Analysis of Crack Influence Vibration Characteristics of Tower Tank

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Abstract. The vibration of the cylindrical tower tank was analyzed in the finite element method. The natural frequencies and modes of the cylindrical tower tank in the condition of different thickness and crack, etc. were obtained and influence rules were analyzed. This paper provides the basic research for identifying the crack damage of tower tank through vibration performance.

Introduction

Vertical cylindrical tower tank is widely used in various industries. Crack is found in the process of production or use sometimes. The presence and extension of these cracks can destroy the integrity of the structure and reduce the stiffness and strength of tower tank, then causing major accidents. The structure of the tower tank should be diagnosed and evaluated timely to understand if exists crack, the location of the crack, crack size. Then ensuring the normal use becomes necessary technology in engineer.

The Establishment of Calculation Model

The tank diameter D=2200mm, height L=3650mm, the height of top shell f=350mm. Cracks can be divided into axial cracks and circular cracks to study and seven axial cracks and seven circular cracks were set up. The length of cracks is 500mm.

SHELL63 element is adopted, Shell thickness is 20 mm, material of tower tank is carbon steel, elasticity modulus is 200GPa, poisson ratio is 0.3 and material density value is 7800 kg/m³. This paper studies two kinds of constraint conditions. The constraint I: bottom surface is completely fixed. The constraint II: The four symmetrical points are fixed at the bottom edge.

Modal Calculation of Different Constraints and Cracks

According to solve the vibration characteristics of the tower tank, natural frequency and vibration mode figure of the cracked tower tank included in the selected location and length of cracks can be obtained. Because the selected vertical cylindrical tower tank is symmetrical completely, the natural frequency of every two order is the same. So 4 order natural frequency and mode of vibration are taken to study, they are from one, three, five and seven order. Considering the space, the conditions of having no crack and
having crack in the constraint I are taken to study. In the condition of y=1835mm, crack length is 500 mm and the direction of crack is annular. The natural frequency and mode of vibration of tower tank is shown in table 1, figure 2 and figure 3.

|                  | first order | third order | fifth order | seventh order |
|------------------|-------------|-------------|-------------|--------------|
| no crack         | 81.672      | 87.475      | 88.318      | 105.15       |
| crack            | 80.772      | 86.320      | 87.850      | 104.87       |

![Figure 2](image.png)

(a) the first order vibration mode with no crack
(b) the seventh order vibration mode with no crack

![Figure 3](image.png)

(c) the first order vibration mode with crack
(d) the seventh order vibration mode with crack

**Reseaching the Law that Crack Has an Influence on the Natural Frequency of Cylindrical Tower Tank**

At the bottom with fully-constrained, taking circular crack at y=1835mm as an example and researching the law that length of circular crack has an influence on the natural frequency of tower tank. Calculating each order natural frequency by changing length of circular crack and obtaining curves that show each order natural frequency is changing with different length of crack. As shown in figure 4.

![Figure 4](image.png)

Figure 4. Curves that show each order natural frequency is changing with different length of crack.

It is observed: (1) with the increase of crack length, the rate of change of each order natural frequency
is increasing. (2) The increase of the rate of change of the fifth and seventh order natural frequency is slower and the increase of the rate of change of the first and third order natural frequency is faster. It illustrates that the first and third order natural frequency is more sensitive to the change of length of crack.

Conclusions

(1) In the case of the bottom surface is completely fixed: in the condition that the thickness and the crack location of tower tank are constant, with the increase of length of crack, the rate of change of each order natural frequency is increasing. But when the crack is circular crack, the rate of change of the first and third order natural frequency is more apparent; when the crack is axial crack, the rate of change of the first and seventh order natural frequency is more apparent; with the crack move from the bottom up, when the crack is circular crack, the rate of change of each order natural frequency is reducing; when the crack is axial crack, the rate of change of each order natural frequency climb up and then decline; with the increase of the thickness of the tower tank, the rate of change of each order natural frequency is increasing. But when the crack is circular crack, the rate of change of the first and third order natural frequency is more apparent; when the crack is axial crack, the rate of change of the first and seventh order natural frequency is more apparent.

(2) In the case of the four symmetrical points are fixed at the bottom edge: in the condition that the thickness and the crack location of tower tank are constant, with the increase of length of crack, the rate of change of each order natural frequency is increasing. But when the crack is circular crack, the rate of change of the first, third and fifth order natural frequency is more apparent; when the crack is axial crack, the rate of change of the third order natural frequency is more apparent; with the crack move from the bottom up, when the crack is circular crack, the rate of change of each order natural frequency is reducing and the change of the first order natural frequency is obvious; when the crack is axial crack, the change of the third order natural frequency is obvious and climb up and then decline; with the increase of the thickness of the tower tank, the rate of change of each order natural frequency is increasing. But when the crack is circular crack, the rate of change of the first and third order natural frequency is more apparent; when the crack is axial crack, the rate of change of the third order natural frequency is more apparent.

(3) In the case of others are unchanged: for tower tank containing circular crack, the rate of change of natural frequency in constraint II is bigger than in constraint I, illustrate the tower tank containing circular crack is more sensitive to constraint II; for tower tank containing axial crack, the rate of change of natural frequency in constraint I is bigger than in constraint II, illustrate the tower tank containing circular crack is more sensitive to constraint I; for tower tank containing circular crack, the rate of change of the tower tank containing circular crack is more sensitive to constraint II; for tower tank containing axial crack, the rate of change of the tower tank containing axial crack is more sensitive to constraint I.

After the vibration of the cylindrical tower tank is analyzed in this paper, the natural frequency and mode of the cylindrical tower tank in the condition of different crack length, direction and constraints, etc is obtained and its influence rule is analyzed. It provides a useful exploration for identifying crack damage of similar equipment with vibration performance.

References

[1] Cawley P, Adams R D. The location of defects in structures from measurements of natural frequencies [J], Journal of Starin Analysis, 1979, 14:49-57.

[2] Smith RA. Finite element modelling of fatigue crack growth of surface cracked plates D Part I: The numerical technique [J], Engng Fracture Mech.1999 63: 503-522.

[3] H. P. Lee, T. H. Tan and G. S. B. Leng. Dynamic Stability of Spinning Timoshenko Shafts with a Time-Dependent Spin Rate,Journal of Sound and Vibration, 1997, 199(3): 401-415.

[4] Yaoguo Yu. The Research on the Crack of Middle Thick Plate [D], Wuhan University of Science and Technology, 2007.
[5] Degang Xu, Junping Xu, Yapeng Shen. The Research on Experiment of the Dynamic Characteristics of Cylindrical Thin Shell Containing Crack [J], Mechanics and Practice vol. 24, No. 3 2002.

[6] Degang Xu, Junping Xu, Daoming Shen, Yapeng Shen. The Research on Experiment of the Dynamic Characteristics of Cylindrical Thin Shell Containing 450 Oblique Crack [J], Mechanics and Practice, 1.28 No. 1 Feb 2006.

[7] Wei Guo Numerical Analysis of Sheet Damage Based on The Rate of Change of Strain Modal [D], Daqing Petroleum Institute, 2006.

[8] Renxi Hu, Qingwu Wang. ANSYS 8.2 Advanced Application Instance of Machine Design [M], Beijing: China Machine Press, 2005.

[9] Benwen Xu, Qunying Jiao. Mechanical Vibration and Basis of Modal Analysis [M], Beijing: China Machine Press, 1998.

[10] Yanzhu Liu, Wenliang Chen, Liqun Chen. Mechanics of Vibration [M], Beijing: Higher Education Press DB, 2008.