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Synopsis :
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Polyethylene Coated Large Diameter Pipe* —Its Manufacture and Quality—

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Manufacture of external polyethylene (hereinafter called "PE") coated large diameter pipe was started in April, 1979 in the UOE pipe mill plant of Chiba Works. The main feature of the PE coating is its corrosion prevention of the steel pipe by extruded PE film that spirally wraps around the outer surface of the pipe. The PE coating machine is of the T-die extrusion type, and is one of the largest of its kind in the world in terms of production capacity and product size available, with a pipe diameter of 20 in. to 64 in. and a maximum pipe length of 60 ft.

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1 Introduction

In recent years, a great number of pipelines have been constructed and planned for effectively transporting various kinds of fluids and gas such as crude oil, liquid natural gas and water. These pipelines were constructed with life expectancy of more than 20 years ordinarily and more than 40 years in special cases. Since pipelines are laid on the ground, underground or immersed in water such as on the sea bottom, anticorrosion is one of the highest concerns in view of the environmental conditions under which the pipelines are laid. Anticorrosion techniques have recently made great strides and consequently a remarkable improvement has been made on corrosion resistance of pipelines. The typical anticorrosive method is an electrochemical anticorrosive process, often combined with coating by highly anticorrosive organic compounds.

The essential requirements for anticorrosive coating materials are strength, toughness, adhesion to steel pipe, and ease of repairing possible surface defects of pipe before the pipelaying stage. An excellent property of being usable in a wide temperature range from −45°C to +80°C is required of coating materials in view of the conditions of steel pipe in transport, storage and assembly until pipelines are completely laid and also the operating conditions of pipelines after their completion.

Previously bituminous coating was mainly used as external anticorrosive material for steel pipe, but in recent years, PE coating has come to be frequently used for pipelines in order to meet the above-mentioned requirements. Further, due to the difficult pipeline coating conditions at pipe installation sites, the mill-coated pipe is getting popular.

To meet this demand, Kawasaki Steel Corporation in April, 1979 started up the T-die extrusion type PE-coated pipe manufacturing facilities—capable of manufacturing pipe of 20 in. (508 mm) to 64 in. (1 626 mm) in outside diameter—at the Large Diameter Pipe Mill Plant of Chiba Works.

The above-mentioned facilities are designed to improve adhesion between the steel pipe and anticorrosive PE which was considered disadvantageous in such adhesion. Pellets of adhesive PE (inner layer) and compound PE (outer layer) are melted and extruded

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** Chiba Works
*** Chita Works

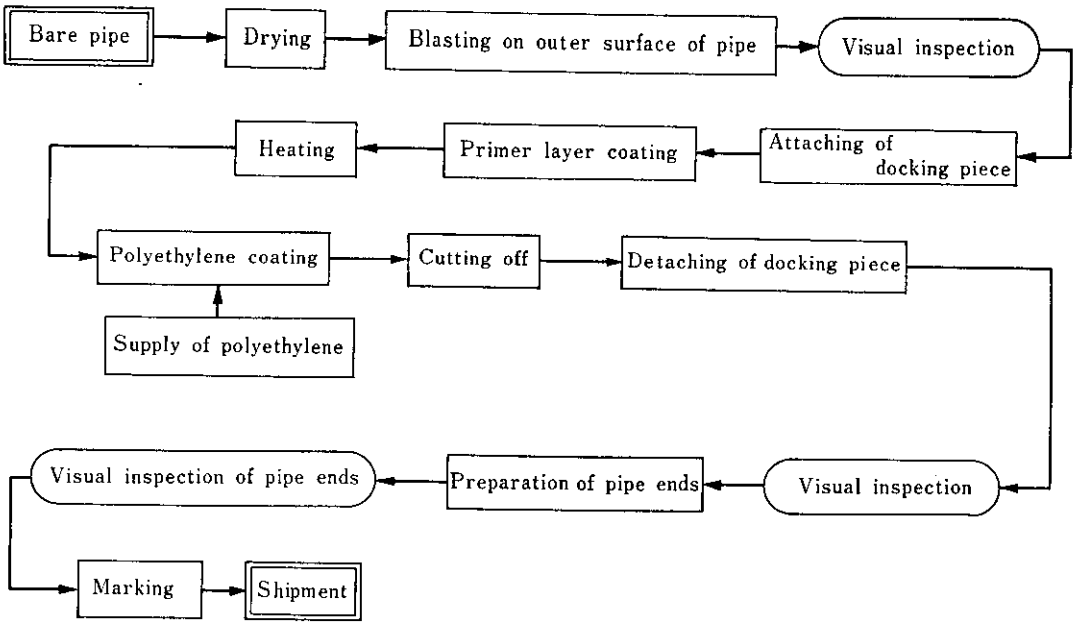

Fig. 1 Manufacturing process of polyethylene coated pipe

into a thin film through a slit of a T-die by screws installed in the extruders. The film is wound around the pipe spirally to coat the pipe after adhesive primer is applied to the steel pipe surface, thereby satisfying all the requirements for external PE coated large diameter pipe. The abovementioned facilities have had a remarkable production record including production of large diameter steel pipe for the U.S.S.R. since their start of operation. This report describes the external PE coated large diameter pipe manufactured by these new facilities.

