Evaluation of Mechanical property of HDPE using flat-ended cylindrical indentation

J. Won[1], O. M. Kwon[1], S. Kim[2] and D. Kwon[1*]

[1]Department of Material science and engineering, Seoul National University, Seoul, Republic of Korea
[2]Samsung electronics, Hwaseong, Republic of Korea

[*]Corresponding author: dongilk@snu.ac.kr

1. Introduction

Recently, the importance of polyethylene (PE) piping has been continuously increasing in the heavy chemical industry. polyethylene piping has good chemical resistance and low maintenance cost makes it economical. However, there is little research on the reliability evaluation of polyethylene piping compared to metal piping. the welds of the structurally fragile polyethylene piping are performed by ultrasonic inspection and visual inspection. However, these test methods have limitations on field applications, and are difficult to quantitatively assess. Unlike these test methods, instrumentation indentation test is a non-destructive test method and it is a suitable test method to be used in real industry. In this study, we propose a technique to evaluate the yield strength of HDPE materials using a cylindrical flat-ended indenter.

2. Representative stress-strain based on expanding cavity model

Based on the expanding cavity model [1,2], the representative stress and strain can be expressed using new assumption for flat-ended cylindrical indentation. Fig. 1 shows the schematic diagram of new expanding cavity model.

Using new expanding cavity model, stress field beneath the indenter was analyzed. And plastic constraint factor, which shows the correlation between tension and indentation, is obtained to evaluate tensile yield strength of high density polyethylene. In addition, we estimated the core hardening factor $\left(k\right)$ to define accurate indentation mean pressure [3]. Therefore, we can evaluate representative stress and strain using new expanding cavity model on cylindrical indentation.

3. The effect of friction

Many researches have been studied to investigate friction effect when using cylindrical indentation because of two reasons [4,5]. First, friction of indenter can change load and depth curve. Second, experimental and numerical results were different, when comparing when there is the friction force and when there is no friction. So, the extracting frictional force from original indentation load and depth curve is essential.

Wright et al. expressed total indentation force as compressive force and frictional force [4]:

$$F_{IIT} = F_{Comp.} + F_{Fric.} \tag{1}$$

F_{IIT} is total frictional force. $F_{comp.}$ and $F_{fric.}$ are pure compressive force and pure frictional force. The cylindrical indentation load depth curve can be divided by three stage [5]. First plastic stage is almost linear and second plastic stage is sudden slope change part and third plastic stage is shown as constant slope trend. We can obtain pure compressive load and depth curve using the constant slope of third plastic stage. Eq. (1) can be rewritten by:

$$F_{Comp.} = F_{IIT} - \left.\frac{dF_{Fric.}}{dh}\right|_{thrid-plastic} \cdot h \tag{2}$$

Therefore, we can estimate pure compressive indentation load and depth curve using Eq. (2). And Applying to indentation load and depth curve from cylindrical indentation, the normalized $P_m - h/R$ curve is modified like red line in Fig. 2.

4. Evaluation of tensile yield strength of HDPE

The tensile yield strength of high density polyethylene is evaluated by using plastic constraint factor from new expanding cavity model. Fig. 3 shows tensile yield strength varied with strain rate. And tensile yield strength evaluated from tension and indentation shows a rapid change according to strain rate and saturates to about 30 MPa at strain rate of after 1/s.

As shown in Fig. 3, the trend of graph between tension and indentation agrees well. Finally, we have verified that indentation can be used to evaluate tensile yield strength of HDPE.

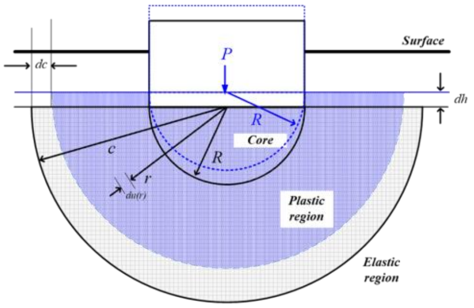

Fig.1 Schematic diagram of expanding cavity model

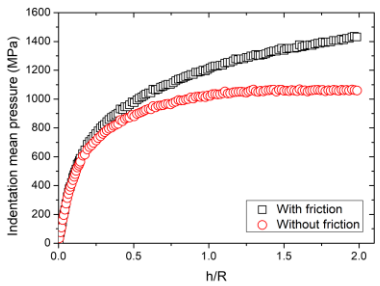

Fig. 2 Comparison of original normalized curve and non-frictional curves

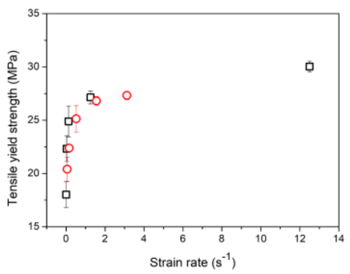

Fig. 3 Tensile yield strength of indentation and tensile test

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