Level of damage assessment of polypropylene pipes (PPR) subjected to burst pressure tests using experimental damage

Abderrazak Ouardi, Fatima Majid, Mohamed El Ghorba and Abdelilah Hachim

***Abstract*— Polypropylene Random copolymer (PPR) is a thermoplastic material widely used to transport hot and cold water under pressure. In operation, PPR pipes are sometimes subjected to accidental damages that may cause a reduction in residual strength or even a complete fracture of the structure. Hence the need to characterize the behavior of virgin and defective PPR pipes under pressure to develop carefully a maintenance strategy to ensure a minimum cost with the maximum reliability. In this article, a set of real tests of bursting on virgin and notched pipes was conducted to mechanically assess the level of damage reaches and characterize the behavior in PPR pipes. The estimation of the damage degree by the model experimental damage led to identify stages of the evolution of damage.**

I. Introduction

The use of plastics in the piping is well established because of low cost, light weight and excellent performance that can offer comparing to metallic pipes such as iron and copper. Have achieved a high level of penetration in different applications, ranging from water supply to gas distribution networks, from sanitary systems to sewage networks, the use of the plastic material does not cease to continue growing in a consistent manner with a rate of about 5-10% per year [1].

According to product specifications, PPR pipes can be used under a hydrostatic pressure of 20 bars and high temperatures up to 70 ° C continuously for 50 years [2]. Comparing with other polymers for the transport of hot and cold water under pressure, the PPR is the usually used polymer for hot and cold water for residential buildings, commercial complexes, offices and hotels due to its physical, chemical and mechanical performance and especially its low cost [3].

Several researchers have studied the behavior of PPR pipes. Litvinov and Soliman [2] have studied the failure modes and the effect of temperature on the time to failure of PPR pipes under hydrostatic pressure at different temperatures. Furthermore, authors did additional analyses to examine the influence of time and temperature of pressure tests on the intrinsic characteristics of PPR pipes such as crystallinity, melting temperature and the induction time of oxidation ILO) by several techniques, among others, the wide angle X-ray diffraction (WAXD) and differential scanning calorimetry (DSC). Zgoul and Habali [3] evaluated the convenience of two types of thermoplastic pipes to transport domestic hot water and industrial by a comparative study of tubes PPR and PEX in terms of the melting temperature and the mechanical strength (tensile test and under pressure). To do this, the authors used the differential scanning calorimetry (DSC), uni-axial tensile tests and hydrostatic pressure. Geertz et al [4] have put under hydrostatic pressure pipes PPR for 3000 and 10000 hours, the goal was to study the influence of the internal pressure and temperature on the diffusion of the antioxidant (Irganox1010) by means of infrared spectroscopy (IR) and differential scanning calorimetry (DSC).

Abderrazak. Ouardi, Fatima. Majid and Mohamed El Ghorba are with Control and Mechanical Characterization of Materials and Structures Laboratory, National Higher School of Electricity and Mechanics, BP 8118 Oasis, Hassan II University, Casablanca, Morocco. (e-mail: abderrazak.ouardi@yahoo.fr).

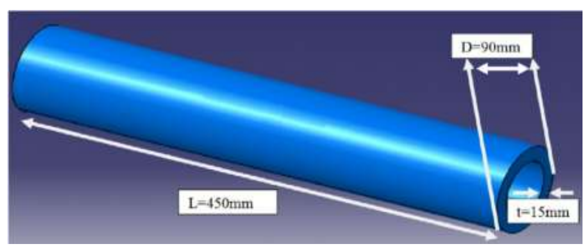
Abdelilah. Hachim is with the Higher Institute of Maritime Studies, Km 7 Road El Jadida, Casablanca, Morocco. (e-mail: abdelilah.hachim@gmail.com).

II. Materials and Methods

A. Geometry and pipes preparation

First, Pipes made of PPR material with an external diameter of 90 mm and 15 mm of thickness were prepared according to ASTM D1599 [5]. Fig 1 shows pipes dimensions:

Figure 1. Pipes dimensions



Eight pipes were notched using a universal milling machine with grooves of 6 mm width, lengths of 100 mm and depths ranging from 2.42 to 14.5 mm. The fraction of β life is defined as the ratio of the depth of the notch (a) to the total depth of the tube (t). The goal is to study the effect of the notch on the strength of PPR pipes under pressure. The model of notches is described in Fig 2.

Figure 2. Model of notches used.

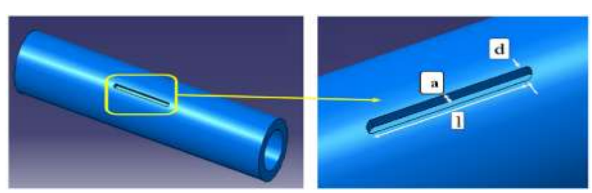


Table 1 shows the dimensions of the performed grooves

TABLE I. PREFORMED GROOVES DIMENSIONS.

