ABSTRACT

The analytical basis of the ExxonMobil tangency-based modelling approach for tensile strain capacity prediction is a large set (thousands) of parametric finite element analyses (FEA) used to simulate the behavior of defects in pipeline girth welds. The model accounts for pipe and weld physical properties, pipe and defect geometry including weld joint misalignment, and internal pipe pressure. The FEA approach simulates crack growth using a series of models having stationary cracks of increasing depth. Maximum load carrying (strain) capacity is predicted to occur when the applied loads create a crack growth driving force larger than can be supported by the structure’s fracture resistance. By comparison to over 100 full-scale tests, it has been determined that stationary crack modeling can, in some scenarios, over predict crack growth driving force which, in turn, can create an under prediction of strain capacity. This under prediction appears to be caused by limitations in the stationary crack approach’s ability to account for all of the energy absorbed by a growing crack (tearing) including the associated spread of plasticity in the vicinity of the defect. This outcome indicates that model calibration using full-scale tests is essential. This paper provides an explanation of the limitations of a stationary crack approach for strain capacity prediction and it provides recent comparisons of model predictions to full-scale tests. Additionally, a discussion is provided regarding steps being taken to develop an improved strain capacity prediction modelling technology using an FEA approach based on damage mechanics.

KEY WORDS: Pipelines; strain-based design; tensile strain capacity; ductile tearing; engineering critical assessment, girth weld defects; damage mechanics.

INTRODUCTION

From the late 1990’s to the present, ExxonMobil has designed and/or installed about one dozen strain-based design (SBD) pipelines. The pipe grades range from X60 to X80 and the diameters range from 8” to 52”. Tensile strain demands of 3% and beyond have been addressed [Noecker, 2014]. To prepare for and assist these SBD projects, research has been conducted on many topics including tensile strain capacity (TSC) prediction and engineering critical assessment (ECA) procedures. Equations for tensile strain capacity prediction have been published along with strain-based ECA (SBeca) procedures (Fairchild, 2012). Considerable effort has been devoted to the validation of the capacity prediction equations. This effort is warranted because TSC depends on a large number of variables and it is prudent to only use the equations within variable ranges that have been validated using full-scale tests (FSTs). While existing technology is practical and available for use, a desire to expand its range of applicability exists. Work to retrospectively examine FST data and to apply advanced computational fracture mechanics modeling has been conducted to explore the performance of the existing TSC prediction model. The current paper will explain recent work that has improved understanding of some limitations of the existing model. It has been determined that the model basis, namely stationary crack modeling and the tangency approach, often produces an over prediction of crack growth driving force and this, in turn, leads to an under prediction (conservative) of TSC. Therefore, while the existing TSC prediction equations have been calibrated to work well within the defined use limits, they may have reduced accuracy outside of these limits. This paper will describe (1) the background of the current model, (2) model predictions versus recent FST results, (3) the limitations of the current model, and (4) steps being taken to develop a new model with broadened use limits compared to the stationary crack and tangency approach.

STATIONARY CRACK MODELING AND TANGENCY

This section provides an overview of the TSC model. The details of model development have been published previously and where appropriate, specific references will be given.

The engineering challenge for SBD-related TSC prediction is essentially one that lies in the domain of fracture mechanics. A