Determination of stresses for repairing crack lengths with and without single composite patch by finite elements method

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Abstract

In this work, the finite elements method is used for the determination of the stress intensity factor (SIF) and stresses (radial and circumferential) with and without patch. This study is aimed, to compare the design of single composite patch and without patch for repairing cracked API X65 pipeline. The obtained results show that, when the 5 and 65 mm longitudinal crack are applied, the single patch presents lower stress intensity factor for the entire crack tip. Furthermore, the radial and circumferential stresses are higher for the case of the single patch then without patch. The procedure eventually, given by the single patch technique, can be very significant and this method depends on the patch geometry and the adhesive characteristics.

Keywords: Crack, pipeline, API X65, finite elements, adhesive, patch

Introduction

Pipelines are very essential components in some stations systems for transportation of hydrocarbons for a long distance. The reason of crack of these networks of pipe constituents is associated to the existence of defects during fabrication and different types of welding [1-11]. The new resource of in-line examination of pipelines permits revealing a great number of cracks. For all of them, the worker has to create a confirmed result via their acceptability or the types and rapports of repair. The stress investigation of pipes, with the computation of stress intensity factors for cracks, is a main component of such a decision [12-14]. Many problems when analyzing a pipe with an under internal pressure, the detecting effect of the pressure and the poorly defined geometry permit a presence of a local defect [12, 15]. Cracks are the main reasons that affect concrete quality from the point of observation of defending reinforcing steel from corrosive types [12, 16-18]. The protection of gas pipelines against such ruptures was formerly appraised by absorbed energy in influence analysis of pipeline materials [12, 19-21]. Pipelines play a main role in transporting hydrocarbons in the world. Failure is a critical problem in pipelines because changing, fixing and maintaining them may be very expensive. The emulsions (water-oil) creation procedure has been originate to be a significant reason in the interior corrosion of pipelines as the water comprises various corrosive helpful such as naphthenic acid and sulfur [22-24]. Stress intensity factors in pipelines may be obtained by finite element method (3D). Three-dimensional finite element investigates have been applied by some authors to calculate stress intensity factors for
longitudinal cracks in pipelines. All authors show in their results that stress intensity factors depend on geometrical conditions and loading parameters [25]. Firstly, the aim of this work is the investigation the stress intensity factor of repaired crack with single patch in an API X65 Pipeline in mode I using the finite element method. And secondly, we studied the different stresses of longitudinal crack ($\sigma_{rr}$ and $\sigma_{\theta\theta}$) at the crack tip which is affected by the presence of the single patch with a 5 mm distance crack.

2. Geometry and finite elements method

In this study, the longitudinal crack at different positions in the wall of pipe was investigated. The crack sizes are characterized by dimensions of a single patch, and an adhesive. The geometrical characteristics are described in Fig. 1.a, where $R_i$ ($R_i = 147$ mm) is the inner radius, $L$ ($L = 500$ mm) is the length longitudinal and $t$ ($t = 17.5$ mm) is the wall thickness.

The crack is repaired with a boron–epoxy composite patch bonded cylinder form having thickness ($e_p=12$mm) with an adhesive cylinder form having a thickness $e_a = 3$ mm. The longitudinal length of the patch and the adhesive is 300 mm. The pipeline is subjected to an applied radial load of $\sigma = 70$ MPa [1, 5-6, 8]. In this study, we were used three-dimensional finite element method by applying the Abaqus finite element code. The finite element model is based on three parts to model the cracked pipeline, the adhesive, and the composite patch (fig (1.b)).

![Fig. 1. Geometrical and mesh models.](image)

3. Results and discussions

3.1. SIF calculation of a function of the pressure for two types of patch

Fig. 3 presents the variation of the SIF with regard to the used pressure for two configurations of patch (single and without patch):

For two configurations using different longitudinal crack distance as: 5 and 65 mm, the SIF, affected by the two parameters such as the thickness of the adhesive and the path, increases almost linearly up to the pressure of 75 MPa. Also, it increases when the longitudinal crack
increases and the SIF for single patch is lower than the SIF for without patch for the same crack distance [1, 3, 6, 24].

![Graph showing SIF for single and without patch vs. the pressure for different values of crack distance.](image)

**Fig. 4.** SIF for single and without patch vs. the pressure for different values of crack distance.

### 3.2. Stresses

For the objective of comparison, the analysis was performed by using the finite element package ABAQUS for investigating the single and without patch for different longitudinal cracks at 70 Bar. Analyses of the crack for pipeline should be showed to confirm approximately the safety of the design, dimension and structure.

![Graph showing stress (σrr and σθθ) for single and without patch vs. the normalized distance at 70Bar.](image)

**Fig. 4.** Stress (σrr and σθθ) for single and without patch vs. the normalized distance at 70Bar

#### 3.2.1. Radial stresses (σrr)
Fig. 4(a) shows the distribution of the radial stresses for crack distance (5 mm) for the single and without patch. The risk of rupture of pipeline is important according to the radial direction for the 5mm single patch. The highest principal radial stress in the pipe occurred around the crack which is located in the critical zone. One can conclude that there is risk of fracture in this case because the pipe, in general, has a good resistance to dilatation loading for the same pressure and crack distance for single patch [24].

3.2.2. Circumferential stresses ($\sigma_{\theta\theta}$)

Fig. 4(b) shows the angular stresses distribution for 5 mm crack distance of the single and without patch. One notices that the angular stresses $\sigma_{\theta\theta}$ are less important than the radial stresses $\sigma_{rr}$. Accordingly, the risk of the fracture of the pipe is not important. The radial stresses level is very important, they can reach 300 MPa when the 5 mm longitudinal crack for the case of a single patch. For the same longitudinal crack, the circumferential stresses are lower than the other case; the maximum stress value is about 90 MPa [24].

4. Conclusion

This work shows that the using of the single patch increases considerably the repair performances. The stress intensity factor at the crack tip is reduced by the use of the single patch, which increases the pipeline material fatigue life. This application corresponds to the mechanical properties of the adhesive. The analysis of patch shear stresses ($\sigma_{rr}$) distribution presents essential stresses for the single patch compared to the without one. The obtained values are acceptable but an optimization of the repair factors is recommended [12, 24].

The obtained results allow us to give the following conclusions:
– The different stresses of longitudinal crack ($\sigma_{rr}$ and $\sigma_{\theta\theta}$) at the crack tip are highly affected by the presence of the single patch with 5 mm distance crack. The risk of crack propagation with opening mode is important when it is positioned at 5 mm distance crack for a single patch.

References


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