NAME :YUSUKE IKEDA
COUNTRY : JAPAN
REGISTRATION NUMBER : 7719

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Development and research of the XLPE cable laid in HPFF steel pipe

1. Introduction

While the number of aged pipe type oil-filled (HPFF) cables is increasing, it is difficult to manufacture new HPFF cables and pumping plants and maintain technology in Japan. In addition, if an accident occurs on the HPFF cable, there is a risk of environmental pollution and fire due to oil leakage, so it will be necessary to replace them with XLPE cables in the future.

When replacing HPFF cables with XLPE cables, by re-utilizing the existing HPFF steel pipe on direct buried lay type, it is possible to reduce the construction cost of new ducts and significantly shorten the construction period. Therefore, we have developed the XLPE cable that can be laid inside a HPFF steel pipe (hereinafter referred to as the XLPE cable laid in HPFF steel pipe). In addition, we examined measures against thermal contraction and expansion and the HPFF cable removal method, which were issues. This study is scheduled to be completed in 2023.

2. HPFF Pulling Method System

From the viewpoint of prevention of insulated oil splashing, we have been developing a system in which cable extraction, cutting, cleaning, and packing can be performed in a manhole, and the cable can be carried out to the ground for removal. However, in the cable cutting process, there had been an issue in speeding up the process, namely the remaining of skid wire, which is unique to HPFF. It became possible to adopt a device that can cut the cable hydraulically by improving the structure of the cutting blade. As a result, we are now promoting research and development in the direction of adopting a method in which the cable is pulled out in the manhole, guided to the ground, cut, and packed in the truck.

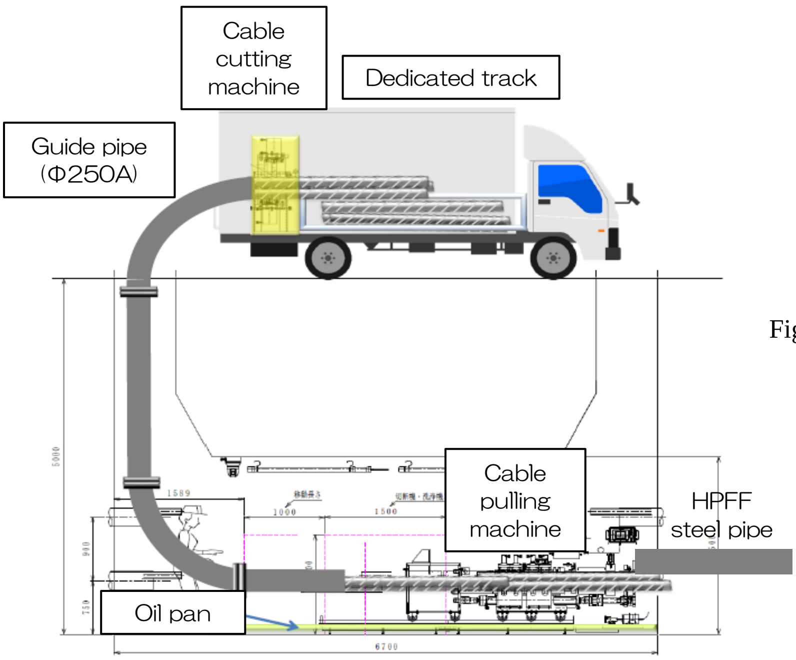


Fig 1: Schematic diagram of the HPFF pulling method system

Fig 2. Hydraulic cable cutting machine

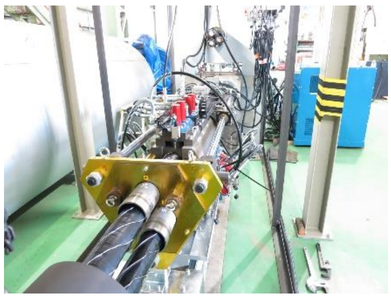


Fig 3. 3-phase simultaneous cable pulling machine

3. Method of cleaning inside steel pipes

The need to remove and clean the insulating oil in steel pipes without affecting the environment led us to examine methods for cleaning the inside of steel pipes.

Tests were conducted on insulating oil cleaning inside steel pipes using the blade pigging method and the water jetting method. The same test method was used to check residual oil in steel pipes when only the blade pig was inserted into the residual oil pipe and when the water jet was inserted additionally.

As a result, cleaning effect at a level that does not affect the environment was confirmed for both methods although negligibly small amount of oil and oil + water were remained by the blade pigging method and the water jetting method respectively, on the collar and the surface of the steel pipe.

