the fitting effect is quite good.

3.2 Pipe Diameter

The figure 7 shows the relationship between the maximum displacement and pipe diameter under the different ratio of longitudinal dent length and pipe diameter (L/D) when the other parameters is unchanged.

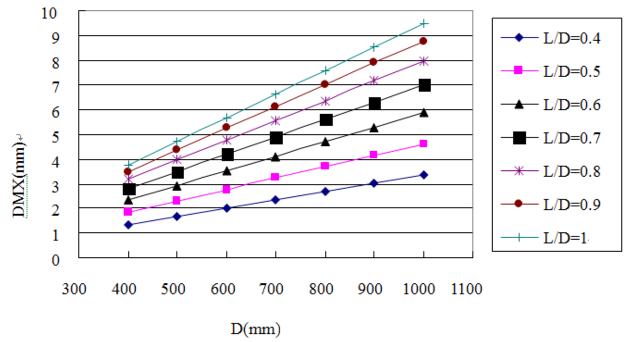

Fig. 7 The relationship of the maximum displacement and pipe diameter.

As can be seen from figure 7, at different ratio of longitudinal dent length and pipe diameter, the maximum pipe displacement increased with the increase of the pipe diameter. After a series of comparison and calculation, when the other parameters are unchanged, the relationship between and the maximum pipe displacement and pipe diameter can be expressed by linear function under the different values of L/D, which fit it best. The common expression as follows:

$$DMX = a \times D + b \tag{2}$$

The table 3 and table 4 list out the coefficient *a* and *b* of the expression between the maximum displacement and pipe diameter under the different values of L/D.

Table 3: The values of *a, b* under different *L/D*

L/D	***a***	***b***
0.4	0.0034	-0.0121
0.5	0.0046	-0.0125
0.6	0.0059	-0.0122
0.7	0.0007	-0.0101
0.8	0.008	-0.0105
0.9	0.0088	-0.0084
1	0.0095	-0.0085

The correlation coefficient square values of the table 3 are all equal to 1, so the fitting effect is quite good.

Table 4: The values of *a*, *b* and R^2 under different *L/D*

L/D	***a***	***b***	R^2
(0.4,0.5)	0.004	-0.0123	0.75
(0.5,0.6)	0.0053	-0.0123	0.84
(0.6,0.7)	0.0064	-0.0112	0.91
(0.7,0.8)	0.0075	-0.0103	0.95
(0.8,0.9)	0.0084	-0.0094	0.97
(0.9,1)	0.0087	-0.0091	0.94

As can be seen from table4, when the values of L/D are less than 0.5, the fitting effect is quite good.

4. Conclusions

(1) At different values of d/D, the maximum displacement of the dented pipe decreased with the increase of the pipe wall thickness. When the other parameters are unchanged, the relationship between the maximum displacement and pipe wall thickness of the dented pipeline can be expressed by power function model, as follows: $DMX = at^b$.

(2) At different values of L, the maximum displacement of the dented pipe increased with the increase of the pipe diameter. When the other parameters are unchanged, the relationship between the maximum displacement and pipe diameter of the dented pipeline can be expressed by linear function model, as follows: $DMX = a \times D + b$

Acknowledgments

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