Analysis of stress on dented pipeline with geometries

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Abstract

The pipeline safety directly determines the safety of oil and gas transportation. However, pipeline damage is a general phenomenon. The mechanical damage is the major cause of pipeline accidents, and the most familiar type of the mechanical damage is dent. Dent geometry is one of the important factors affecting the strength of pipeline. Therefore, for accurate assessment of pipeline safety, it is necessary to analyze the influence of dent with different geometries on pipelines. In allusion to the three typical shapes of dents in spheroid and sphere, analyzing the relationship between maximum stress and dent depth when the application size, pipe pressure and pipe size change and obtaining the influence degree of each factor on the stress that is pipe size, application mark size and pipe internal pressure. To provide some theoretical support for the safe operation of the pipeline.

Keywords

Dented pipeline; Geometry; Numerical analysis; Size of application mark

1. Introduction

The most common type of mechanical damage is dent [1-2]. In the actual operation of the pipeline, it is found that not only the dent depth, dent length, dent, shoulder slope and dent sharpness can cause the pipeline to fail, but also the geometry of the dent is of particular interest. Because different dent shape will lead to the breaking point of different. Therefore, to accurately assess pipeline safety, it is necessary to analyze the influence of dent shape on the pipeline [3-4].

This paper mainly analyzes the defects of pipeline dent ellipsoid and sphere three typical shapes of the mark, and then mark the size, in the application of pipeline internal pressure, pipe size (wall thickness and pipe diameter ratio) change under the condition relationship of maximum stress σ(MPa) and dent depth d (mm). When the debris is ellipsoid, it is divided into two cases. The first dent is formed by pressing the pipe through the vertical axis of the ellipsoid's application mark, as shown in figure 1. This dent can be referred to as a short dent because the width of the dent is much larger than the length [5].

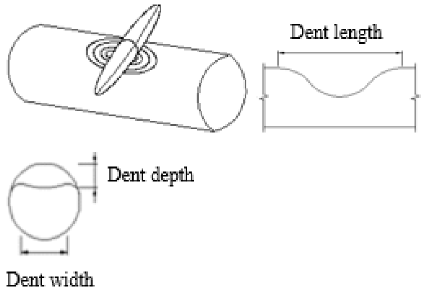

Fig. 1 Short dent in an ellipsoid

The dent length along the pipe axis on both sides of the adjacent distance between the cross section deformation, dent width along the pipeline to ring distance between two saddle vertex occurrence of radial displacement, the dent depth for the maximum displacement of the pipe cross section. The second dent is formed by pressing the pipe through the vertical axis of the ellipsoid, the short axis of the projection, as shown in figure 2. This dent can be called a long dent because the length of the dent is much larger than the width [6]. When the marker is a sphere, see figure 3. This dent can be called a round dent because the length of the dent is not as wide as the width

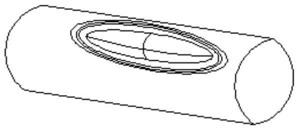

Fig. 2 Long dent in an ellipsoid

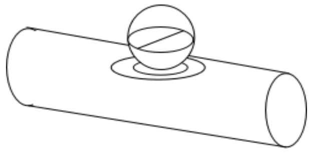

Fig. 3 Round dent in a sphere mark

2. Finite element modeling analysis step

(1)Using the SHELL181 unit in ANSYS software, the pipeline model is established, and the SOLID185 unit is applied to establish the model of the cast mark. Then the mesh is divided, the boundary is restrained, and the contact pairs are defined;

(2)Making the mark perpendicular (parallel) to the pipe line, press the pipe and apply dent to the pipe;

(3)Removing cast marks;

(4)Applying the uniform pressure to the inner side of the pipe, record the maximum stress of the dent area at different dent depth, and draw the analysis. Stress is expressed by von Mises stress.

The short axis of the ellipsoid is represented by a (mm), and the long axis is represented by b (mm). The diameter of the sphere is represented by c (mm), and the internal pressure is expressed by P (MPa). The wall thickness is expressed by t (mm). Assuming that the pipe diameter is D=1000mm, the pipe model is L/2=3D along the axial length.

