PE 112 HDPE 신소재의 특성 및 응용

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Characteristics and Applications of PE 112 HDPE

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Introduction

Plastic pipe systems have increasingly replaced traditional piping materials like ductile iron, clay and concrete pipes in cold-water distribution, gas distribution and sewage and drainage applications over the last 50 years. Polyethylene (PE) and polypropylene (PP) piping systems have been particularly prominent in this development. Due to its excellent material characteristics, PE has been increasingly used for pressure pipes such as gas and water distribution, and for non-pressure pipes including cable protection. In fact, it may be said that use of PE materials for pipe applications has gained momentum and the demand is expected to increase rapidly. The flexibility of PE has been recognized as one of the most important characteristics as a pipe material. This flexibility provides several advantages over other piping materials, such as easier joints between pipes, quicker installation, low sensitivity to earthquake and excellent potential for relining process. Besides flexibility, the non-corrosiveness and tough, lightweight characteristics of PE further add advantages as a pipe material. In particular, the non-corrosiveness of PE is an important material property in replacing steel pipes, whose corrosiveness is the major contributing factor for pipe failures.

The continuous development of PE materials has extended PE pipe into pressure piping applications. Starting from LDPE (low density PE) PE 32 (MRS 3.2 MPa) some 40 years ago PE materials began to develop and in 1974 MDPE (medium density PE) PE 80 (MRS 8.0 MPa) materials were used for water and gas distribution. A real breakthrough has been the development of PE 100 HDPE in the early 1990's and from then, PE materials for pressure pipe applications entered into a new era. Samsung General Chemicals has recently developed the first PE 112 (MRS 11.2 MPa) material, and they are now developing markets for this new material.

Experiments

A high activity catalyst is required to produce PE 112 HDPE in the two-reactor cascade polymerization process (Fig.1). This catalyst system allows effective production of low molecular weight polymer under high hydrogen concentration and efficient incorporation of comonomer in the high molecular weight fraction in a bimodal process.

Tests of pipe properties include 'Long term hydrostatic strength', 'Resistance to rapid crack propagation(ISO 13477)', 'Resistance to Slow Crack Growth(ISO 13479)', and 'Processibility'.

The MRS (Minimum Required Strength) value of Long term hydrostatic strength is obtained by hydrostatically testing the PE material according to ISO1167, and then calculating σLPL value at 20℃, 50 years according to ISO 9080. Resistance to rapid crack propagation is experimeted according to ISO 13477. Slow crack growth is defined as the growth of a crack through the wall of a pipe over a long period of time. The notch test according to ISO 13479 is generally regarded as a representative test for slow crack growth characteristics of a pipe material. Processibility is tested with RDS.

Results and Discussion

1. Long term hydrostatic strength

The PE material is classified based on the MRS value according to ISO 12162 and shown in the following Table 1. The regression curve of PE 112 according to multiple linear regression analysis is depicted in Fig.2. This new material shows the σLPL value of more than 11.2MPa and no knee-points at 80℃ after 8760 hrs (1 year). According to ISO12162, Samsung PE 112 HDPE is classified as a MRS 11.2 material and is listed in PPI(Plastic Pipe Institute, USA) TR-4 with a minimum required strength (MRS) rating of 11.2 MPa.

2. Resistance to rapid crack propagation

PE 112 HDPE shows an outstanding resistance to rapid crack propagation in the S4 (Small Scale Steady State) test according to ISO13477. In Fig. 3 the crack length is plotted versus the test pressure at 0℃. The critical pressure cannot be detected up to 20 bars, which is the experimental limitation of the S4 test equipment. Consequently, PE 112 HDPE offers a greater safety margin, which enables higher pipe operating pressure and larger pipe sizes.

3. Resistance to Slow Crack Growth

The initiation and growth of a crack depend on the combined effect of internal pressure, residual stress in the pipe, installation stress, ground and traffic loading, etc. Once a crack has initiated, it will grow at a slow rate depending on the driving force and the ability of material to resist crack growth. The brittle failure process due to the slow crack growth may be explained by the molecular disentanglement of tie molecules connecting the crystal lamellae. PE 112 HDPE provides an excellent resistance to slow crack growth because the selectively placed comonomer on the high molecular weight tie molecules makes this disentanglement more difficult. Hence, the crack cannot grow very well. When this test is conducted according to test condition for PE 100, PE 112 shows a failure time over 1,000 hours(Table2.). Also it shows a failure time over 500 hours at a higher testing pressure as a condition for PE 112.

4. Processability

PE 112 HDPE has excellent pipe processability due to the unique design of bimodal molecular weight distribution. It has higher melt strength compared to PE 100 material (Fig.4). Therefore, it can be processed into larger-diameter pipe with much reduced wall sagging problems occurring in the large diameter pipe applications.

5. Core Technology of Samsung PE 112 HDPE

The properties of PE depend on the distribution of short chain branches, molecular weight and molecular weight distribution. Molecular weight and molecular weight distribution play an important role in the rheological properties, and therefore, extrusion processability of the pipe. Molecular weight and short chain branches dominate the mechanical properties of the pipe. For piping applications, both stiffness and stress crack resistance are the most important properties. A balance of these properties is required in the design of the material. Samsung PE 112 HDPE is designed using a proprietary catalyst and molecular architecture technology in a two-reactor cascade process to obtain bimodality and more tie molecules in the high molecular weight fraction. It offers excellent balance between creep properties and slow crack growth resistance and good processability.