Table 1. Comparison of cleaning methods

Method	Purpose	Result
Blade pig	Identifying the best cleaning method	Two pig insertions have cleaning effect. The inner surface of the steel pipe remains slightly sticky with residual oil.
Water jet		One pig insertion and one water jet insertion are effective in cleaning. Steel pipe inner surface is quite clean.

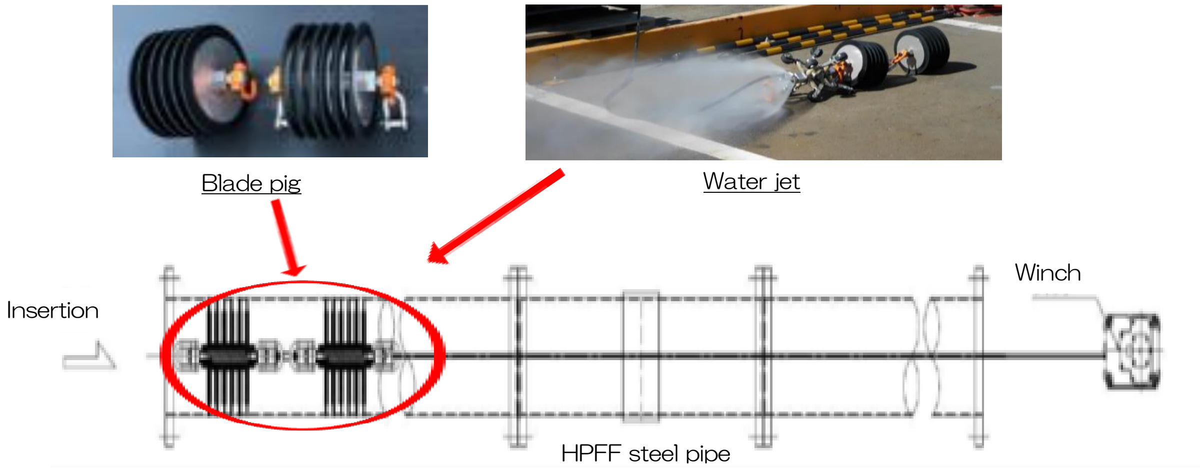


Fig 4. Overview of cleaning test in steel pipe

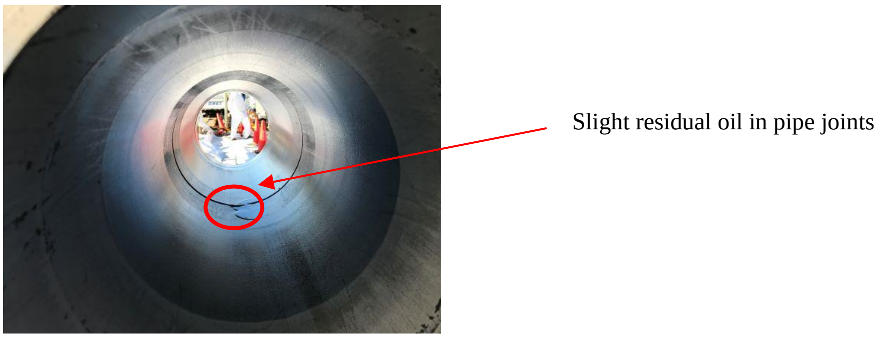


Fig 5. Inside of steel pipe after cleaning

Pig lining inside steel pipes was examined as a measure for long-term use of steel pipes, including measures against corrosion of steel pipes after cleaning. Pig lining is a method of applying a lining resin (flake resin) to the inner surface of steel pipes to prevent rusting of the inner surface, and because the resin is thin with a minimum thickness of 1 to 2.5 mm, it can prevent the inner diameter from becoming smaller. Although there were concerns about the effect of residual oil on the inner surface, the test work confirmed that there would be no problem as long as the oil was swept away by pigging, and although there were some remaining issues such as odor generation during drying, the prospect of on-site application was achieved.

