Mechanical Property Characteristics of Butt-Fusion Joint of High Density Polyethylene Pipe for NPP Safety Class Application

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1. Introduction

In nuclear power plants, lining carbon steel pipes or PCCPs (pre-stressed concrete cylinder pipes) have been widely used for sea water transport systems. However, de-bonding of linings and oxidation of PCCP could make many problems in aged NPPs (nuclear power plants). Recently, several NPPs in United States replaced parts of sea water or raw water system pipes to HDPE (high density polyethylene) pipes, which have outstanding resistance for oxidation and seismic loading.

ASME B&PV code committee developed Code Case N-755[1], which describes rules for the construction of Safety Class 3 polyethylene pressure piping components. Several NPP's in US proposed relief requests in order to apply Code Case N-755. Although US NRC permitted using Code Case N-755 and HDPE materials for Class 3 buried piping, their permission was limited to only 10 years because of several concerns for material performance of HDPE. US NRC's major concerns are about material properties and the quality of fusion zone of HDPE.

In this study, material property tests for HDPE fusion zone are conducted with varying standard fusion procedures.

2. Methods and Results

2.1 Scopes of Consideration

Butt-fusion process of HDPE pipes includes heating, compression and cooling. According to pipe diameter, thickness and fusing procedure, various fusing variables can be applied, in which the most important variables are heating temperatures (the temperature of heating plate) and fusion pressure.

Code Case N-755 presents Standard Fusion Procedure Specification including heating temperature and fusion pressure. However the fusion pressure specified in N-755 is much higher (about 4 times max.) than that of ISO 21307[2], which is another standard for polyethylene pipe butt-fusion developed by international standard organization.

In this experiment, four kinds of fusion procedure were used in order to compare the properties of fusion zone from Code Case N-755 and ISO 21307.

2.2 Material Property Test Methods

ASME Code Case N-755 requires high speed tensile test for smooth tensile specimen, bending test, sharp notch tensile test (long-time) and internal pressure test (long-time) as qualification test for a fusion procedure. ISO 13953[3] requirement includes tensile tests for blunt notch specimens. In recent studies[4~6], some researchers considered various types of qualification tests including the tests mentioned above, blunt notch creep tests and etc.

In this study, high speed tensile test, bending test and sharp notch tensile test (long-time) were performed according to Code Case N-755. Additionally, blunt notch tensile tests and blunt notch creep tests were conducted, in which blunt notch tip radius was optimized to have proper biaxial stress state. Fig.1 shows an example of finite element analysis for notch tip optimization.

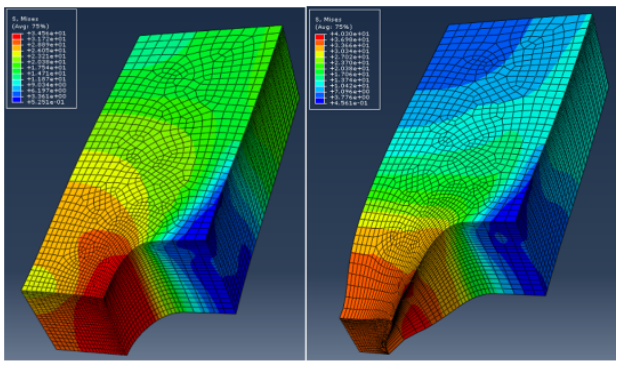

Fig. 1. Finite element analysis for notch tip optimization

2.3 Test Results

Fig.2 shows the high speed tensile test results of smooth specimens. All tested specimens passed the criterion of Code Case N-755 and there was no

difference of ultimate strength among four kinds of fusion procedure.

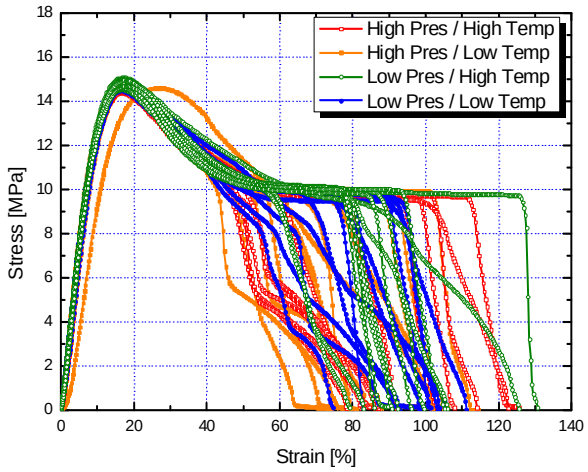

Fig. 2. High speed tensile test results of smooth specimens

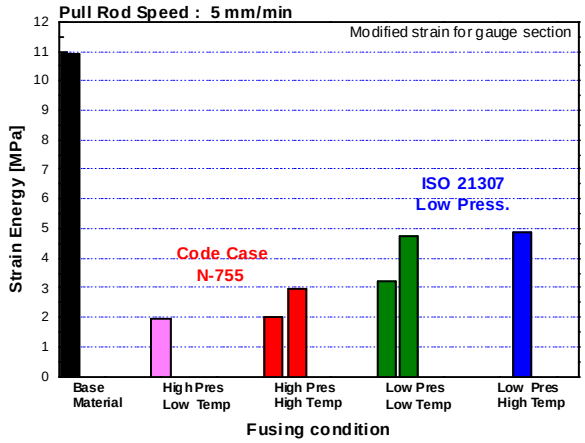

Fig. 3. Rupture strain energy from tensile tests of blunt notched specimens

Fig.3 shows the rupture strain energy measured from tensile tests of blunt notched specimens. In these specimens, the strain energy values of fused material are much smaller than that of base material. The fused material of lower fusion pressure (ISO 21307) shows higher toughness than that of higher fusion pressure (Code Case N-755).

Currently, sharp notched tensile tests (long-time crack growth test, PENT test) and blunt notched creep tests are being conducted in order to compare long-time properties.

3. Conclusions

Mechanical property tests for fused material for HDPE pipes were conducted. Fused material shows lower toughness than base material and fused material of lower fusion pressure shows higher toughness than that of higher fusion pressure.

REFERENCES

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