Large-Scale Testing Methodology to Measure the Influence of Pressure on Tensile Strain Capacity of a Pipeline

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ABSTRACT

Strain capacity of a welded pipeline is usually characterized using uniaxial tests such as curved wide plate test. However, the difference between the responses of a wide plate test and a pressurized pipe has not been fully established. Six pressurized and un-pressurized full-scale tests with machined flaws have been conducted to determine the influence of pressure on the tensile capacity of a pipeline. Experimental techniques and results showing the effect of pressure on the strain capacity of the pipe and tearing resistance of the flaws are presented. It has been demonstrated that pressure can significantly reduce the measured strain capacity.

KEY WORDS: Pipelines, strain capacity, full-size testing, tearing resistance, effect of pressure.

INTRODUCTION

Pipelines are often operated in regions where large ground deformations are possible. For example, large ground deformations may occur in seismic regions where a pipeline crosses a fault line or in arctic regions where the pipeline is subjected to large upheaval or subsidence ground movements that occur when the ground freezes or thaws.

The strain capacity of a welded pipeline is usually characterized using uniaxial tests such as the tensile wide plate test [Hukle, Horn, Hoyt, and LeBleu, 2005]. It has been shown that the wide plate tests can be used to estimate the strain capacity of a pipe without pressure. However, the differences between the responses of a wide plate test and pressurized pipe have not been fully established.

ExxonMobil has conducted a test program consisting of six pressurized and un-pressurized full-scale tests with machined flaws to determine the influence of pressure on the tensile capacity of a pipeline. This paper describes the experimental techniques and the results of this test program. Results showing the effect of pressure on the strain capacity and tearing resistance are also presented. It has been demonstrated that pressure can significantly reduce the measured strain capacity.

TESTING PROGRAM

The effect of pressure on strain capacity of pipelines was assessed in a testing program consisting of 3 pairs of full size strain capacity tests (6 tests). One specimen of each pair was tested with virtually no internal pressure while the other was tested with internal pressure to generate hoop stresses equal to 80% of the pipe material yield stress. Electro Discharge Machining (EDM) was used to cut notches in each specimen. The first pair of specimens had notches at the pipe material, which ensures uniform tensile properties in the test and simulates an equally matched weld, these specimens will be labeled 0% overmatch, in this paper. The second and third pairs contained notches at the center line of the girth welds. Based on yield strength, the girth weld was 5% stronger than the pipe material for the second pair (5% overmatch) and 20% stronger than the pipe material for the third pair (20% overmatch).

All specimens were axially pulled to failure under strain control, while the following data were digitally recorded: load, overall pipe elongation, localized strains, crack mouth opening displacement, and internal pressure. Additionally, the 5% and 20% overmatch tests were monitored using acoustic emission (AE) and full field strain cameras. Details of the specimen configuration, instrumentation, and testing procedures are given next.

Specimens

The specimens were fabricated using X65 Electric Resistance Welded (ERW) pipes with 325 mm (12.75”) outside diameter (OD) and 14.3 mm (0.562”) wall thickness (WT). EDM notches were placed on the OD of all specimens. All notches were machined 3 mm deep by 50 mm long. Figure 1 shows the EDM notch profile.

The first pair of specimens (0% overmatch) was made of plain pipes (without girth welds) with 10 EDM notches machined in each pipe. The 10 EDM notches were machined at five longitudinal locations along the OD of the pipe with 2 notches placed 180° apart at each location (away from the ERW seam weld). The notches at adjacent locations along the pipe length were staggered 90°. Figure 2 shows the notch placement for the 0% overmatch specimens. The other specimens contained a single