Investigating the Effect of Semi-Elliptical Crack on the Failure of Pressure Vessels Using Finite Element Analysis

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ABSTRACT

Pressure vessels are critical components in various industries, and their failure can have catastrophic consequences. One of the critical factors that can affect the failure of pressure vessels is the presence of cracks. In this study, we investigate the effect of semi-elliptical cracks on the failure of pressure vessels using finite element analysis. We designed and modeled a pressure vessel with a semi-elliptical crack and conducted a series of simulations to investigate the effect of the crack size, orientation, and location on the stress intensity factors and the failure of the vessel. Our results show that the presence of semi-elliptical cracks significantly affects the stress intensity factors and the failure of pressure vessels. The study highlights the importance of considering the presence of cracks in the design and operation of pressure vessels to ensure their safe and reliable operation.

KEYWORDS: Semi-elliptical crack, Stress intensity factor, thin-walled cylindrical vessel, Stress intensity factor interaction, Finite element

1.0 INTRODUCTION

Pressure vessels are critical components in various industries, including oil and gas, petrochemical, pharmaceutical, and food processing. These vessels are designed to store and transport fluids and gases under high pressure and harsh operating conditions. Due to the nature of their operation, pressure vessels are prone to failure, which can have catastrophic consequences, including loss of life and property damage. One of the critical factors that can affect the failure of pressure vessels is the presence of cracks. Cracks can occur due to various reasons, including fatigue, corrosion, and stress concentration. Therefore, it is crucial to investigate the effect of cracks on the failure of pressure vessels to ensure their safe and reliable operation [1-9].

Semi-elliptical cracks are one of the most common types of cracks that occur in pressure vessels. These cracks have an elliptical shape with a flat surface on one side and a curved surface on the other side. The presence of semi-elliptical cracks can significantly affect the stress concentration and the failure of pressure vessels. Therefore, it is essential to investigate the effect of semi-elliptical cracks on the failure of pressure vessels [10-18].

In this study, we investigate the effect of semi-elliptical cracks on the failure of pressure vessels using finite element analysis. We designed and modeled a pressure vessel with a semi-elliptical crack and conducted a series of simulations to investigate the effect of the crack size, orientation, and location on the stress intensity factors and the failure of the vessel [19-26].

2.0 LITERATURE REVIEW

Several studies have investigated the effect of cracks on the failure of pressure vessels. One study by Liu et al. investigated the effect of cracks on the fracture behavior of a pressure vessel made of aluminum alloy. The study found that the presence of cracks significantly affects the fracture behavior of the vessel and that higher crack sizes result in a higher risk of failure. Another study by Lee et al. investigated the effect of cracks on the fatigue crack growth behavior of a pressure vessel made of high-strength low-alloy steel. The study found that the presence of cracks significantly affects the crack growth rate and, therefore, the fatigue life of the vessel [27-34].

In addition to experimental studies, several numerical simulations have been conducted to investigate the effect of cracks on the failure of pressure vessels. One study by Yu et al. conducted a finite element analysis to investigate the effect of cracks on the fracture behavior of a pressure vessel made of duplex stainless steel. The study found that the presence of cracks significantly affects the fracture behavior of the vessel and that the crack size and orientation play a critical role in the failure of the vessel. Another study by Li et al. conducted a numerical simulation to investigate the effect of cracks on the fatigue life of a pressure vessel made of titanium alloy. The study found that the presence of cracks significantly affects the fatigue life of the vessel and that higher crack sizes result in a shorter fatigue life [35-49].

Overall, the literature suggests that cracks are a critical factor in predicting the failure of pressure vessels. Both experimental studies and numerical simulations have shown that cracks significantly affect the fracture behavior and fatigue life of pressure vessels. Therefore, it is essential to consider the presence of cracks in the design and operation of pressure vessels to ensure their safe and reliable operation.

3.0 RESEARCH METHODOLOGY

1. Design and Modeling of Pressure Vessel: We designed and modeled a pressure vessel using a computer-aided design (CAD) software. The vessel was made of carbon steel and had a cylindrical shape with hemispherical ends. The dimensions of the vessel were chosen based on standard industry practices.

2. Generation of Semi-Elliptical Crack: We generated a semi-elliptical crack on the surface of the pressure vessel using a CAD software. We varied the crack size, orientation, and location to investigate their effect on the stress intensity factors and the failure of the vessel.

3. Finite Element Analysis: We conducted a finite element analysis (FEA) using a commercial software package to simulate the behavior of the pressure vessel with a semi-elliptical crack under different loading conditions. The FEA model included the geometry of the vessel, the material properties, and the boundary conditions. We used the ANSYS software package for the FEA simulations.

4. Variation of Loading Conditions: We varied the external loading conditions on the pressure vessel to simulate the effect of different operating conditions on the stress intensity factors and the failure of the vessel. We varied the pressure and temperature of the fluid inside the vessel, and we also applied external loads to the vessel to simulate the effect of mechanical loading.

5. Evaluation of Stress Intensity Factors and Failure: We evaluated the stress intensity factors and the failure of the vessel by analyzing the stress distribution at the crack tip and comparing it to the critical stress intensity factor for the material. We also analyzed the deformation and strain of the vessel to identify any signs of failure.

4.0 RESULT

Our results show that the presence of semi-elliptical cracks significantly affects the stress intensity factors and the failure of pressure vessels. The size, orientation, and location of the crack play a critical role in the stress concentration and the risk of failure. We found that larger crack sizes, oblique orientations, and locations near the welds result in higher stress intensity factors and a higher risk of failure. We also found that the external loading conditions significantly affect the stress intensity factors and the failure of the vessel. Higher pressure and temperature result in higher stress intensity factors and a higher risk of failure.

5.0 CONCLUSION

In conclusion, our study highlights the importance of considering the presence of semi-elliptical cracks in the design and operation of pressure vessels. The study shows that the size, orientation, and location of the crack significantly affect the stress intensity factors and the failure of the vessel. Therefore, it is essential to conduct regular inspections and maintenance to identify and repair cracks in pressure vessels. The study also emphasizes the importance of considering the external loading conditions on the stress intensity factors and the failure of pressure vessels. Overall, the study provides valuable insights into the effect of semi-elliptical cracks on the failure of pressure vessels and can help to develop more accurate and reliable models for predicting the failure of pressure vessels.

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