Conclusions

PE 112 HDPE, first developed by Samsung General Chemicals, was shown to have superior material properties over PE 100 and PE 80 materials. PE 112 HDPE has the following advantages compared to other PE materials

- *Increased service pressure by 12% to PE 100, 40% to PE 80*
- *Reduced material cost by 24% to PE 80*
- *Better processability*
- *PE 112 is the most likely material to replace steel and ductile iron*

Now we are actively involved in standardization of PE 112 in ISO/TC138/SC 4. It is our hope that our development of PE 112 HDPE helps open a new horizon for PE gas pipe applications and prompts a new material development for expansion of this market.

References

1. Mats Backman Christer Lind, Plastics Pipes XI, p85-95, 2001

2. New generation PE112 for pressure pipe applications: W.Lee, J.Y.Park, S.S. Woo, Dubai Plast Pro 2001

3. The Characteristics of PE112 Class HDPE in pressure pipe application : S.S.Woo, Weon Lee, Ji Yong Park, IUPAC World Congress 2002, the 39th International Symposium on Macromolecules

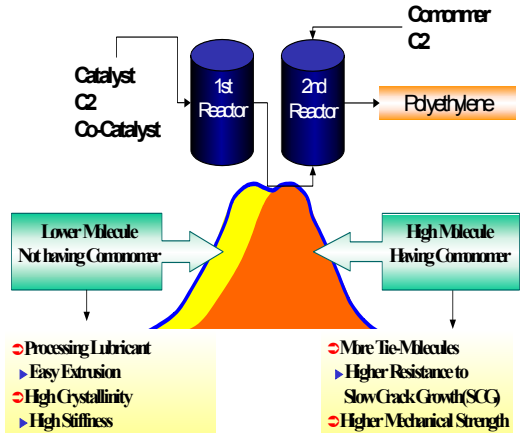


Fig.1 Molecular Architecture Technology

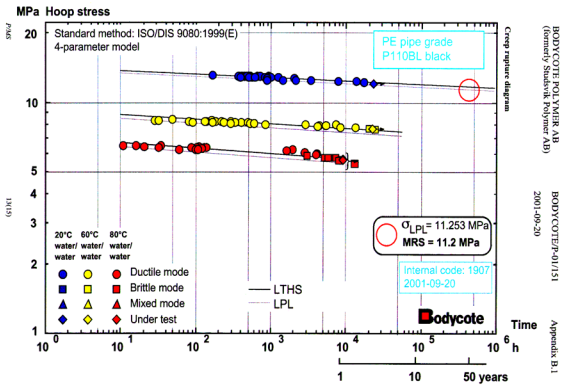
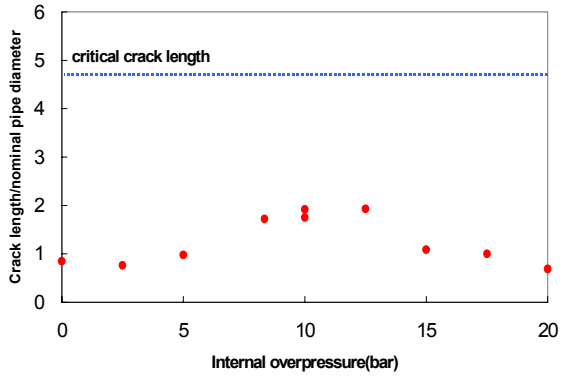


Fig.2 Regression analysis of PE 112



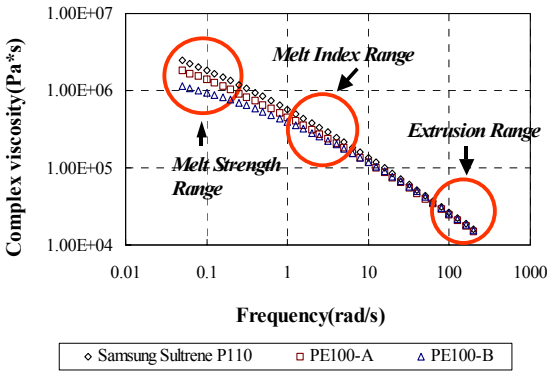


Fig.3 Resistance to Rapid crack propagation of PE 112 Fig.4 Low sagging property of PE 112

Table 1. PE Classification according to ISO12162

Designation	σLPL value(MPa)	MRS Classification
PE112	11.2 ≤ … < 12.5	11.2
PE100	10.0≤ … < 11.2	10
PE80	8.0 ≤ … <10.0	8
PE63	6.3≤ … <8.0	6.3

Table 2. Resistance to Slow crack growth of PE 112

Slow crack resistance	Test Method	Requirement	Samsung P110BL	Test Institute
(80℃,110Φ mm SRD11) at 9.2 bar (for PE 100) at 10.0 bar (for PE 112)	ISO 13479	>165hr >165hr	>1000 hr >500 hr	Bodycote Polymer