Evaluation of Tensile Strain Capacity for Pipelines Using Strain-Based Design

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ABSTRACT

The strain capacity of tensile deformation of pipeline is evaluated by the strain-based design using standards and numerical methods in this study. We calculate the allowable tensile strain according to the given geometries and flaws of the pipeline by strain-based design rules given in DNV-OS-F101 and CSA-Z662. They are compared with the tensile strain capacity by classical crack band model using commercial software of ABAQUS. We propose the fracture toughness (crack tip opening displacement (CTOD))-crack growth-strain chart for evaluating the strain capacity for given fracture toughness. In addition, they are also compared with the chart by the recently developed extended finite element method (XFEM) which shows better resolution than classical crack band model.

KEY WORDS: tensile strain capacity; pipeline; strain-based design; classical crack band model; CTOD-crack growth-strain; extended finite element method

INTRODUCTION

Pipeline construction in the deep water is subjected to non-negligible deformation due to the construction method and the geography of the seabed. To accommodate such conditions, high performance steels with high-strength and high-ductility are often used for the pipelines. The classical stress-based design concepts cannot take advantage of the use of high performance steels because the maximum stress should always be limited below the yield strength. The strain-based design was developed relatively recently, and it is able to handle the ductility of steel during design procedure. It is necessary to investigate proper strain limits and conditions for strain-based design.

DNV-OS-F101 and CSA-Z662 are well-known standards for introducing the newly developed strain-based design in the form of the limit state design. They introduced several limit states such as buckling, fatigue, rupture, and ovalisation limit states for strain-based design. In the case of compressive behavior of the pipeline like buckling, it can be considered using standards and finite element model with different types of imperfections obtained from numerous previous works. On the other hand, the tensile behavior of the pipeline like rupture is difficult to control. Therefore, we summarize the methods for evaluating tensile strain capacity using standards such as DNV-OS-F101 and CSA-Z662.

The finite element method was also used to evaluate the tensile strain capacity of pipeline. The classical crack band model is widely used for this purpose. The extended finite element method (XFEM) which can control the discontinuity of the body such as crack can be used also. In this study, the numerical methods are used to compare with the results obtained from the standards. The extended finite element method for the evaluation of the strain-based tensile capacity is developed.

EVALUATION SUBJECT

Geometries and Flaws of the Pipelines

Since the surface flaw is more dominant than the embedded flaw for the tensile strain capacity of pipelines, the surface flaw of pipeline is only considered in this paper as shown in Fig.1. The limit conditions of the flaw size and the geometries of each standard (DNV-OS-F101 based on BS7910:2005 and CSA-Z662) are different, and they are presented in Table 1.

Figure 1. A planar surface flaw in the pipeline considered in this paper (CSA Z662-11, 2011).