Accepted Manuscript

Finite Element Analysis of a Repaired Thin-walled Aluminum Tube Containing a Longitudinal Crack with Composite Patches under Internal Dynamic Loading

Mohammad Malekan, Carlos Alberto Cimini Jr.

PII: S0263-8223(16)32894-X
DOI: https://doi.org/10.1016/j.compstruct.2017.10.079
Reference: COST 9054

To appear in: *Composite Structures*

Received Date: 19 December 2016
Revised Date: 24 October 2017
Accepted Date: 27 October 2017

Please cite this article as: Malekan, M., Cimini, C.A. Jr., Finite Element Analysis of a Repaired Thin-walled Aluminum Tube Containing a Longitudinal Crack with Composite Patches under Internal Dynamic Loading, *Composite Structures* (2017), doi: https://doi.org/10.1016/j.compstruct.2017.10.079

Finite Element Analysis of a Repaired Thin-walled Aluminum Tube Containing a Longitudinal Crack with Composite Patches under Internal Dynamic Loading

Mohammad Malekan[1,*], Carlos Alberto Cimini Jr.[1]

[1] Department of Structural Engineering, School of Engineering, Federal University of Minas Gerais (UFMG), Belo Horizonte, MG, Brazil

*Corresponding author: mmalekan1986@gmail.com, malekan@dees.ufmg.br

Abstract

One of the main issues with the cylindrical tubes is the propagation of cracks during their operational life wherein most of the cracks happen along the axial direction of the tube. This paper reports a 3D finite element simulation of the mechanical responses of an aluminum tube containing a longitudinal crack repaired with composite patches. After several loading-unloading cycles of the dynamic load, mechanical stresses at the crack tips may result in unstable crack propagation. Therefore, it is necessary to use a repair process to prevent the structure from final rupture. Glass/epoxy and boron/epoxy composite patches, with different number of patch layers, are considered in the analysis of the composite material repair effect on the crack tips stress distribution, evaluating the possibilities of crack propagation and patch delamination onset. Numerical simulations were partially compared with literature results to verify the modeling procedure, while a parametric study on the patch thickness was performed to verify the repair effectiveness. In general, boron and longer (140 mm) repair patches presented better performance than glass and shorter (70 mm) patches. Although thinner patches (2 layers) do not present the required resistance, thicker patches (16 layers) may precipitate delamination onset and thus should be avoided.

Keywords: aluminum tube, finite element analysis, longitudinal crack, composite patch, dynamic loading, delamination onset

1 Introduction

Finite element analysis of cylindrical tubes under dynamic loading has been received more attention in recent years, because of various application of this kind of structures. A typical application is in aerospace industries, while other can be oil/gas transportation systems and biological blood vessels. One of the main issues with the cylindrical tubes is the propagation of the cracks during their operational life. Literature studies show that most of the crack are happen along the axial direction of the tube under quasi-static or fatigue loading [1]. One of the main applications of fracture analysis of cylindrical tubes is the crack propagation and failure analysis of pulse detonation engines (PDE). The PDEs received many attentions among engine industries in last decade because of their performance and advantages over conventional engines [2].

There are different studies on the behavior of crack-free tube under dynamic loading [e.g. 3, 4, 5, 6, 7], while there are other studies on fracture analysis of the cracked tube. Chao and Shepherd [8] conduct various experimental tests on different tube and flaw sizes. Cirak et al. [9] performed a fluid-structure interaction simulation of deformation and fracturing of an experimental aluminum tube. A developed explicit FE method for the prediction of dynamic crack growth in shells by Song and Belytschko [10], and FE simulation of detonation-driven fracture of thin-walled shells by Gato [11] are various studies in this area. The latest models of analyzing tube fracture under dynamic wave load are developed by Rouzegar et al. [12], Mirzaei et al. [13, 14], Malekan [15] and Du et al. [16]. They all reported that the self-similar growth of the initial axial crack in the tube was a fatigue-type incremental growth governed by the structural waves.

A possible solution to prevent the catastrophic failure of the structure is to repair the cracked body with either welded method or composite patches. Bonded repairs can be applied either as a precaution to reinforce undamaged structures or as a remedy to cracked structures [17]. In this case, the stress intensity factor of the cracked structure being repaired has been significantly reduced. There are many investigations on the application of composite patches to repair the damaged pipelines [18, 19, 20]. Onshore pipelines are typically concerned with circumferential stresses associated with internal pressure and repairing these structures with composite patch involves the restoration of hoop strength [21]. Bian et al. [22] presented an experimental and theoretical fatigue crack propagation analysis of steel pipes with flawed subjected to tensile. A 3D displacement analysis technique based on optical dynamic was used to evaluate the crack propagation in a threaded pipe assembly by Van Wittenberghe et al. [23]. Reinforcement and repair of components using composite patches is a well-known technique in many engineering areas; such as aerospace, civil and mechanical