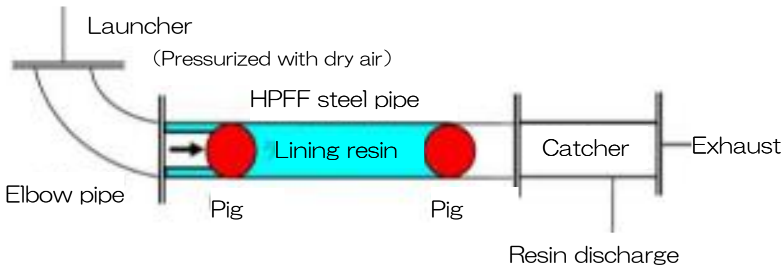


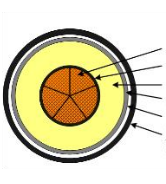
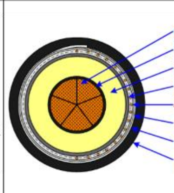
Fig 6: Pig Lining Overview


Fig 7. Post-construction status

4. Specifications of the XLPE cable laid in HPFF steel pipe

Table 1 shows a comparison between the XLPE cable laid in HPFF steel pipe which has been developed and the XLPE cable that we have delivered in the past. Both are specifications of 275 kV with conductor size of 1400 mm^2. The thickness of insulation has been reduced to 19.5 mm by reviewing the minimum breakdown electric field at the joint. Considering that the grounding current will partially flow through the steel pipe, copper wire was chosen as the shielding layer and aluminium water proof layer was installed. Since a small amount of pipe oil may remain in the steel pipe, an oil-resistant high density polyethylene (HDPE) sheath was used.

Table 2.Comparison between the XLPE cable laid in HPFF steel pipe and the ordinary XLPE cable

	The ordinary XLPE cable	The XLPE cable laid in HPFF steel pipe
Cross section		
Thickness of insulation	23.0 mm	19.5 mm
Shielding layer	Aluminum sheath	Copper wire Water proof layer
Anti corrosion jacket	PVC sheath	HDPE sheath
Outer diameter	138 mm (Three-phase 298 mm)	108 mm (Three-phase 234 mm)

5. Measures against thermal contraction and expansion

If a large difference in axial force occurs at the joint due to thermal contraction and expansion, the interface between the cable and the rubber block may become misaligned, which may lead to breakdown. As measures inside the manhole, three reaction force increasing devices were installed on each offset part on both sides, and the joint stand was made movable. It is designed to reduce the axial force applied to the joint by the reaction force increasing devices, and to relieve the difference in axial force applied to the joint by the movable joint stand.

The effectiveness of the above measures against thermal and contraction expansion was evaluated by actual machine test in the narrowest manhole (7.5 m × 2.5 m × 2.4 m) at the site. Fig 1 shows outline diagram of actual machine test. Axial force of 20 kN was applied from both sides in the direction of the joint, simulating thermal expansion and contraction, and then pulled back to the opposite side with 20 kN, which was repeated 10 times. It was confirmed whether or not the rubber block was out of alignment after the test and the amount of movement of the movable joint stand was measured.

Fig 2 shows the actual machine test result. It was confirmed that the joint stand moved stably in the horizontal direction by about ±3 mm due to the axial force from both sides. The range of movement is up to ±25mm. In addition, it was confirmed by X-ray photography that the rubber block did not shift after the test.

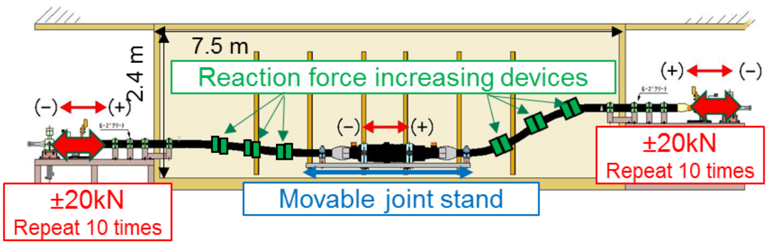
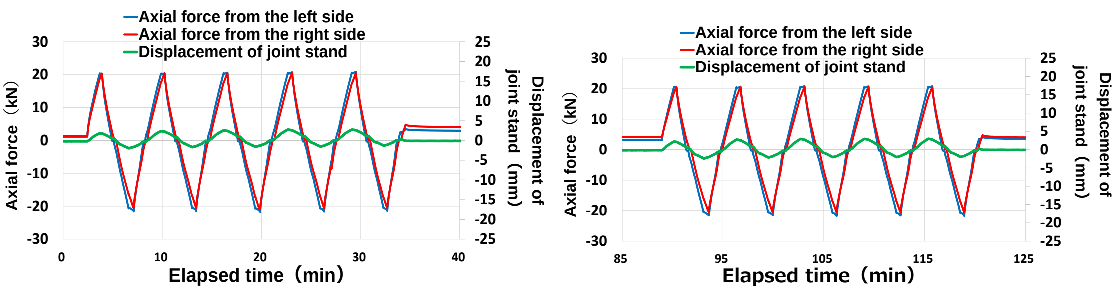


Fig 8.Outline diagram of actual machine test



(a) 1-5 times (b) 6-10 times

Fig 9.Actual machine test result