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Materials Today: Proceedings 4 (2017) 5803–5808

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DAS 2016

The effect of overloading on toughness characteristics

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Abstract

A controlled overloading of some structures containing sharp defects can lead to improvement of the integrity of the structures due to blunting the defect tip, enlarging the plastic zone and giving rise to residual compressive stresses at the defect tip. On the other hand, the overloading of a structure, free of sharp defects, to the plastic region can reduce the integrity of the structure. This is proved by impact and fracture toughness tests of specimens manufactured from sheets which were prestrained to the plastic region. While impact toughness was improved the fracture toughness was found to be reduced.

Selection and/or Peer-review under responsibility of 33rd Danubia Adria Symposium on Advances in Experimental Mechanics.

Keywords: overloading; prestrain; plastic strain; fracture toughness; impact toughness; X46 steel

1. Introduction

An issue that is quite often discussed among operators of high pressure gas pipelines concerns the positive effects of overloading pipelines. Favorable effects of overloading can be observed particularly when there are sharp defects in the pipeline wall and overloading is then performed. For the purposes of industrial practice, it is useful to extend our investigation to the effect of overloading a gas pipeline that has been in operation for a long time on its toughness characteristics, namely notch toughness and fracture toughness, with cracks developed in the pipe wall

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2214-7853
Selection and/or Peer-review under responsibility of 33rd Danubia Adria Symposium on Advances in Experimental Mechanics.

after overloading. Controlled overloading is commonly carried out up to the point when the plastic component of the integral strain reaches a value of $\varepsilon_{pl} = 0.0001$. A gas pipeline composed of seamless pipes Ø 273/7.3 mm made from X46 steel (according to ISO 3183) was used in the investigation. The pipeline had been in operation for about 40 years at a pressure of p = 4 MPa.

2. Preparation of the specimens

The flat sheets for manufacturing the Charpy and CT (compact tension) specimens were made without straightening pipe bands cut from a pipe segment. This was done by successively removing layers of metal by milling in the tangential direction of the curved bands. Three types of bands were manufactured: type T (for tension specimens), type Ch (for Charpy specimens), and type CT (for CT specimens) – see Fig. 1.

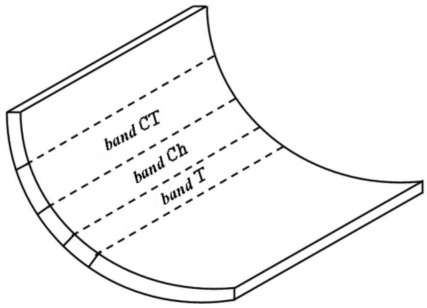

Fig. 1. Sampling of the pipe segment

The Ch-type sheet was divided into two parts: one part remained without overloading, while the other was overloaded to receive a plastic strain of $\varepsilon_{pl} = 0.0007$. The CT-type sheet was divided into three parts – A, B, and C. Part A remained without overloading, part B was overloaded to $\varepsilon_{pl} = 0.0005$, and part C was overloaded to plastic strain $\varepsilon_{pl} = 0.0011$. The reason for overloading two parts of CT sheets (B and C) instead of a single part was the limited height of the working space between the grips of the machine. Because the overloading test was controlled by the total strain ($\varepsilon_t = 0.0022$) for both bands, while the corresponding stress levels were slightly different, the real values of the plastic strain were also different. For illustration, the $\sigma - \varepsilon$ dependence during overloading for sheet CT-B is presented in Fig.2.

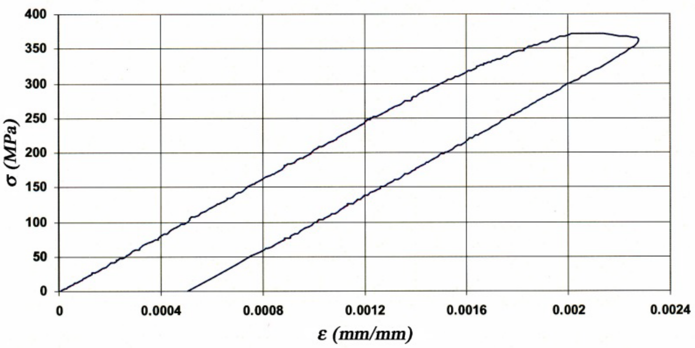

Fig. 2. Dependence $\sigma - \varepsilon$ in overloading the CT-B band

After the sheets had been overloaded, the Charpy and CT specimens were manufactured from the respective sheets. The starting notch and the subsequent crack in specimens lay in the longitudinal direction of the pipe (see Fig. 3).