Engineering Failure Analysis 88 (2018) 35–53

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

# Mechanical response of a lined pipe under dynamic impact

Obeid Obeid*, Giulio Alfano, Hamid Bahai, Hussam Jouhara

*College of Engineering, Design and Physical Sciences, Brunel University, UB8 3PH Uxbridge, UK*

ARTICLE INFO

*Keywords:*
Lined pipes
Dynamic impact
Residual stresses
Energy
Velocity

ABSTRACT

An experimental and numerical investigation on the mechanical response of a lined pipe (compound pipe) under a dynamic impact is presented. The influence of the impact energy has been studied in terms of the depth of the dent formed, and of the strains and residual stresses. To this end, a three-dimensional explicit dynamic non-linear finite element model has been developed and successfully validated against the results of impact-test experiments conducted on pipes made of AISI 10305 steel, with and without the AISI304 stainless steel liner. The validation was made by comparing numerically computed strains with those measured by strain gauges, as well as in terms of permanent deformation. The model is then utilized to evaluate the residual stresses, the amount of energy dissipation and the velocity of impact process as a function of different pipes (i.e. with or without liner) and of the free drop heights.

## 1. Introduction

Oil & Gas pipelines face cyclic loading generated by fluid pressure changes, especially in the case of offshore pipelines which have high internal pressure, or as a result of waves and currents, the latter possibly leading to vortex-induced vibrations [1].

On the other hand, corrosive production fluids make the use of C-Mn steel pipe for flow line impossible, so that the need for corrosion mitigation is required [2]. One alternative is the use of a lined pipe, consisting of a thinner inner layer (the liner) and outer layer (backing steel) [3]. The liner is made of corrosion resistant alloy (CRA) such as Alloy625, 304 and 316 L stainless steel (SS) whilst the backing steel is made of low-cost carbon steel in which Magnesium Mn percentage is over 1% [4]. A lined pipe is sufficiently a good option for reasonable cost and high corrosion resistance for pipeline design life. However, due to the use of corrosion resistant liner, the thickness of C-Mn pipe can be significantly reduced. In this case, the lined pipe can be damaged either during construction process, or by third party interference such as dropped object or trawl gear impact of fishing boats. If the pipeline with liner is dented due to an impact, it could cause loss of pressure containment, hydrocarbon leak, and catastrophic consequences. Therefore, if the dent size exceeds the allowable size, it must be repaired.

Pipeline and Hazard Materials Safety Administration PHMSA [5] reported that the external interference was responsible for 27% of failures in liquid transmission pipelines and for 31% of failures on natural gas pipelines in the USA. Furthermore, the failure resulted from third party damage could be either immediate or not immediate. In the latter case, generated cracks could grow and cause pipe fatigue failure in service after short time of the first impact because of the aforementioned cyclic nature of loading. Thus, dented pipes require more monitoring and the high localized stresses in the dented zone need to be evaluated.

In the last century, great effort has been devoted to the analytically determination of stresses in dented pipes. Durkin [6] proposed an analytical model to determine the remaining strength of dented pipe subjected to axial loads and moments. The predicted results of ultimate strength were within 5% compared with FE results carried out by Shell Research. The stress concentration, based on an

* Corresponding author.
*E-mail addresses:* obeid.obeid@brunel.ac.uk (O. Obeid), giulio.alfano@brunel.ac.uk (G. Alfano), hamid.bahai@brunel.ac.uk (H. Bahai), hussam.jouhara@brunel.ac.uk (H. Jouhara).

https://doi.org/10.1016/j.engfailanal.2018.02.013
Received 16 December 2017; Received in revised form 26 January 2018; Accepted 22 February 2018
Available online 25 February 2018
1350-6307/ © 2018 Elsevier Ltd. All rights reserved.