2 Coating Process and Facilities

Fig. 1 shows the coating process of large diameter PE coated steel pipe.

The coating process is broadly divided into the following 3 steps:

(1) Surface preparation
(2) Coating
(3) Inspection

Major PE coating facilities are outlined below.

2.1 Surface Preparation Facilities

Surface preparation facilities roughly consist of a dryer for improving shot blasting efficiency, a shot blasting machine and a heater.

The shot blasting machine is enclosed in a 3-fold chamber to prevent powder dust from dispersing to the coating line.

For the skid, magnet skids are installed to prevent the pipe surface from being scratched during transportation after shot blasting. The skew rolls are made of hard rubber.

2.2 Coating Facilities

Coating facilities consist of a primer coating machine, PE extruders, a PE supply unit and a device for pressing the extruded PE sheet against the steel pipe (refer to **Table 1**).

PE is extruded into a single sheet having excellent adhesion by combining two extruders, one for adhesive PE and the other for compound PE, with a single T-die.

This sheet is wound around the pipe while being pressed against it by a special pressure roll, and gives extremely high adhesion, assisted by the action of the primer which has been applied beforehand.

Also by selecting the setting method of the wrapping sheet and pressure roll during spiral wrapping, it is possible to wrap various kinds of surfaces ranging from a completely flat surface to an undulating pattern.

2.3 Inspection Facilities

In order to provide sufficient quality assurance to meet users' requirements, careful consideration is given to the facilities for testing and inspecting PE coated pipe by introducing an on-line automatic holiday detector. Specifications and capacities of major inspection facilities are shown in **Table 2**, and the on-line automatic holiday detector is shown in **Photo. 1**.

Table 1 Main equipment for polyethylene coating

Equipment	Maker	Type and capacity
Blasting machine	NIPPON BLAST MACHINE Co.	Rotary type Capacity : 750 kg/min Cleaning width : 900 mm
Induction coil for heating	FUJI ELECTRIC Co., Ltd.	Electric induction heater Capacity : 3 100 kW
Supply of polyethylene	COLOR TRONIC Co.	Method : Polyethylene colour master batch pellet Drying hopper and automatic blending
Polyethylene extruder	TOSHIBA MACHINERY Co.	Number of extruders : 2 sets Capacity of extruder : 170 kg/h & 450 kg/h

Table 2 Test and inspection equipment for polyethylene coating

Equipment	Maker	Number	Type and capacity
Automatic holiday detector	SANKO DENSHI KENKYUSHO Co.	1	Type : High voltage pulse arc type Voltage : 5 - 35 kV Audible warning system : Automatic marking device & buzzer
Peeling test machine	YOSHIDA SEISAKUSHO Co., LTD.	1	Peeling velocity : 0-50 mm/min Peeling load : Max.200 kg
Impact test machine	YOSHIDA SEISAKUSHO Co., LTD.	1	The method consists of a mechanical test in which a tup of fixed weight is dropped through varying heights to produce point impact on the surface of the pipe specimen Diameter of tup nose : 12.7, 16.0 & 25.4 mm Impact resistance : Max. 10 kgf·m
Penetration test apparatus	YOSHIDA SEISAKUSHO Co., LTD.	1	Test temperature : −50°C-150°C Diameter of penetrated pin : 1.8 mm

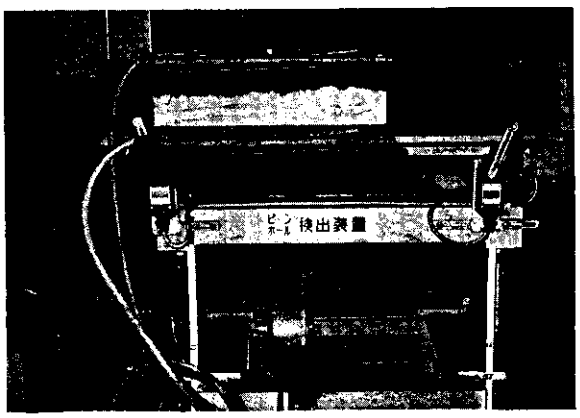

Photo. 1 Automatic holiday detector

3 Quality Characteristics of Large Diameter PE Coated Pipes

In making large diameter PE coated pipe, strict selection is performed of PE and adhesives to be used as pipe coating materials. The basic characteristics of PE resin used for its PE coated pipe and characteristics of such pipe are described below.

