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Collapse Pressure Prediction and Measurement Methodology of UOE Pipe

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ABSTRACT

In recent years, an increasing number of deepwater pipeline-construction projects has been planned for intercontinental transportation of natural gas. The pipelines to be laid in the deep sea must have adequate collapse resistance to withstand the high external pressure. This paper describes the collapse resistance of the UOE pipe to be used for the deepwater pipeline: The mechanical properties of the UOE pipe are determined, the collapse pressure is estimated, and the appropriate test methods for measuring the collapse resistance are examined. Consequently, this study has established a method for measuring mechanical properties to predict collapse pressure, the correction factors for collapse tests under various conditions, and numerical analysis simulation modeling methods.

INTRODUCTION

Over the past 10 years, the feasibility of laying pipelines on the seabed has been examined mainly in Europe (Hillenbrand, Gräf, Gross-Weege, Knauf and Marewski, 2002). Because in deep water the collapse resistance of the UOE pipe determines the size of the pipe, the collapse strength of the UOE pipe has been studied extensively. Especially useful theses were published during the course of the Oman-India pipeline project, and it was made clear that the circumferential compressive yield strength (C-YS) that exerts an influence on the collapse strength deteriorates. It was also shown that age heat treatment is effective in recovering collapse strength (Stark and McKeehan, 1995; Al-Sharif and Preston, 1996). These studies showed the progress that had been made in test methods using full-size pipes and the collapse strength evaluation technique using finite element analysis (FEA). Kyriakides et al. conducted numerical analyses of the UOE forming process and the collapse model, and made clear that the Bauschinger effect generated during the pipe forming process acts to reduce the collapse strength of the UOE pipe (Kyriakides and Corona, 1991). We, as a pipe manufacturer, conducted this study to establish guidelines for stabilizing the collapse strength of the UOE pipe so we could supply reliable products.

The objectives of this study are to determine the sampling procedure for evaluating the collapse pressure, to identify the effect on the collapse strength of the test using the full-size pipe, and to assess the suitability of a simplified model in FEA.

In the experiment, the C-YS, the residual stress and Young's modulus were studied in the UOE pipe, and the re-yield stress and the heat treatment effect were evaluated for X-65 using the coupon samples. To grasp the relations between these data and the collapse pressure, the collapse tests were performed using the full-size X-65 pipes (660-mm OD × 25.4-mm t). Before testing, the effects of the pipe end condition, L/D (length/diameter) and D/t (diameter/thickness) on the collapse resistance were investigated using a numerical simulation of pipe collapse. In this study, a collapse model, i.e. a continuous numerical analysis model from formation through collapse (consecutive model), was established to identify the shape and residual stress during the forming operation.

For technical points with which to evaluate the collapse strength with the margin of safety based on the above-mentioned experiments and numerical analyses, we determined the sampling positions for measuring the C-YS and proposed correction factors depending on the collapse test conditions using the full-size pipe.

EXPERIMENTAL PROCEDURE

Measurements of the mechanical properties and residual stress in UOE pipe were made for estimating the collapse pressure. Coupon tests were made for optimizing the sampling position for the various pipe sizes. The heat treatment effect was discussed as a positive treatment to improve the collapse resistance. Table 1 gives a summary of the test program.

Sample Pipe

Sample pipes were selected after considering the microstructure of the plate material and the collapse modes described in API Bul 5C3 (1989). The effect of pipe size and microstructure on the C-YS can be evaluated from these combinations. The mechanical properties in Table 1 were measured by the tensile test using the circumferential full thickness specimen. The residual stress was measured for Groups A, B and C. The collapse tests were performed for Groups B and C.

Compressive Yield Test

The C-YS measuring method is the most important for evaluating the pipe's collapse resistance. Fig. 1 illustrates the typical sampling positions of the column samples for Group B. The compressive yield tests were performed using the column samples with 5-mm OD × 10-mm L for Group D, and 6-mm OD × 12-mm L for Groups A through C. The 2 samples were machined at 3 positions in thickness and 4 to 5 positions in circumference, respectively. Also, the column samples were obtained from plate left over from manufactured pipe in order to evaluate the yield stress change.

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KEY WORDS: UOE linepipe, collapse pressure, measurement, prediction, deepwater pipeline.