3. Numerical analysis of stress in dented pipes

3.1 Short dent

3.1.1 Size of application mark

Assuming that t/D and P remain the same, the relation between stress and dent depth at different application sizes is shown in Figure 4.

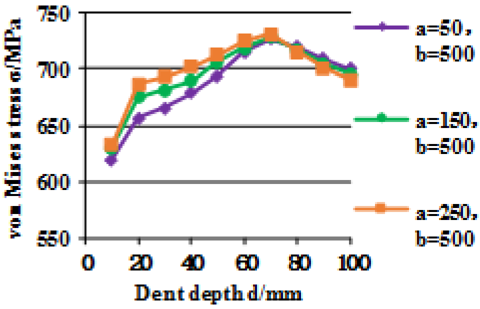

Fig. 4 Relation diagram of stress and dent depth under different marks

Figure 4 shows that the maximum stress increased with the dent depth first increases and then decreases the dent area, increases with the size of the application trace; when d is less than 30mm, the stress changes faster; when d is greater than 70mm, the stress and the dent depth is almost a linear relationship between.

3.1.2 Pipe internal pressure

Assuming that t/D and a and b remain the same, the relation between stress and dent depth under different internal pressures is shown in Figure 5.

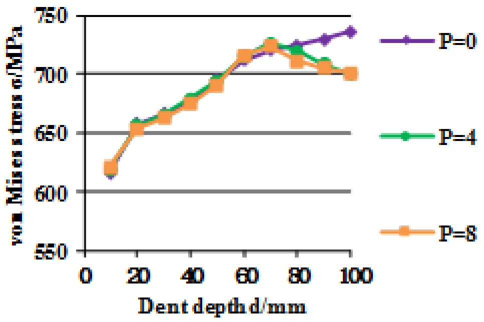

Fig. 5 Relation diagram of stress and dent depth under different pipe internal pressure

Figure 5 shows that when P=0 MPa, the biggest dent in the regional stress increase with the dent depth monotonously increases. When the P=4 and 8MPa, with the increase of the dent depth increases first and then decreases, but different pressure between the stress change is very small, which shows little influence of internal pressure on pipeline dent region stress.

3.1.3 Pipe size

Assuming that P and a and b remain the same, the relation between stress and dent depth at different pipe sizes is shown in Figure 6.

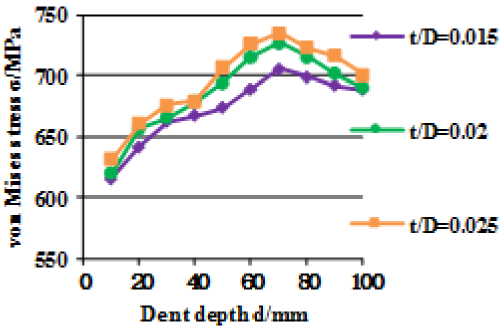

Fig. 6 Relation diagram of stress and dent depth under different pipe sizes

Figure 6 shows that the maximum stress increased with the dent depth first increases and then decreases the dent area; when the d is less than 50mm, between different pipe size stress value of the smaller the gap; in the dent depth under the same pipe size is greater, the greater the stress.

3.2 Long dent

3.2.1 Size of application mark

Assuming that t/D and P remain the same, the maximum stress versus dent depth at different application sizes is shown in Figure 7.

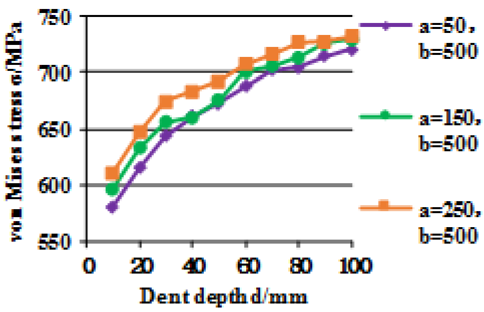

Fig. 7 Relation diagram of stress and dent depth under different marks

Figure 7 shows that the maximum stress of the indent region increases with the size of the application mark increases, but different between the marks the size of the stress value of the smaller the gap, and increases with the dent depth, almost a linear relationship.

