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Comparative study on deformation and mechanical behavior of corroded pipe: Part I—Numerical simulation and experimental investigation under impact load

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Abstract

Experiments and a numerical simulation were conducted to investigate the deformation and impact behavior of a corroded pipe, as corrosion, fatigue, and collision phenomena frequently occur in subsea pipelines. This study focuses on the deformation of the corrosion region and the variation of the geometry of the pipe under impact loading. The experiments for the impact behavior of the corroded pipe were performed using an impact test apparatus to validate the results of the simulation. In addition, during the simulation, material tests were performed, and the results were applied to the simulation. The ABAQUS explicit finite element analysis program was used to perform numerical simulations for the parametric study, as well as experiment scenarios, to investigate the effects of defects under impact loading. In addition, the modified ASME B31.8 code formula was proposed to define the damage range for the dented pipe.

Keywords: Subsea pipeline; Impact test; Corrosion; Pipe deformation; Dynamic response; Finite element analysis

1. Introduction

A study on a submarine oil field was spotlighted as the occasion of a massive oil spill in the Gulf of Mexico. Subsea energy development is a business that several countries and the petrosaurus have their sights set on. It has been called the next frontier and is well under way without opposition from environmentalists despite the environmental contamination it causes. To exploit the deep ocean energy sources, the petrosaurus have performed research and development for a subsea production system. As a result, oil and liquefied natural gas can be extracted from a depth of several kilometers under the sea surface. In addition, it is well known that the installation of subsea pipelines for subsea production systems has rapidly increased in subsea region, particularly, difficult area such as the Arctic Ocean and extremely deep subsea regions.

In 2012, Infield Systems, which is an energy research and analysis firm, estimated that the deep oceans of the world may hold as much as 5 billion barrels of oil and 2 trillion cubic meter of liquefied natural gas, as shown in Fig. 1. They also announced that more than 89,000 km of the subsea pipelines and control lines would be installed from 2012 to 2016 (Infield, 2012). Currently, many companies are preparing to develop techniques and equipment for subsea production systems, such as subsea trees, subsea manifolds, etc.

However, engineers and technicians, who involved in the design, construction, or operation of oil and gas subsea production systems, must consider field safety, as many lives can be lost because of the accidents such as explosions in the development and installation of such systems. Especially in the design and installation of pipelines for subsea production systems, risk factors such as corrosion and collision must be considered. Corrosion and collision change the material

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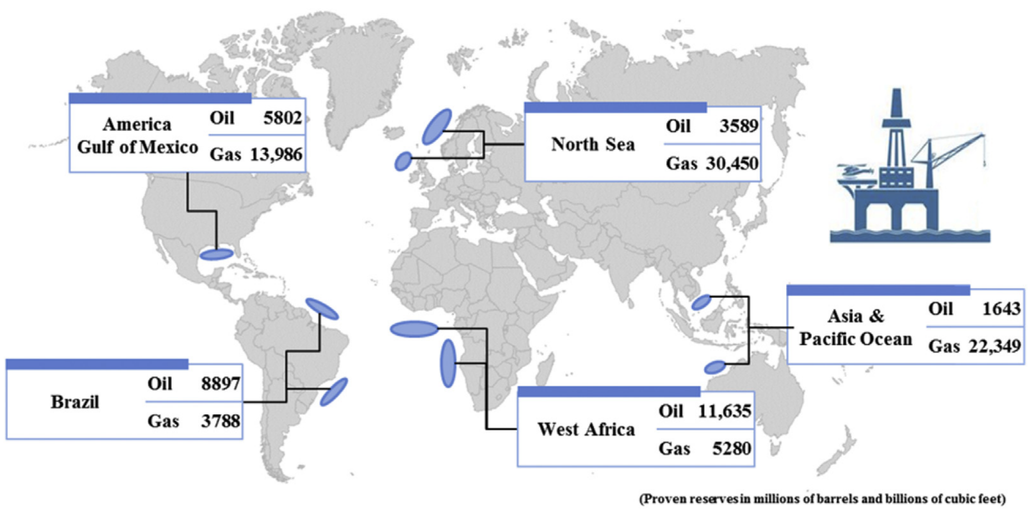

Fig. 1. Proven reserves in the deep-sea oilfield (Infield, 2012).

properties and shape of pipes, and can lead to explosion hazards caused by variations in the pressure due to the reduction of the pipe thickness.