Number of pipes	Dimensions		
	d (mm)	*l(mm))*	*β=a/t*
Virgin	6	100	0
1	6	100	0,16
2	6	100	0,32
3	6	100	0,43
4	6	100	0,54
5	6	100	0,71
6	6	100	0,80
7	6	100	0,90
8	6	100	0,97

B. Experimental device.

The experimental device as shown in Fig 3 consists of a tank filled with water to absorb damage of the burst, and a hydraulic pump for pressurizing and displaying the instantaneous pressure within the pipe.

Figure 3. Experimental device.

C. Experimental protocol

In order to prevent leakage giving bad results and to provide a pressure inside the tube, end-caps are attached to the ends of the pipes and strongly clamped by means of bolts; these ends are connected with the hydraulic pump through pressurizing pipes.

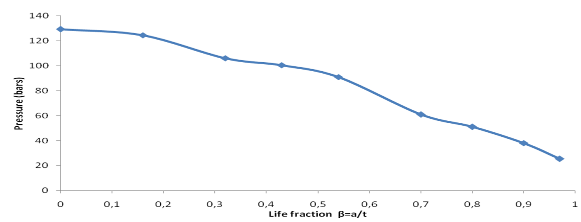
At room temperature, Pipes were immersed in the tank filled with water. Then, a pressure gradient is applied by the hydraulic pump up to burst. The purpose of this test is to determine the evolution of the residual ultimate pressure at failure according to the life fraction β.

III. RESULTS

A. Loss of the strength of notched PPR pipes under pressure

The variation of the ultimate pressure inside the pipes as a function of the fraction β of life is described in Fig 4.

Figure 4. Pressure evolution in function of the life fraction β



Virgin tubes can withstand an ultimate pressure of 129,3 bars. As much as the reduction of the thickness increases, residual ultimate pressures decrease in a gradual manner; this is explained by a loss of the strength of notched PPR pipes under pressure because of the increase in depth of the notch.

B. Experimental damage

Experimental damage Ds allows a quantification of the damage in function of the ultimate, critical residual forces [6]. By analogy, a formulation based on pressure is given by:

$$D_s = \frac{1 - \frac{P_{ur}}{P_u}}{1 - \frac{P_a}{P_u}}$$

With:

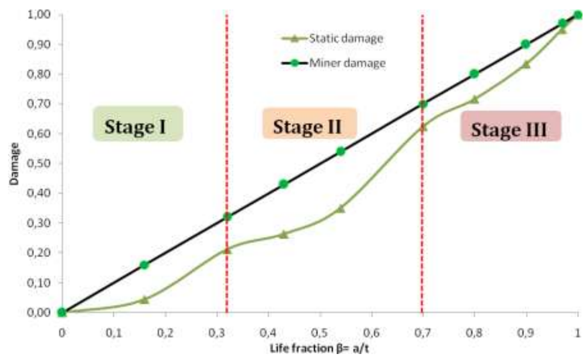
Pu: Ultimate pressure at failure of the virgin pipe

Pur: Residual pressure at failure of notched pipes.

Pa: Critical pressure.

Fig 5 illustrates the variation of the static damage depending on the β fraction of life. We note that the damage Ds gradually increases with the decrease of the effective thickness of the pipe; this is explained by a loss of mechanical properties caused by an increase of the depth of the notch. In fact, the evolution of the damage is divided into three stages. In the first stage (0<β<0,32), the damage starts with zero and grows slowly (initiation of the damage). The second stage (0,32 <β<0,70) is characterized by an increase of the damage with the increase of the notch depth, from β = 0,70 begins the third stage, whose damage accelerates to have a value of 1 for a fully damaged pipe.

Figure 5. Experimental damage variation in function of the life fraction β.



IV. Conclusion

In this article, an investigation of the damage has been provided based on simple burst tests and easy to implement. This study provides both a mechanical characterization of virgin pipes of PPR material, and damage control of pipes made of the same material but with notches as an external longitudinal grooves.

Results show that the notch caused a drop in residual bursting pressures of notched pipes comparing to virgins ones. In addition, the increasing of the depth of notches leads to a drop in the residual pressure of notched pipes themselves.

The interest of using static damage is determining theoretically the three stages of development of damage (initiation, progression, and acceleration of the damage).

For preventive maintenance, the quantification of the damage by Experimental damage helps maintenance department to implement a wise strategy to intervene at the right time in order to minimize the cost of interventions and maximize the reliability of the installation.

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