3.1 Basic Characteristics of PE Resin

PE is generally classified into high density PE and low density PE. After overall evaluation of various types of PE in respect of characteristics such as anti-corrosiveness, quality stability, strength, and impact resistance, necessary for manufacturing anticorrosive steel pipe for pipeline, it was decided to use high density PE having the characteristics shown in **Table 3**.

Table 3 Properties of coated material

Item	Test method	Units	Properties of coated material
Density	ASTM D 1 505-67	g/cc	0.950-0.955
Melt flow index	ASTM D 1 238-65T	g/10min	0.18-0.22
Softening point	ASTM D 1 525-65T	℃	120-125
Melting point	ASTM D 2 117-64	℃	125-130
Brittleness temperature	ASTM D 746-55T	℃	<-80
Disruptive voltage	ASTM D 149-64	kV/mm	<35
Hardness	ASTM D 2 240-68	Shore D scale	60 - 65
ESCR[2]	ASTM D 1 693	F_{50}, hour	$>1\,000$

Note 1) Final carbon content : 2.5% weight
2) ESCR: Enviromental Stress Cracking Resistance

3.2 Characteristics of PE Coated Pipe

Characteristics of PE coated pipe (effects of temperature on adhesion, impact strength, tensile properties, and hardness) which is wrapped, after application of the hard type primer, with adhesive PE having the characteristics shown in **Table 3** and with excellent compound PE are shown below.

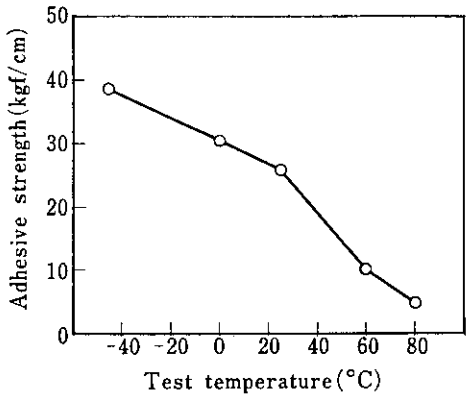

Fig. 2 Effect of test temperature on adhesive strength

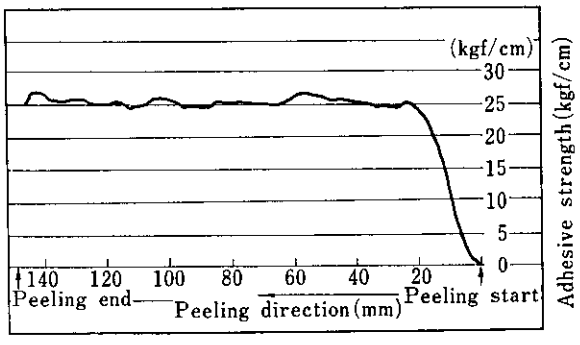

Fig. 3 Typical example of adhesion test result at room temperature

3.2.1 Relationship between adhesive strength and temperature

Due to the use of hard-type primer, the PE coated pipe has excellent adhesion and, particularly even in higher temperatures, exhibits high adhesive strength as shown in **Fig. 2**. Adhesion test was conducted by using the peeling test machine shown in **Table 2**. A typical chart of the results of the test is shown in **Fig. 3**.

3.2.2 Relationship between impact strength and temperature

Fig. 4 shows the relationship between the temperature and impact strength at the time of destruction of the PE coated surface according to the ASTM G14-72 method by using test pieces having base metal taken from a PE coated pipe. As shown in **Fig. 4**, the PE coated pipe has very high impact strength.

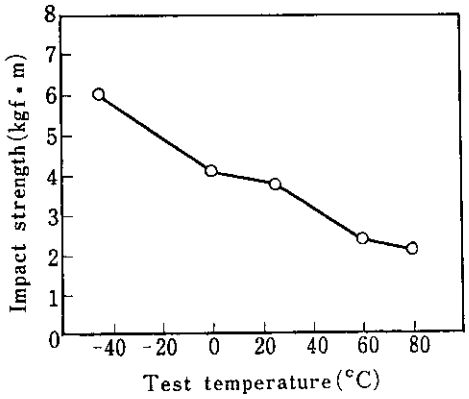

Fig. 4 Effect of test temperature on impact strength

3.2.3 Relationship between tensile properties and temperature

A tensile test was conducted (JIS K6760 method) using a test sample of PE film peeled off from the PE coated pipe. **Fig. 5** shows the test results which indicate satisfactory values at the high temperature region where strength usually drops.

