Development of Highly-durable Steel Pipe Lining for Seawater

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In nuclear power plants in Japan, seawater is used as the cooling water. The inner surface of piping for circulating the seawater to the cooling system of each facility is lined with polymeric materials such as rubber or polyethylene (PE) to prevent corrosion caused by the seawater. In recent years, cases of degradation caused by aging of the lining materials have occurred, such as cavitation erosion in high flow velocity sections including the narrowed portion of valves and orifices, slurry abrasion, and cracking due to the degradation of physical properties, and demand from power companies, which are the users of the equipment, for the development of a lining material with higher durability and reliability, has been increasing. Therefore, we have developed a highly-durable lining material that has higher cavitation erosion resistance and greater cracking resistance than the existing lining materials in cooperation with Ube-Maruzen Polyethylene Co., Ltd., and started applying the developed lining material to nuclear power plants in Japan as a lining material that can withstand harsh environments.

1. Features

The developed highly-durable steel pipe lining has not only all the advantages of various lining materials that were used separately depending on the use environment in the past, but also significantly higher performance (in particular, the cavitation resistance and cracking resistance) than existing lining materials, and can characteristically be produced using the same manufacturing method and at an equivalent cost as conventional polyethylene steel pipe lining. The developed highly-durable steel pipe lining meets almost all the use requirements of seawater piping in nuclear power plants in Japan, while attaining significant improvement in durability, and allows the unification of lining materials that were used separately depending on the use condition and a reduction of the maintenance and inspection burden of seawater piping.

2. Specifications

The basic physical properties of the developed highly-durable seawater pipe lining material are as noted below (**Table 1**).

The material used as the base of the developed lining material is linear low density polyethylene resin (LLDPE), which has conventionally been used as a general lining material, and the performances of the developed material were improved by adjusting the molecular structure of the resin.

Table 1 Basic physical properties of highly-durable seawater pipe lining material

Item	Test method	Characteristic value*
Tensile stress at break (MPa)	JIS K 7161	24
Tensile strain at break (%)	JIS K 7161	880
Melting point (℃)	JIS K 7121	126
MFR** (grams per ten minutes)	JIS K 7210	2.7
Hardness (HDD)	JIS K 7215	59
Adhesion strength (N/mm)	JWWA K-132	18

* Representative value ** Melt Flow Rate

2.1 Cavitation erosion resistance

For the lining around narrowed sections such as flow control valves and orifices, measures for cavitation erosion need to be taken. **Figure 1** shows the verification results of the cavitation erosion rate of conventionally-used chloroprene rubber/PE resin (low density PE resin (LDPE) and LLDPE) and the developed highly-durable PE implemented using a cavitating jet test method in accordance with ASTM G134-95.

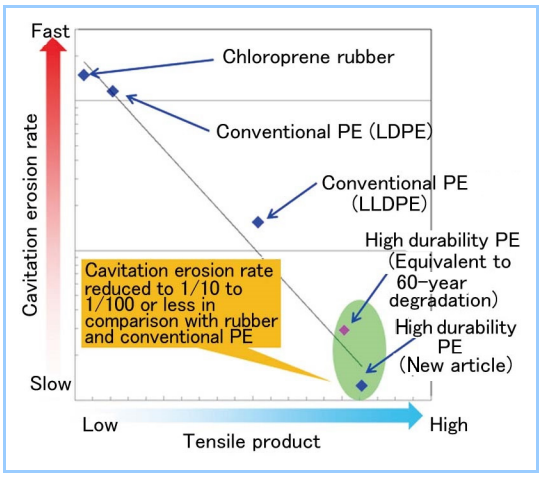

Figure 1 Comparison of cavitation erosion rate of various lining materials

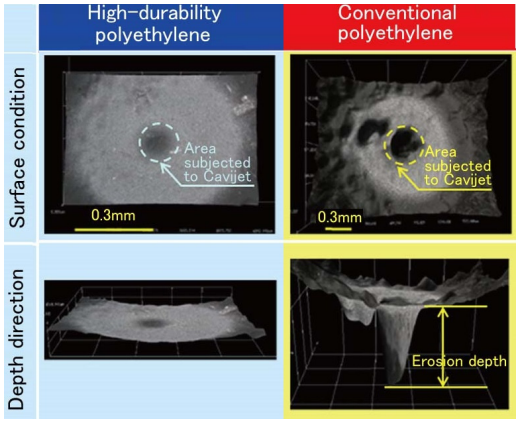

Figure 2 Erosion state of Cavijet irradiation part

Figure 2 shows the external view of the test pieces after the cavitation erosion test. In this cavitation erosion test, multiple kinds of lining materials with different physical property values were made on a trial basis and their cavitation erosion rates were measured. The test results show a strong correlation between the tensile product (equal to the tensile stress multiplied by the tensile strain at break) and the cavitation erosion rate. Through improvement in the tensile product, the cavitation erosion rate was successfully reduced to about 1/100 of that of rubber and about 1/10 of conventional LLDPE. The tensile product is used as an index of the tensile fracture energy of rubber and plastic materials. When the tensile product value is larger, fractures are less likely to occur.

