Numerical simulation study of coupling between stress and magnetism for magnetic memory effect of the welding crack

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ABSTRACT

With the execution of national energy strategy, a large number of long-distance gas transportation pipelines and storage tanks that requires high technology and quality have been put into service successively. Due to the complexity of structures and welding processes of these special equipments, stress concentration in welding seam is an inevitable outcome during the process of fabrication and application. The high stress may lead to the expansion of fatigue cracks, a reduction of security and equipments' service life, and may even bring about a fatal accident. Therefore, it is socially and economically substantial to practise early diagnoses and evaluate the security and service life of equipments by ascertaining the distribution and level of stress concentration.

Based on magnetostrictive effect, metal magnetic memory inspecting method which involves detecting stress of ferromagnetic material is a new kind of non-destructive testing method. It obtains leakage field information reflective of stress concentration beneath the surface of structures located in geomagnetic field, and then realizes the evaluation of early damnification. In this paper, a pressure test was introduced and a metal magnetic memory inspecting for welding cracks with different dimension and position was performed. Then tress and strain analysis and magnetic memory behavior for welding crack in the pressured pipeline was researched by ANSYS software based on the stress-magnetism coupling model established. Finite element analysis (FEA) results indicated that spatial distribution of stress and leakage field were coincident, and stress distribution influenced leakage field distribution. Stress analysis result showed that stress concentration existed around crack tip. With increasing distance off the crack tip, stress decreased and reached stable to a level of reference stress. Variation of equivalent stress (SEQV) near crack slowed down with increasing internal pressure. Crack dimension hardly influenced stress concentration of crack tip and crack position had a huge effect on spatial distribution of stress concentration.Leakage analysis result indicated that crack surface leakage gained an increase when internal pressure level was heightened. Increase was fast during elastic stage and slowed down when crack tip underwent plastic deformation. Effect of crackdimension on surface leakage field was very little. However, leakage first showed an increase and then a decrease with increasing crack dimension, while it dropped fast with larger burying-depth. Finally, contrast between experiment result and FEA was conducted, and results showed that FEA numerical simulation can exactly analyze stress concentration and magnetic memory behavior of welding crack tip.

KEY WORDS ： metal magnetic memory, welding crack, stress-magnetism coupling model, stress field analysis, leakage field analysis