3.2.2 Pipe internal pressure

Assuming that t/D and a and b remain the same, the relation between the maximum stress and the dent depth at different internal pressures is shown in Figure 8.

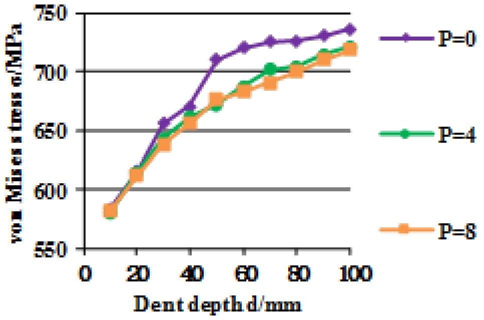

Fig. 8 Relation diagram of stress and dent depth under different pipe internal pressure

Figure 8 shows that the maximum stress indent region increases with the dent depth; when P=0MPa, changes in the magnitude of stress first rapidly, then gradually leveling off. When P=4, 8MPa, different pressure between the stress value of the smaller the gap, the influence of internal pressure on pipeline dent regional stress.

3.2.3 Pipe size

Assuming that P and a and b remain the same, the maximum stress versus dent depth at different pipe sizes is shown in Figure 9.

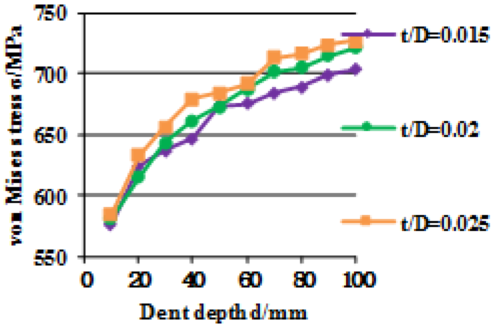

Fig. 9 Relation diagram of stress and dent depth under different pipe sizes

Figure 9 shows that the maximum stress in the dent zone increases with the increase of the pipe size and increases with the dent depth; when the d is less than or equal to 30mm, the stress gap under different pipe sizes is smaller.

3.3 Round dent

3.3.1 Size of application mark

Assuming that t/D and P remain the same, the maximum stress versus dent depth at different application sizes is shown in Figure 10.

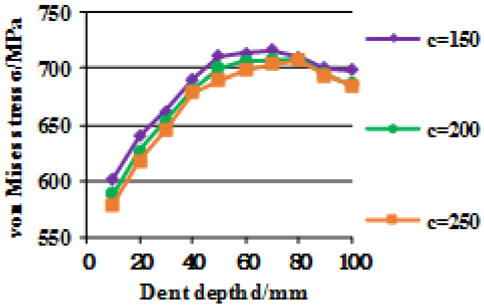

Fig. 10 Relation diagram of stress and dent depth under different marks

Figure 10 shows that the maximum stress in the dent area increases first and then decreases with the increase of dent depth, and decreases with the increase of the size of the applied mark; when the d is larger than 80mm, the stress of the different size of the mark is very small.

(2) Pipe internal pressure

Assuming that t/D and C remain the same, the relation between the maximum stress and the dent depth at different internal pressures is shown in Figure 11.

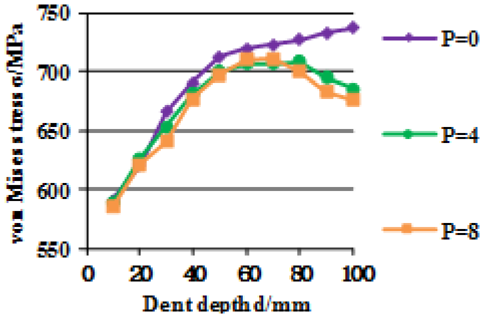

Fig.11 Relation diagram of stress and dent depth under different pipe internal pressure

Figure 11 shows that the maximum dent stress region and dent depth into a nonlinear relationship; when P=0MPa, the stress increases with the dent depth. When P=4, 8MPa, the stress value is increased with the dent depth increased first and then decreased.

