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Characterization of the Stable Tearing During Pipeline Strain Capacity Tests

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ABSTRACT

ExxonMobil has developed a methodology to predict the strain capacity of welded pipelines based on tearing analysis. However it has not been fully established by the industry that accounting for tearing is important for an accurate prediction of strain capacity. To that end ExxonMobil has performed a series of full-scale tests using an unloading compliance technique to measure crack extension. Final flaw sizes are measured on opened fracture surfaces confirming unloading compliance accuracy. Test results show tearing initiation long before the final strain capacity suggesting that not accounting for tearing may lead to unnecessary conservatism.

KEY WORDS: Pipelines, strain capacity, full-size testing, tearing.

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. To design pipelines under these plastic strain demands it is essential to have a strain capacity prediction tool, such that, a pipeline engineer will not have to execute hundreds of tests to qualify pipeline welding procedures.

It has been shown that the strain capacity of a welded pipeline can be predicted using tearing-analysis [Minnaar, Gioielli, Macia, Bardi and Biery, 2007]. Additionally, it has been suggested that the tearing resistances measured in pressurized and un-pressurized pipes are equivalent [Gioielli, Minnaar, Macia and Kan, 2007]. However, there has been debate, across the industry, regarding the need to perform tearing analysis as opposed to the use of a more traditional critical toughness value, such as, critical Crack Tip Opening Displacement ($CTOD_{critical}$), as the failure criteria. One common justification for the $CTOD_{critical}$ criteria is a hypothesis that cracks do not tear until the pipe is strained close to its capacity. To that end ExxonMobil has performed a series of full-scale tests using an unloading compliance technique to measure crack extension. Final flaw sizes are measured on opened fracture surfaces confirming unloading compliance accuracy.

TESTING PROGRAM

The ability of using elastic compliance to measure crack size and tearing history as a function of pipe plastic deformation was assessed. The testing program consisted of two full size strain capacity tests. Specimens were tested with internal pressure to generate hoop stresses equal to 40% and 80% of the pipe material yield stress. Electro Discharge Machining (EDM) was used to cut notches in each specimen.

Both 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. Details of the specimen geometry, configuration, instrumentation, and testing procedures are given next.

Specimens

The specimens were fabricated using seamless X65 pipes with 219 mm (8.625”) outside diameter (OD) and 17.5 mm (0.688”) wall thickness (WT). Two test welds were included in each specimen and the welds were produced using the mechanized gas metal arc process. To improve the consistency of mechanical properties the specimens were welded in the 1G (rolled)position. Yield strength (YS), ultimate tensile strength (UTS), and uniform elongation (EL) for the pipe and weld materials are presented in Table 1. Figure 1 shows the specimen configuration. Note that the distances between test welds and between these welds and the end-cap welds are around 2x and 3x OD, respectively. These distances were checked by finite element analysis (FEA) to ensure the absence of interference between welds.

Table 1. Mechanical properties.

Material	σ_{ys}		σ_{uts}		EL
	MPa	ksi	MPa	ksi	%
Pipe	524	76	621	90	28
Weld	552	80	655	95	32