To overcome these problems, studies on the corrosion and the impact behavior of pipes have been performed in the past few decades. Rajani et al. (2000) investigated the variation of the structural capacity of pipes according to the corrosion pit and proposed an assessment method for estimating the remaining service life of pipes. The variation in the capacity of the pipes was estimated using a model based on corrosion pit measurement and the expected corrosion rate. Li and Mahmoodian (2013) presented a method for quantitatively estimating the risk of collapse for a pipe and predicting the endurance time of a pipe using a time-dependent reliability theory. In addition, they defined a failure criterion for collapse reported that the risk of pipe collapse increases with the pipe diameter under external and internal corrosion. Ji et al. (2015) investigated the stress concentration factors of an ovoid shaped corrosion pit and performed simulations on buried pipes for various corrosion patterns. Studies have been conducted on the failure pressures and the fracture shape depending on the shape, number, and dimensions of the corroded areas in the corroded pipe tests and simulations, in addition to studies on the assessment method and failure criterion of corrosion (Qleksiy et al., 2016; Adilson et al., 2016; Al-Owaisi et al., 2016). Furthermore, the impact response of pipes under impact loading has been investigated in many studies. Jones et al. (1992) performed experiments for the lateral impact of fully clamped mild steel pipes. They investigated the impact response from 130 impact tests on mild steel pipes in two drop hammer rigs and various impact velocities. Zeinoddini et al. (2002, 2008) examined the experimental studies and numerical simulation for the impact behavior of the steel pipe according to the specimen squash load. Ng and Shen (2006) conducted impact tests and numerical simulations for the failure of pipe specimens with different internal pressure levels and foundation supports. They presented the dynamic inelastic response and failure prediction of a pipe under impact loading at the mid-span position. To investigate the impact behavior of a pipe, Yang et al. (2009) performed experiments and numerical simulations for a pipe–on–pipe impact event. The energy dissipated in the target pipe and the local indentation zone of the impactor was calculated for different impact conditions.

In addition, studies on the effects of soil–pipe interaction and empty, concrete, cement composite and water-filled pipes have been conducted with regard to the dynamic response of the pipe (Palmer et al., 2006; Bambach et al., 2008; Bambach, 2011; Zeinoddini et al., 2013; Martin et al., 2014; Wang et al., 2014, 2015).

However, collision and corrosion may occur concurrently in subsea pipelines, and it is not large enough to study the deformation or the effects of corrosion for a pipe under impact loading. The main objectives of this study are to investigate the shape and impact behavior of a corroded pipe through impact testing and simulation. Experiments concerning the defects of the pipe specimen were performed, and the results were compared with the results of a nonlinear finite element analysis. In addition, simulations were conducted with scenarios other than the existing scenarios to examine the effects of defects caused by impact loading, and the modified ASME B31.8 (2010) formula was proposed to define the damage range for the dented pipe according to the defect dimension.

This study is part of studies for a failure of the subsea pipelines under an impact load, and the geometries for the corrosion defect were considered to simulate a real condition. In addition, in previous study, a dynamic response of the subsea pipelines according to the foundation under the impact load had been investigated in order to determine the effect of the soil (Ryu et al., 2015). A study to estimate a burst pressure in corroded pipe is also performing as well as the studies for an impact behavior. Therefore, the results of this study will be reflected in a design of the subsea pipelines with the results of the previous study, and a structural integrity assessment for the subsea pipelines will improve based on the results of these studies, as shown in Fig. 2.

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