(3)Pipe size

Assuming that P and c remain the same, the maximum stress versus dent depth at different pipe sizes is shown in Figure 12.

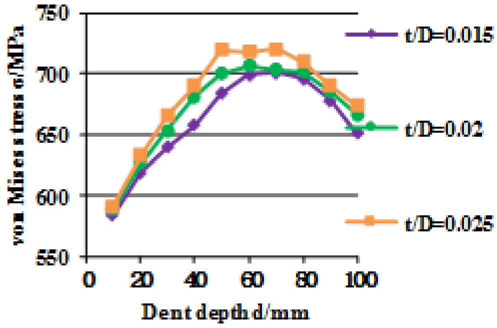

Fig.12 Relation diagram of stress and dent depth under different pipe sizes

Figure 12 shows that the maximum stress increased with the increase of regional dent dent depth increases and then decreases with increasing line size increases; when d is equal to or less than 50mm, the stress increases rapidly; when d is greater than 50mm and less than 70mm, the growth rate is relatively slow stress.

4. Sensitivity analysis of influencing factors

From the above analysis, it is found that the size of the mark, the internal pressure and the size of the pipe have the greatest influence on the maximum stress. Therefore, it is necessary to master the importance of various factors on the maximum stress at the dent. For the dent of three shapes, under the condition of certain depth, orthogonal design is adopted to design the simulation program of 3 factors and 3 levels. Take the short dent for example, the level of the factor is shown in Table 1.

Table 1. Factor level table

Factor / Level	1	2	3
	Size of application mark	Pipe internal pressure	Pipe size
1	0.1	0	0.015
2	0.3	4	0.02
3	0.5	8	0.025

Then, 9 simulation schemes are made by using the orthogonal principle, and the maximum stress is used as the evaluation standard to simulate the calculation. Then, an improved grey relational grade method is adopted to analyze the simulation scheme and the results of the orthogonal test, and the steps are as follows [7]:

(1)Setting the reference sequence X0={x0 (T), t=1,2,... N}, compare sequence Xi={xi (T), t=1,2,... N}, i=1,2,3. The maximum stress is the reference sequence, and the other 3 are comparative series. On X0, Xi in turn down:

$$y_{0,i} = x_{0,i}(t+1) - x_{0,i}(t) \tag{1}$$

(2)Calculating relative change rate k:

$$k_{0,i}(t+1) = \frac{y_{0,i}(t+1)n}{\sum_{t=1}^{n} x_{0,i}(t)} \tag{2}$$

(3)Calculating the correlation degree γ_i between X_0 and X_i:

$$\gamma_i = \sum_{y=2}^{n} \frac{\pm 1/(1+\left\| k_i(t) \right| - \left| k_0(t) \right\|)}{n-1} \tag{3}$$

(4)Sorting. The calculated results of correlation degree γ_i are shown in Table 2.

Table 2. Results of correlation degree

Influence factor	Size of application mark	Pipe internal pressure	Pipe size
i	1	2	3
γ_i	0.3504	0.1250	0.5256

5. Conclusion

(1)The maximum stress of short dents and round dent are increased with the increase of the dent depth first increases and then decreases; increases with the increase of the size and application of trace pipe size; the internal pressure, the internal pressure of the size of the maximum stress has little influence on the shape of the two dent.

(2)The maximum stress of the long dent increases with the dent depth, the size of the applied mark and the size of the pipe. The size of the internal pressure also has little effect on the maximum stress of the dent.

(3) For the dent of three geometries, the size of the pipe has the highest influence on the maximum stress in the dent area, followed by the size of the applied mark and finally the internal pressure of the pipeline.

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