Fabrication of an instrumented fuel rod mock-up using a precise drilling machine

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1. Introduction

When a new nuclear fuel is developed, Irradiation test needs to carried out in the research reactor to analyze the performance of the new nuclear fuel. In addition, to check the performance of the nuclear fuel during the burn up test in the test loop, it is necessary to attach sensors near the fuel rod and connect them with instrumentation cables to the measuring device located outside of the reactor pool. In particular, to check the temperature fluctuation of a nuclear fuel during the irradiation test, a thermocouple should be instrumented at the center of the nuclear fuel. Therefore, A hole needs to be made at the center of a fuel pellet to put in the thermocouple. However, because the hardness and density of a sintered UO2 pellet are very high, it is difficult to make a small fine hole on the sintered UO2 pellet with a simple drilling machine.

In this study, an instrumented fuel rod mock-up was fabricated using an automated precise drilling machine. Four sintered alumina were drilled off and assembled into the zircaloy tube and a K-type thermocouple was instrumented in the fuel rod mock-up.

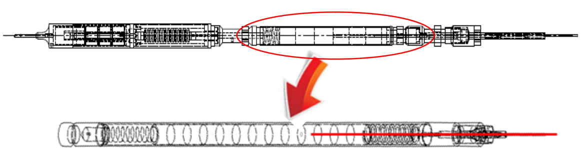

Fig. 1. Section view of instrumented fuel rod assembly

2. Development of a drilling machine

2.1 Material properties of a fresh fuel pellet

The materials and their properties used in this study are as follows.

(1) Workpiece: sintered UO2 (cylindrical/annular), sintered alumina (Al2O3)
- Diameter: Ø8.0~15.0
- Height: 10.0mm

(2) Material property:
- Density 10.3g/cm3
- Hardness 700Hv (HRC 61)
- Yield stress 370MPa

(3) Tooling type:
- hole drilling
- hole diameter Ø0.7~ Ø1.2 (±0.05)
- hole depth 1.0~15.0mm (±0.1)

2.2 Design and development of a drilling machine

Fig. 2 shows the modeling of the drill machine and its implemented machine. First, a fuel pellet can be fixed on a chuck assembled on the X-Y table to adjust the position to be drilled. A drill tip is attached to a high-frequency spindle which has 2.2kW power and 30,000 rpm. To remove the heat generated by a high speed rotation, 21℃ cooling water is circulated by a chiller. And, the drill tip is vertically fed to the fuel pellet whose position and feed rate are controlled with a step motor, a ball bearing, and two LM guides. Feeding is controlled by up to 0.01mm and the feed rate is controlled by up to 0.1mm/min.

During the drilling process, because the heat generated by the friction between the drill tip and a workpiece affects the tool wear and the oxidation of a fuel pellet, cooling water should be continuously supplied to the drill tip. In addition, because this cooling water will be mixed with chips so as from the nuclear fuel, it is circulated in a closed loop not to pollute the circumstance of the tools, and then filtered with a HEPA filter.

To enhance the tool life by completely removing chips generated during the drilling process, a step motor which controls the position of the spindle is programmed to feed a drill tip stepwise and return to the initial position. Then, the cooling water eliminates the chips remaining in the hole and lets the drill tip cool down. This stepwise tooling is repeated until the drill tip reaches the target depth. The drill tip is made of SKH 51, the diameter of which is Ø1.0, and the thickness of the diamond coating is 12 µm.

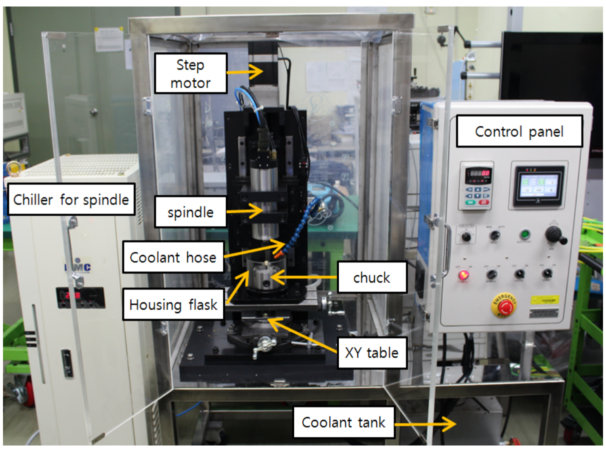

Fig. 2. Modeling and implemented drilling machine

Finally, the tooling part is doubly encapsulated by the plastic panel to prevent the spread of chips and to enhance the safety of the human body from the potential danger of broken tools.

3. Fabrication of An instrumented fuel rod mock-up

Drilling of a fuel pellet mock-up was carried out with a Alumina, whose properties are almost the same with a fresh nuclear fuel pellet. the rotating speed of the spindle was set to 8000rpm. Also, total feed was 12mm, which considers the tooling margin, and the amount of feed rate was 5mm/min and step feed was 0.15mm/step.

Fig. 3 shows the results of drilling on a sintered alumina block, and shows that a fine hole whose diameter is Ø1.004mm was made with the implemented machine in this study.

Fig. 4 shows the An instrumented fuel rod mock-up. Four sintered alumina were drilled off and assembled into the zircaloy tube, and a K-type thermocouple was instrumented.

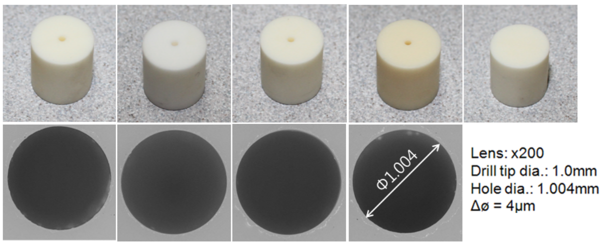

Fig. 3. Drilling experiment using a sintered alumina

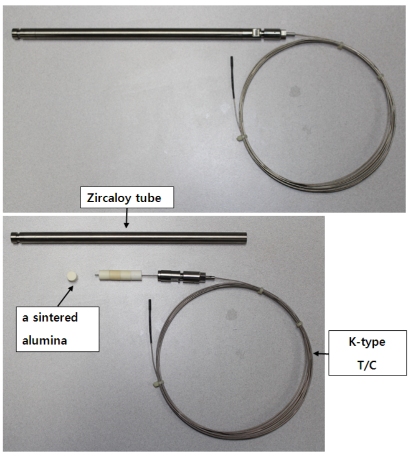

Fig. 4. An instrumented fuel rod mock-up

4. Conclusions

In this study, an instrumented fuel rod mock-up was fabricated using an automated precise drilling machine. Four sintered alumina were drilled off and assembled into the zircaloy tube, and a K-type thermocouple was instrumented in the fuel rod mock-up.

After welding of the end plug, the helium will be charged with 20bar inside the fuel rod mock-up. The integrity of the seal will then be verified by carrying out the helium leak test at a temperature of 200℃.

REFERENCES

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