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The Recovery of the Metal Insulation Cable in the Instrumentation of Nuclear Fuel Rod

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1. Introduction

Mineral-insulated (MI) cables are widely used to prolong the instrumentation cable of instruments such as a thermocouple (TC), linear variable differential transformer (LVDT) and self-powered neutron detector (SPND), which are used to measure various irradiation characteristics of nuclear fuels and materials [1]. MI cables are expected to be helpful for instrumentation of nuclear fuel and material irradiation because of their high electrical insulation, heat resistance and mechanical strength [2]. The MI cable used to extend thermocouple wires is classified as the following: 1) For common metal types of thermocouples, the thermocouple extension wire is of substantially the same composition as the corresponding thermocouple type and it can offer advantages in cost or mechanical properties when used for the connection between a thermocouple and instruments. 2) For noble metal types of thermocouples, the thermocouple compensation wire is an entirely different alloy formulated to match the noble metal characteristics, which is necessary due to the high cost of noble metals. During the installation of an instrument, an MI cable damaged by impact must be recovered because it is difficult to change the entire thermocouple. And for MI cable recovery, it is necessary to develop the instrumentation technology of FTL.

This paper described the experimental results of MI cable recovery, which consists of a removal test of the MI cable sheath and a joining test of the compensation of the wire and MI cable/ wire/compensation wire and sheath of MI cable/bushing**, f**or carrying out irradiation tests of nuclear fuel and materials in the FTL facility of HANARO.

2. Methods and Results

2.1 MI cable and bushing properties

The temperature measurements for a fuel centerline and coolant are important factors for the evaluation of irradiation behavior. In this test, the specifications of the MI cable of C-type and K-type thermocouples used to measure irradiation temperature of nuclear fuel rods are shown in Table 1. The sheath materials of the C-type and K-type thermocouples are AISL 304L. The insulation material packed in the MI cable core is Al_2O_3, which has a high purity at more than 99.7% and a density of at least 65% of theoretically.

Table 1. Specifications of MI cable used in tests.

Type	Material (diameter)		
	Sheath	**Insulator**	**Wires**
C	AISL 304L (1.0±0.01 mm)	Al_2O_3	Alloy 405/426 (0.18mm)
K	AISL 304L (1.0±0.01 mm)	Al_2O_3	Chromel/Alumel (0.18mm)

The extension wires of a C-type thermocouple are compensation wires that consist of Alloy 405 and Alloy 426. These alloys are made of 94.5% Ni+2% Mn+1.5% Al+1% Si (405), and 80% Ni+20% Cu (426). The extension wires of K-type thermocouple are of the same composition as K-type thermocouple wires, which consist of 90% Ni+10% Cr (Chromel) and 94% Ni+3% Al+2% Mn+1% Sb (Alumel). The bushing used to join MI cables was fabricated with AISL 304L materials, which is identical to a MI cable sheath, and is about 20mm in length and 2mm in outer diameter.

2.2 Removal test of MI cable sheath

To develop a sheath removal method of an MI cable damaged by impact, removal tests were carried out under each condition. Above all, the sheath of the MI cable is grinded to 5-10 mm from the end using a pinch or grinder. The remaining sheath is squeezed gently at 0^o and 90^o several times and is removed by twisting it gently from side to side until it breaks. At this time, the end of the MI cable must be confirmed to have no contact between the wire conductors and sheath, and the wire conductors should be clean. A striped MI cable is then closed by resin (epoxy) at the ends to seal the insulator inside the MI cable tube from moisture. Fig. 1 shows a photograph of the end of an MI cable removed a sheath by using a diamond grinder.

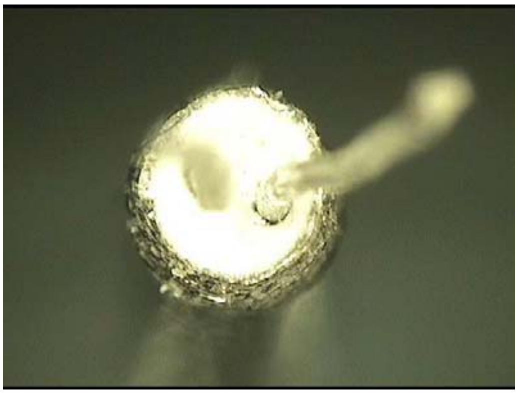

Fig. 1 Photograph of the end of an MI cable removed a sheath.

The MI cable was completely separated between the MI cable sheath and extension wires, and was not deformed by any removal handling.

2.3 Joining test

A micro TIG welding system designed and manufactured for this study was adopted to weld bushing/sheath of the MI cable. The extension wires of the MI cable were welded by using a resistance welder. This welding test was carried out to investigate the welding properties of the MI cable.

Fig. 2 Photograph of a busing/MI cable sheath specimen welded by using a micro-TIG welder

The photograph of a busing/MI cable sheath specimen welded by using a micro-TIG welder is shown in Fig. 2. A bead appearance took place at 2.5A to 3A of the base currents and at 22V of input voltage of the micro TIG welder.

2.4 Inspection and Analyses

A visual inspection was conducted to confirm the specimens treated under the test conditions. To reduce any measurement errors to a minimum, the insulation resistance and electrical conductivity of the MI cable for an electrical verification were measured by using a Megger (SM-8220) and precision multimeter (FLUKE 8846A), respectively, and recorded on a data sheet. The qualification tests for welding were performed using metallographic tests to qualify the welding procedure. The soundness of the weld quality of the MI cable elements was confirmed by microstructural analyses.

3. Conclusions

The recovery process of an MI cable which consists of a sheath, extension wires and an insulator was investigated by using new tools and methods. In sheath removal test, MI cable was completely separated between a MI cable sheath and extension wires, and any deformation in the end when removing the sheath was not found. In a welding test, a bead appearance took place at 2.5A to 3A of the base currents and at 22V of input voltage of the micro TIG welder. The soundness of the welds quality of the MI cable elements was confirmed by microstructural analyses.

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