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The Assessment of the Probabilistic Burst of Honed Steel Pipes Based on Elastic Plastic Behavior

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Abstract

The paper aims to assess the elastic-plastic behaviour of the honed pipes made of steel type E355 subjected to cyclic interior pressure using experimental methods and numerical analysis. In every industry domain, the pipes with thin or thick walls subjected to internal pressure are used. Regardless of the material they are used, the pipes are stressed on axial and circumferential directions, in time. Being subjected to variations of pressure or increasing of pressure over the allowable limit, the pipes can explode causing many damages. The pipes explosion subjected to internal pressure can be predicted knowing the elastic-plastic behavior of the pipe. Starting from theory of stresses in thin and thick pipes, the paper approaches the elastic - viscous and plastic behavior of the steel pipes subjected to periodical internal pressure by experimental. Besides identifying the rheological behavior of thin and thick pipes experimentally tested, the state of stresses and strains were analyzed by numerical method. The behavior of thick wall pipes differs from that of thin-walled pipes, both in terms of rheological and state of stresses and strains. The paper combines experiment and numerical methods for determining the probabilistic burst of the steel pipe. The samples (thin and thick wall pipes) were subjected to 20 loading cycles at 400 bar: the first 10 cycles of loading and unloading were produced for 60 second/cycle and than the other 10 cycles were produced for 120 second/cycle. The exterior diameter of tested pipes was measured both after 30 seconds of loading and after 30 seconds without pressure. These measurements were repeated for each cycle.

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Keywords: state of stresses and strains; probabilistic burst; fatigue; rheological behaviour; strain rate; finite element method.

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1. Introduction

For transportation of the gas or liquids at the different pressure are used pipes with various diameters and from different materials. The variation and intensity of interior pressure, the wall thickness of pipe and the environment factors influence the axial and radial strains [1, 2, 3]. So, the pipe failure occurs from the inside to the outside, the crack propagating along the pipe. The steel pipes without welding and with small diameters are commonly used in mechanical engineering, automotive, aviation, oil and gas, chemical and petrochemical industry, energy and hydraulics industry [4, 5, 6, 7]. These pipes can be used to build networks, but also for practical applications such as making hydraulic cylinders. Depending on the application where will be used, these pipes may be subject to processing improvements, such as chrome plating, galvanizing, grinding, honing, etc. For example, in order to achieve the hydraulic cylinders, the steel pipes are honed to obtain a resistant surface with low roughness [8, 9, 10]. The periodic verification of the deformations of pipes constitutes a measure to avoid the occurrence of the burst [11 - 15]. The paper examines the strains evolution of pipes subjected to periodical cycles of internal pressure, in order to anticipate their behavior over time. Thus the paper is structured in two chapters: one based on the analysis of stresses and strains by finite element method, and the other based on the experimental tests to determine the rheological behavior of the pipes and the strain rate.

Nomenclature

FEM	Finite Element Method
ℓ	Length [mm]
d_i	Interior diameter [mm]
d_e	Exterior diameter [mm]
β	The ratio between exterior diameter and interior diameter of pipe [-]
σ_c	Admissible yield stress [MPa]
σ_r	Maximum stress [MPa]
ε	Strain [%]
E	Elasticity modulus [MPa]
HV	Vickers hardness [N/mm^2]
$\sigma_{e'}$	The strength for elastic creep cycle [MPa]
$\sigma_{f'}$	The fatigue resistance [MPa]
P	Pressure [N/mm^2] or [MPa] or [bar]
h	The thickness of wall pipe [mm]
σ_{max}	The maximum stress von Mises [MPa]
U_{tot}	The magnitude displacement [mm]

2. Numerical analysis of pipe subjected to internal pressure

2.1. Preprocessing step

The geometric design of tubes with FEM analysis was conducted using SolidWorks software then models were imported into Abaqus software. From the point of view of the thickness of the pipe, two types of pipes were designed: thick-walled and thin-walled. In terms of the strength calculus of tubing pipes are distinguished two cases:

- the case of thin-walled tubes - characterized by $\beta < 1.1$, β being the ratio of the outer diameter and the inner diameter;
- the case of thick-walled pipes - characterized by $\beta > 1.1$.

After imported 3D model in Abaqus, the characteristics of steel E355 were associated (Table 1). Then the boundary conditions (fixed at both ends) and loading (p = 80 *N/mm*^{2}) were applied (Fig. 1).