Engineering Failure Analysis 57 (2015) 171–187

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Plastic limit load of Grade 91 steel pipe containing local wall thinning defect at high temperature

Jilin Xue, Changyu Zhou *, Xiaofeng Lu, Xiaochun Yu

School of Mechanical and Power Engineering, Nanjing Tech University, Nanjing 211816, China

ARTICLE INFO

Article history:
Received 13 January 2015
Received in revised form 19 June 2015
Accepted 9 July 2015
Available online 30 July 2015

Keywords:
High temperature
Plastic limit load
Local wall thinning
Creep damage
Tensile strength
Burst pressure

ABSTRACT

This paper aims to predict the plastic limit load of Grade 91 pipe at high temperature by experimental and numerical analysis methods. The elastic–plastic constitutive relation of P91 considering creep damage at high temperature is proposed and the effectiveness is verified by high-temperature instantaneous tensile test after creep of P91 sample. Then, using the elastic–plastic constitutive relation considering creep damage, the plastic limit loads of P91 pipe containing local wall thinning (LWT) defect at high temperature have been calculated by finite element (FE) method and the accuracy is checked by high-temperature burst experiment after creep of T91 pipe containing LWT. Finally, the fracture analysis and metallographic analysis of Grade 91 sample and pipe containing LWT defect are performed. The results show that the elastic–plastic constitutive relation of P91 considering creep damage proposed by this paper can well describe the elastic–plastic behavior of P91 under creep condition and is useful to calculate the plastic limit load of P91 pipe containing LWT. The failures of P91 tensile samples and T91 pipes containing LWT defect are both plastic fracture. This research would provide an optional method for structure integrity analysis of the pipe containing LWT defect at high temperature.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Grade 91 steel was developed in the 1970s by Oak Ridge National Laboratory (ORNL) in the USA as a modified 9Cr1Mo steel. The modifications included the additions of Vanadium, Niobium, Nitrogen and a low Carbon content to provide excellent long term high-temperature strength. The main application is tubing and piping for power plants.

High temperature corrosion/erosion, mechanical damage (such as scratch and impact), crack ground and repaired process may induce LWT defect [1,2]. The existence of LWT defect causes stress redistribution of pipes, reduces load carrying capability of pipes and increases failure possibility of pipes at elevated temperature in service.

In the past years, a lot of researches about pipe containing LWT defect have been conducted. Under room temperature the researches about pipes containing LWT defect focus on the stress analysis [3–7], limit load [8–14], fracture behavior [15–20], safety assessment [21] and fatigue behavior [22,23]. The different pipe types (straight pipe [9,10], elbow pipe [8,11,12] and tee pipe [20]), different load types (internal pressure [4,8], bending load [10,17] and combined load [7,13,14]) and different defect numbers (single LWT [3–5,9,10] and multiple LWT [21]) are considered by different research methods (FE numerical simulation [3,7,12] and experimental method [8,9,17]). Many meaningful results have been obtained. Based on the research achievements, many countries develop their national standards [24–26].

* Corresponding author.
E-mail address: changyu_zhou@163.com (C. Zhou).

http://dx.doi.org/10.1016/j.engfailanal.2015.07.010
1350-6307/© 2015 Elsevier Ltd. All rights reserved.

Nomenclature

t	creep time, h
t_r	creep rupture time, h
$\varepsilon^e(\sigma)$	elastic strain
$\varepsilon^p(\sigma)$	plastic strain
$\varepsilon^c(\sigma, t)$	creep strain
$\varepsilon^t(\sigma, t)$	total strain
E, K, m	material constants
H, I, J, M, R, Q	material constants
$\overline{D}$	creep damage equivalent
D	creep damage
D_{cr}	critical damage value
σ_b	tensile strength, MPa
σ_b'	modified tensile strength, MPa
σ_r	creep rupture stress, MPa
$A_0, A_1, A_2, A_3, A_4, C$	material constants
$a_0, a_1, a_2, a_3, a_4, T_a, \lg t_a$	material constants
B, n, A, ν, ϕ, g	material constants
σ	stress,, MPa
$LMP(\sigma)$	L–M parameter, ksi
$T_{emp\text{-}1}$	temperature, F
$P_{M\text{-}H}(\sigma)$	M–H parameter, MPa
$T_{emp\text{-}2}$	temperature, K
ε_{ij}^c	creep strain tensor
s_{ij}	stress tensor
σ_e	equivalent stress, MPa
R_o	outside radius, mm
R_i	inside radius, mm
T	thickness of the pipe
θ	half angle of LWT
d	depth of LWT, mm
L	half length of LWT, mm
S	half length of pipe, mm
P	internal pressure, MPa
P_e	axial load

Many cases showed that significant loss of engineering and even human's lives was threatened by failure at high temperature [27–29]. Under high temperature the researches on pipes with defect were mainly concerned with crack problems [30,31]. But the research on pipes containing LWT defect is not enough, which only focus on the stress analysis [32–35] and ultimate creep load [36]. So, determining the load carrying capability of pipes in service accurately is very important, especially for the pipes at high temperature in power industry and nuclear power plant.

The limit load of pipe at high temperature is different from that at room temperature. There are two meanings for the limit load at high temperature. The failure mode is different for two cases. If the last failure mode is creep failure, the load under this condition is defined as creep limit load. Creep limit load at high temperature is related to creep time. If the last failure mode is plastic failure, the load under this condition is defined as plastic limit load. The failure mode under this situation is creep damage accumulation at beginning and plastic failure at last. Plastic limit load at high temperature reflects the plastic collapse of pipe under high temperature. Similar to creep limit load, plastic limit load at high temperature is also related to creep time and stress state. In other words, plastic limit load at high temperature is related to creep damage during creep time. So, exploring the load carrying capability of high temperature pipe is very important.

This paper focuses on the research of plastic limit load of pipe containing LWT defect at high temperature. According to high-temperature instantaneous tensile test after creep of P91 sample, the elastic–plastic constitutive relation of P91 considering creep damage at high temperature is obtained. Then, using the material property of elastic–plastic constitutive relation of P91 considering creep damage, the plastic limit loads of P91 pipe containing LWT defect at high temperature have been calculated by FE method. At the same time, high-temperature burst experiment after creep of T91 pipe containing LWT defect is conducted to verify the accuracy of plastic limit load calculation results by FE method. At last, the failure analysis of P91 sample and pipe containing LWT defect is performed.

Download English Version:

https://daneshyari.com/en/article/7168177

Download Persian Version:

https://daneshyari.com/article/7168177

Daneshyari.com