2.2 Cracking resistance

The mechanical properties of polymeric lining materials deteriorate over time resulting in an increased risk of cracking. Therefore, it is important to enhance the initial mechanical properties. The developed highly-durable PE shows less degradation of the initial mechanical properties even after a degradation acceleration test corresponding to 60 years of actual service, has a tensile product about 1.4 times higher than that of brand-new conventional PE (**Figure 3**), and reduces the risk of cracking caused by age degradation.

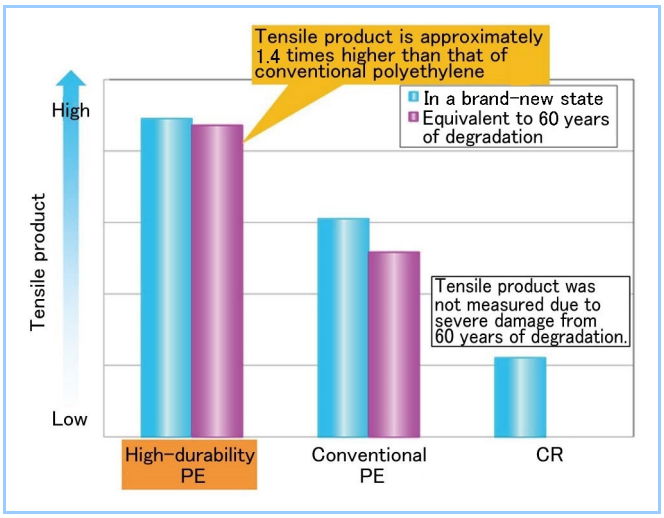

Figure 3 Comparison of tensile product between new and aged materials

2.3 Seawater permeability

When piping is used for seawater for a long-time, the seawater penetrates into the lining material and finally reaches the carbon steel base material, resulting in corrosion, degradation of the adhesion strength and peeling. **Figure 4** shows the water absorptivity measurement results for various lining materials. The water absorptivity of highly-durable PE is about 1/10 of that of chloroprene rubber and about 1/2 of that of conventional PE, and thus the highly-durable PE is effective in reducing the risk of corrosion of the base metal and peeling of the lining.

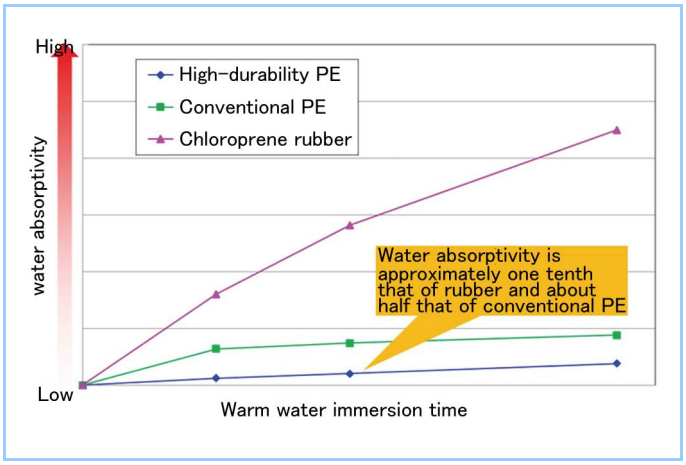

Figure 4 Comparison of water absorptivity of various lining materials

2.4 Slurry erosion resistance

The lining abrasion rate was measured by an abrasion test using high-concentration slurry in order to evaluate the characteristics of lining material abrasion due to sand in seawater (**Figure 5**). The slurry abrasion rate of the developed lining material is equivalent to that of conventional PE and apparently slower than that of chloroprene rubber. Thus, the developed lining material exhibits excellent slurry erosion resistance performance even under the condition of seawater containing sand.

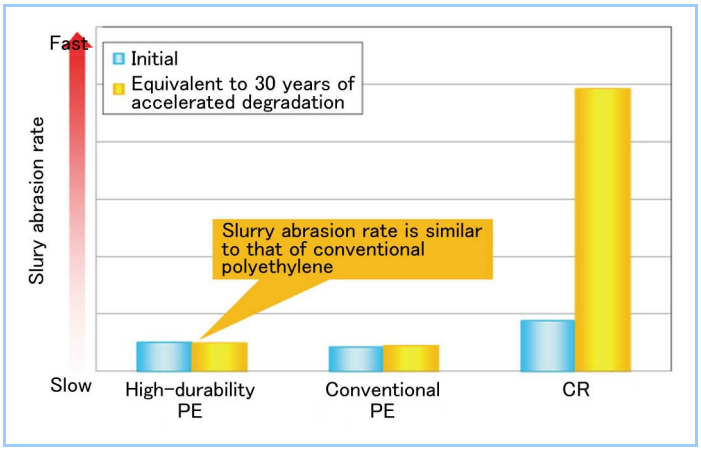

Figure 5 Comparison of slurry abrasion resistance of various lining materials

3. Future prospects

The developed highly-durable steel pipe lining can contribute to improvement in the reliability of seawater cooling systems and a reduction in the user maintenance burden in not only nuclear power plants, but also other industrial plants, and is a product that can be offered to wide range of users.