**Nomenclature**

| | |
|---|---|
| $d$ | Dent depth (mm) |
| $D$ | Pipe outer diameter (mm) |
| $D_{carbon}$ | Outer diameter of undeformed C-Mn pipe (mm) |
| $D_{stainless}$ | Outer diameter of undeformed AISI304 pipe (mm) |
| $E_{TOT}$ | Total energy (W) |
| $E_I$ | Internal energy (W) |
| $E_{VD}$ | Viscous dissipation energy (W) |
| $E_{KE}$ | Kinetic energy (W) |
| $E_{FD}$ | Frictional dissipation energy (W) |
| $E_W$ | Work energy (W) |
| $E_{SE}$ | Recoverable (elastic) strain energy (W) |
| $E_{PD}$ | Plastic dissipation energy (W) |
| $E_{IW}$ | Internal work energy (W) |
| $E_{EW}$ | External work energy (W) |
| $g$ | Acceleration of gravity (m/s$^2$) |
| $H_{carbon}$ | Dent depth of C-Mn pipe (mm) |
| $H_{stainless}$ | Dent depth of AISI304 pipe (mm) |
| I | Height of punched pipe (mm) |
| S, Mises | Von Mises Stress (N) |
| $v$ | Velocity of free drop (m/s) |
| W | Width of punched pipe (mm) |
| $Y$ | strength coefficient |
| BCAST | Brunel Centre for Advanced Solidification Technology |
| EPRG | European Pipeline Research Group |
| PDMA | Pipeline Defect Assessment Manual |
| PHMSA | Pipeline and Hazard Materials Safety Administration |
| TFP | Tight Fit Pipe |
| $\bar{\varepsilon}^p$ | equivalent plastic strain (m/m) |
| $\dot{\bar{\varepsilon}}^p$ | equivalent plastic strain rate (1/s) |

analytical approach in the elastic domain, has been investigated for a dent on a pressurised cylinder by Seng et al. [7]. The maximum concentration stress occurred in the long dent compared with local and short dents. The effects of gouges, dents and weld seams on the fatigue life of pipelines subjected to internal pressure has been addressed in the analytical method developed by Fowler et al. [8]. The dented pipes joined by girth welds had a greater impact on the fatigue life than those joined by longitudinal welds. Furthermore, increasing the gouge depth led to reduce the fatigue life. The maximum stress concentration occurred with the largest dents.

In recent years, the nonlinear finite element code ABAQUS has been often used to numerically simulate the indentation in pipelines. Netto et al. [9] studied the effect on the burst pressure capacity of corroded pipes with different materials and different geometry of corroded zone. The results pointed out that increasing the dent length led to decrease the burst capacity. A new methodology to evaluate the fatigue life behaviour of dented pipes subjected to internal pressure has been examined by Pinheiro and Pasqualino [10]. It was found that strains tangent to the dent periphery were compressive whereas their perpendicular counterparts were tensile. A series of dent and burst tests have been conducted in the work of Allouti et al. [11] to study the effect of dent depth on the internal pressure of the pipelines. The Vickers microhardeness values taken from the dent centre were higher by 30% than those taken from the pipe end. However, one of the most critical problems in lined pipes is the stress/strain behaviour under dynamic impact and it is observed that, to the best of the authors' knowledge, no articles in the literature have addressed the effect of dynamic impact on the lined pipes (compound pipes) using a non-liner numerical explicit approach to account for material (plasticity) and geometric nonlinearities for a dynamic high-speed drop test.

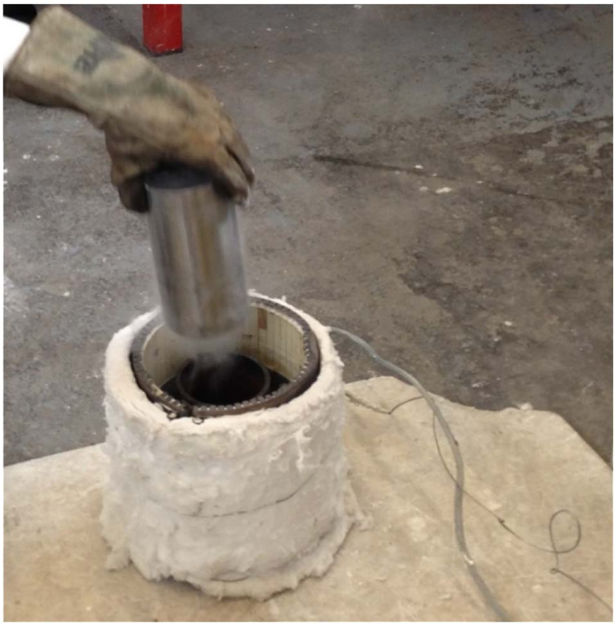

**Fig. 1.** Inserting the liner (AISI304) inside the heated C-Mn pipe.

Download English Version:

https://daneshyari.com/en/article/7167520

Download Persian Version:

https://daneshyari.com/article/7167520

Daneshyari.com