Welding Engineering for High Strain Pipelines

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ABSTRACT

Pipeline engineering and construction are migrating towards installations in remote and potentially harsh environmental locations. Traditional stress based designs (strain demand < 0.5%) are typically inadequate or improper for regions with seismic activity, soil movements, liquefaction, and arctic regions with potential frost heave, thaw settlement, and ice scour. This paper reviews specific design and testing methodologies for the qualification of welding procedures for high strain applications. These methods have been applied in the development and qualification of welding procedures for the construction of pipelines subject to longitudinal tensile strains in excess of 2%. The transition from elastic to plastic design requires considerable effort in terms of qualification and testing requirements. These testing requirements may include the need for full scale pressurized testing for design validation. The cost and effort associated with complex qualification programs provides motivation for the development of analytical tools which can lead to streamlined test programs. The status of such efforts within ExxonMobil will be briefly described.

KEY WORDS: strain-based design, welding, seismic, arctic.

NOMENCLATURE

CTOD Crack tip opening displacement
CVN Charpy V-notch
CWPT Curved wide plate test
DWTT Drop weight tear test
FBE Fusion bonded epoxy
FZ Fusion zone
HAZ Heat affected zone
TMCP Thermo-mechanically controlled processing
TS Tensile Stress
UEI Uniform Elongation
UTS Ultimate tensile stress
YS Yield Stress
Y/T Yield to tensile ratio

INTRODUCTION

In response to increasing world energy demand, the petroleum industry has increasingly moved to regions of the world previously undeveloped due to challenging environmental concerns. These regions include remote seismically active zones and arctic climates. The large soil displacements and liquefaction associated with seismic activity often lead to strains within pipeline structures in excess of 0.5%. Similar large soil displacements are found in areas of discontinuous permafrost, where pipeline temperature can cause either frost heave or settlement due to local conditions. In these cases, a pipeline design that can account for a discrete amount of permanent pipe deformation is required.

Previous ExxonMobil experience has relied on significant weld metal yield strength overmatch to ensure deformation within the pipe body as opposed to strain localization in the weld metal (Hukle, Lillig, Newbury, Dwyer, and Horn, 2007). To qualify these pipe and weld materials, a significant amount of testing was required to verify system performance. However, it becomes increasingly difficult to provide overmatch with increasing linepipe strength grade. This work details a current approach based on previous efforts to qualify welding procedures and pipe material requirements for such high-strain applications.

THE PIPELINE AS A MATERIALS SYSTEM

For high-strain applications, it is important to view the pipeline as an integrated system composed of weldment (weld metal and HAZ) and pipe material. The weldment and pipe material must work in tandem to accommodate the strain demand placed on the system as a whole. This paper is subdivided into separate discussions covering the pipe materials, weldments, and weld procedure qualification, however it is important to keep in mind that all are part of the larger system.