ABSTRACT

There is a lack of formalised standards and procedures in the pipeline industry in engineering critical assessment (ECA) for partially over-matching or under-matching girth welds particularly during reel lay installation. This paper provides a finite element based ECA methodology for assessing such girth welds during reeling. The crack driving force is derived from 3D finite element fracture models. The crack tip blunting and ductile tearing are explicitly distinguished. Tearing-fatigue is considered as the crack growth driving mechanism between multiple reeling cycles. The treatment of welding residual stress is also discussed.

KEY WORDS: Partially over-matching; under-matching; reel lay; ECA; finite element; fracture, tearing-fatigue.

INTRODUCTION

Offshore pipeline typically requires an over-matching girth weld, i.e., the yield strength of the girth weld is higher than the surrounding parent pipe material. However, the increasing use of high strength steel has created the need to address the issue of partially over-matching or under-matching of the girth weld where the parent pipe yield strength is lower than the weld metal counterpart. In the full under-matching cases, both the yield strength and tensile strength of the weld can be lower than the parent pipe material. Partially over-matching or under-matching also arises in carbon steel pipes with metallurgically clad or mechanically bonded internal thin layers of corrosion resistant alloy (CRA) materials for sour service applications when they are butt welded using the same or different CRA weld consumables which generally have lower yield strength than the parent pipe. Similarly, such welds can also be found in duplex steel pipelines such as 13% Cr and 25% Cr which have higher yield strengths.

There has been a concern on the fracture integrity of the partially over-matching weld particularly during reel lay installation where installation strain as large as 2.5% in the pipe can be expected. Strain concentration will occur in the weld region with the partially over-matching weld or under-matching conditions. However, there has been a lack of formalised standards in the industry in the engineering critical assessment (ECA) for such welds particularly in a strain based situation. The conventional ECA standards such as BS7910 and DNV OS F101 are not applicable because of

- limitations in the material specific FAD, e.g., level 2B/level 3B FAD typically based on the parent stress-strain curve which is not capable of describing the cross-over of stress-strain curves between base and weld material

and

- in-adequacy of the reference stress solution (or limit load solution) in a strain based situation which is based on the assumption of a homogeneous pipe conservatively representing both the parent and the weld material.

This paper intends to provide an overall ECA methodology for assessing partially over-matching or under-matching welds during reeling. The methodology, based on 3D Finite Element (FE) has been successfully applied to several projects of industry-wide significance, with partially over-matching welds in offshore pipelines.

In the proposed approach, the crack driving force (CDF) shall be derived from 3D FE models which take into account the pipe containing defects. One feature of the ECA method is to separate the crack tip blunting and ductile tearing so that the crack tip blunting is not taken into account as part of the tearing, therefore effectively reducing the level of conservatism. Tearing-fatigue is considered as the mechanism for driving the crack growth between multiple reeling cycles. The tearing limit can be determined by the tangency criteria between crack driving force and the crack resistance curve (R-curve). The treatment of welding residual stress during reeling is also discussed. Validations of the ECA methodology are provided.