3.2.4 Relationship between hardness and temperature

A penetration test (DIN 30 670 method) was conducted by using test pieces having base metal taken from a PE coated pipe. The relationship between the penetration depth after 24 hr. and the temperature is shown in **Fig. 6**, which indicates highly satisfactory values.

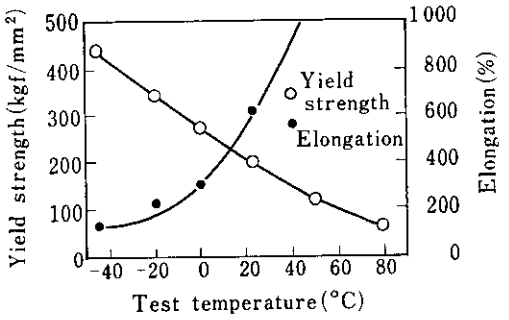

Fig. 5 Effect of test temperature on yield strength and elongation

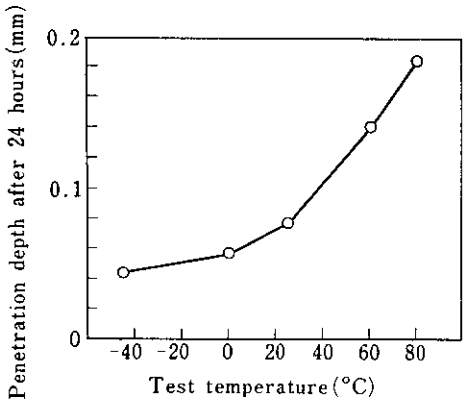

Fig. 6 Effect of test temperature on penetration depth

4 Repairs of Damage to PE Coated Surface

In order to find out a proper procedure for repairing damage to the PE coated surface which may occur during transportation of the PE coated pipe, a simulation experiment was conducted by assuming actual pipeline construction. As a result, it became possible to obtain anticorrosive strength, mechanical strength and adhesive strength sufficient for practical use as anticorrosive coating of the pipeline to be executed at its actual construction site. **Table 4** shows some typical repairing procedures for damage to PE coating.

Table 4 Repairing procedure of damage to polyethylene coating

Portion of damage	Size of damage	Repairing method
Pipe body	Small (Depth ≦ 1 mm)	Remove the damage with grinder or emery paper
	Small (Depth > 1 mm)	Embedding method (Polyethylene stick)
	Middle (Length ≦ 100 mm)	Patch method
	Large (Length ≦ 300 mm)	Apply the anti-corrosion tape with a ½ lap
	Large (Length > 300 mm)	Heat shrinkable tube is centered over damaged area and apply heat the tube with burner
Pipe ends	Small and middle	Anti-corrosion tape
	Large	Heat shrinkable tube

5 Conclusion

The most up-to-date large diameter pipe PE coating facilities installed at the Large Diameter Pipe Mill Plant of Chiba Works have been operating smoothly since their start of operation for manufacturing anticorrosive coated pipe for pipelines.

These facilities are the largest in the world in terms of production capacity and product size available and, moreover, the products show excellent characteristics demonstrating a wide operating temperature range of −45°C to +80°C. PE coated pipe products manufactured by Kawasaki Steel have neat external appearance as shown in **Photo. 2**. Previously, these types of products were easily susceptible to surface scratches, but this drawback has now been corrected to a great extent.

Through the growing records of line pipe manufac-

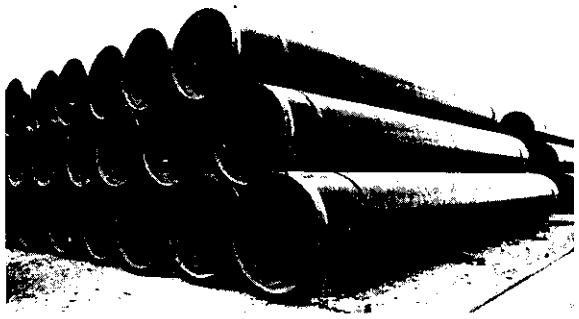

Photo. 2 Polyethylene coated large diameter pipe

ture, Kawasaki Steel desires to contribute to the construction of highly reliable pipelines, while developing yet new applications of large diameter PE coated steel pipe by utilizing their many excellent features.

Finally the authors would like to express their sincere appreciation to various coating material makers who kindly supplied many basic physical property data of PE and who enthusiastically participated in discussions during the course of compiling this report.