Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Development of Moisture-proof Connection Technologies Using Cable Connecting Apparatus

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1. Introduction

The flow rates and amount of cooling water, the pressure and temperature of a fuel rod, the neutron flux around a test rig and other factors resulting from the irradiation properties of nuclear fuel and materials are important factors for evaluating nuclear fuel and material properties in pile. In addition, instrumentation and measurement techniques for nuclear fuel and materials are necessary to measure the exact data. The sensors such as a flow meter, thermocouple (T.C), linear variable differential transformer (LVDT), and self-powered neutron detector (SPND) are instrumented in and out of the fuel rod to measure the various irradiation characteristics of the nuclear fuel [1]. These sensors are made up of the sensor itself and a signal cable. A signal cable is generally used with an MI (Mineral Insulated) cable because of their good heat resistance, mechanical strength, and high electrical insulation. However, it is difficult to handle and treat with care owing to the extremely hard composition, which consists of weak signal wires and insulation powder (alumina, hafnia, magnesia, etc.) in a mineral (Stainless and Inconel) tube [2]. To monitor and acquire signals received from sensors during a nuclear fuel irradiation test by a control computer in a control room, the MI cable drawn from a sensor should be connected to extend as a PVC extension cable. Therefore, it is necessary to develop moisture-proof connection techniques for the signal cables. However, a moisture-proof connection process is complicated and difficult for the treatment and arrangement of MI cables owing to a long cable length and a large number of cables. The sealing of the connection part between an MI cable and a PVC extension cable is very important in terms of the insulation resistance to seal the insulator inside the MI cable tube from moisture [3]. To maintain the insulation of the MI cables, the insulation resistance must be checked in accordance with each instrumentation process. To safely mount the signal cables drawn from a fuel test rig on the terminal block of a junction panel, the MI and extension cables should be easy to connect. Therefore, it is necessary to develop instrumentation technologies of a moisture-proof connection process for the signal cables.

This paper describes not only the design properties and moisture-proof connection methods of the apparatus used to extend an MI cable drawn from the sensor as the PVC insulation cable but also some results from the connection experiments using this apparatus.

2. Cable connecting apparatus and method

The cable connecting apparatus consists mainly of a working jig, a flexible working pole, and an arrangement racks for the working jigs for working jigs, as shown in Fig. 1. The working jig is a cable connecting jig that can use to perform a moisture-proof connection work between an MI cable and a PVC extension cable. A flexible working pole is used to attach the working jig, and can be flexible to make a connection. The arrangement racks are places put the working jigs completed with silver brazing and contractile tubing works.

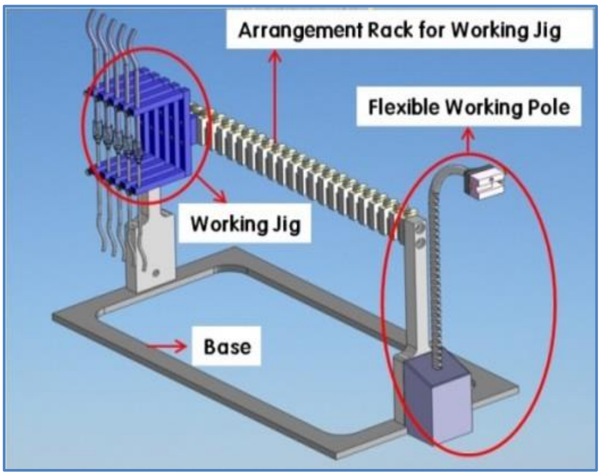

Fig. 1 Cable connecting apparatus for the moisture-proof connection of signal cables

To extend the MI cable of a sensor, a moisture-proof connection process of the MI and extension cables was conducted as follows: First, mount a working jig on the flexible working pole, fix an MI cable and a PVC extension cable, and then insert a thermal contractile tube (80mm in length and 10mm in diameter) around the joint part between the MI cable and extension cable. The joint point of MI and extension cables must be confirmed to have no contact between the wire conductors. Second, the signal wire conductors of the MI and extension cables should be clean. The joint part of the signal wires is conducted with silver brazing at about 870^{o}C. After that, the thermal contractile tube inserted previously around the joint point of the signal cables is moved to the center of the joint point, and the lower end of thermal contractile tube is heated by a heater until it shrinks. Third, a working jig is took from the flexible working pole, and then orderly hang on the arrangement rack. After that, an epoxy mixture (Araldite resin/hardener) through the upper end of the thermal contractile tube is filled to about 8mm from the thermal contractile tube top by an injector. Finally, if the epoxy has cured, the upper end of the thermal contractile tube is heated by a heater. In this process, the epoxy consisting of a resin and hardener was mixed in a scale cup. The mixed composition ratio for the resin and hardener was 100 to 30 by weight. The mixed compound was stirred for about 10 minutes until it formed a homogeneous mixture. It was completely cured for 16 hours at 23 ^{o}C.

3. Experimental and results

To confirm the usability and convenience of the cable connecting apparatus, the connection tests were performed with MI cables drawn from sensors (K-type T.C, C-type T.C, LVDT and SPND). The materials of the signal wires inside the MI cable are the same in LVDT and SPND sensors, but are different in K-type and C-type thermocouples. Therefore, it is important to confirm the polarity (plus and minus) of the cables before connecting between an MI cable and a PVC extension cable. The moisture-proof connection parts of the MI and extension cables to extend the MI cable drawn from sensors instrumented in the nuclear fuel test rod and rig are shown in Fig. 2.

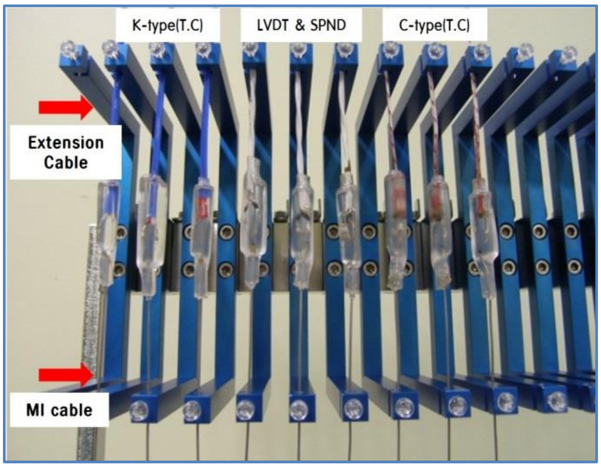

Fig. 2 Signal cables connected with a moisture-proof connection using a cable connecting apparatus

The connection soundness of the signal cables was confirmed after joining between the MI cable and extension cable though the moisture-proof connection method. A visual inspection was complemented to confirm the specimens treated under the test conditions. All samples in this test were well-connected. The insulation resistances of the signal cables to confirm the electrical verification were measured using a Megger (SM-8220) to reduce the measurement errors to a minimum, and their values were confirmed with a soundness of more than 10GΩ. The cable connecting apparatus was confirmed to be usable and convenient through this connection test.

4. Conclusions

A cable connecting apparatus for connecting signal cables was developed to extend an MI cable from the sensors instrumented in a nuclear fuel test rod and rig as a PVC insulation cable. Connection tests for the cable connecting apparatus were performed with the MI cables drawn from various sensors, and the usability and convenience of the cable connecting apparatus were confirmed. The soundness of the signal cables connected by the moisture-proof connection method was confirmed through insulation resistance tests before and after the connection tests.

Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (2012M2A8A5010535)

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