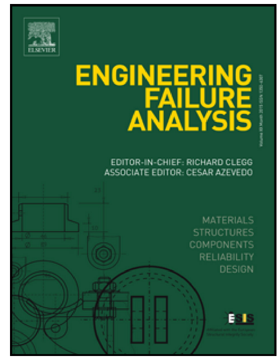

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Analysis and mechanical properties characterization of operated gas main elbow with hydrogen assisted large-scale delamination

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Abstract

The pipe elbows with hydrogen assisted large-scale delamination revealed in 40-years operated lateral pipelines located behind the compressor station were investigated. The crack on the external surface of the pipe elbow above the delamination was observed. The causes of the material degradation were studied by non-destructive testing using ultrasound thickness meter, microstructure observing, hydrostatic pressure testing, and mechanical properties characterization. The degradation degree of the pipe elbow steel was higher than of the straight pipe steel regardless of a section was tensioned or compressed. Basing on the tensile tests carried out on the cylindrical standard smooth and proposed circular notched specimens it was established that the plasticity of the operated steel could be measured correctly only on the specimens with a notch due to localisation of deformation in the cross section. The limitations in using elongation and reduction in area for characterisation of plasticity of the pipe steel with extensive delamination were established. A special short transverse specimen for impact toughness measurement of pipelines steels was designed, fracture plane in which was parallel to the delamination plane. The extremely low KCV values were obtained under designed specimens testing, which correctly characterised brittle fracture resistance of material along structure fibers and a sensitivity of pipe steel to delamination as well. The two stages of in-service degradation of metal, deformation aging and multiple damaging, were analysed, and two substages of the second one were distinguished: dissipated disoriented damaging and damaging oriented in rolling direction.

Keywords: gas pipeline; elbow; delamination; hydrogen; in-service degradation.

1. Introduction

Delamination cracking in pipeline steels is commonly observed, it can be both of metallurgical and operational origin. In the first case such damages are inherent to metallurgical products, while in the second one they are introduced during service under working stresses. Delamination is formed by the plane with relatively weaker texture (so called fiber structure) parallel to the rolling plane within the steel due to the action of any factor that leads to anisotropic microstructure, including: texture, banding, carbide and inclusions particles, inclusion alignment on the rolling plane, intergranular fracture, and anisotropic plastic deformation [1-3]. Hydrogen being accumulated inside the delamination cavity, because of its recombination, creates pressure which eventually leads to a pipeline damage such as was shown in numerous issues reported in [4-8]. As a result of excessive hydrogen pressure, fracture often takes place even in the absence of any external loading (hydrogen induced cracking) [6]. A common feature of delamination cracking in pipelines is that fracture propagates in the circumferential direction, which often results in pipe fracture and its untimely replacement.

Hydrogen induced cracking is typical for oil and gas pipelines, as pipe manufacturing technology involves rolling and consequently lengthening of nonmetallic inclusions and weakening cohesion with matrix. On the other hand, hydrogen charging of a metal from inside the pipe due to electrochemical corrosion [9], leads to molecular hydrogen accumulation in certain trapping sites, e.g. in the formed intergranular defects “inclusion – matrix”, and creation of high pressures in them. The studies [10-12] show that such circumstances promote the formation, evolution and accumulation of microdefects in pipeline steel (so called in-bulk dissipated damaging), deterioration of mechanical

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