Optimization of a drilling machine for the instrumentation in a fuel rod

Jintae Hong [a*], Sung-Ho Ahn [a], Chang-Young Joung [a], Hwang-Young Jeong [a], Ka-Hye Kim [a]
[a] *Neutron Utilization Technology Division, KAERI, Daedeok-daero 989-111, Yuseong-gu Daejeon*
[*] *Corresponding author: jthong@kaeri.re.kr*

1. Introduction

To develop a nuclear fuel, a burn-up test, a power ramp test and a re-irradiation test should be carried out in the research reactor to analyze the performance of the nuclear fuel. To check the fuel performance, several sensors such as thermocouple, LVDT and SPND are needed to be attached in and out of the fuel rod. At that time, the sensors need to be connected with instrumentation cables to deliver the signals measured by the sensors to the signal processing devices located outside of the reactor pool. In particular, to install a thermocouple in a fuel rod, a hole needs to be drilled off on the alumina blocks and fuel pellets. Due to its high hardness of a sintered UO_2 pellet (700Hv), it is very difficult to drill off with a single drill bit in a short time. Therefore, Hong[4,5] developed a special drilling machine which makes a fine hole in a fuel pellet without changing drill bit or breakage of the workpiece (Fig. 2). In this study, an optimization process has been carried out to increase the accuracy of drilled hole and to enhance the tool life.

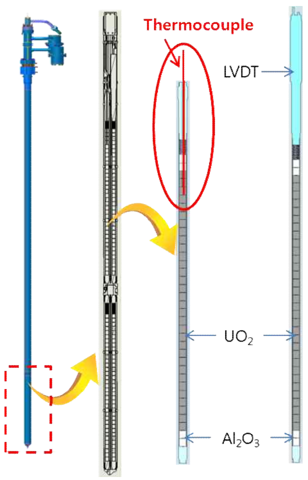

Fig. 1. Section view of the IPS and a fuel rod

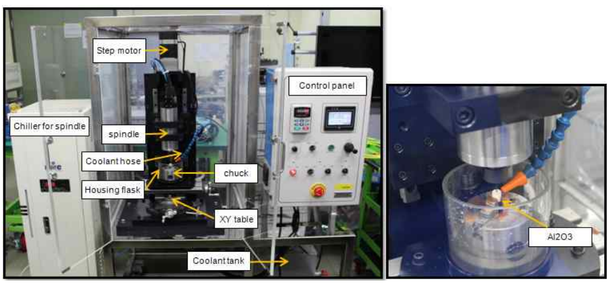

Fig. 2. Drilling machine for a fuel pellet

2. Optimization of a drilling machine

Drilling experiments were carried out using sintered alumina pellets with 99.7% purity. Because the alumina with 99.7% purity has a hardness of 1480Hv, it is more severe drilling condition than using a UO_2 pellet. Normally, because a C-type thermocouple with the diameter of 1.4mm is used to check the fuel temperature, the diameter of drilling hole is decided as 1.4mm.

The implemented drilling machine controls the rotational speed, feed rate, step feed, and drilling depth. Because the drilling depth is not related with the drilling performance, rotational speed, feed rate and step feed are main control variables to optimize the drilling process. Table I shows the range of process variables.

Table I: Selection of process variables

Variables	Range
Drilling depth (mm)	12 (including margin)
Rotational speed(rpm)	8000, 13000, 18000
Feed rate (mm/min)	3, 5, 7, 9
Step feed (mm)	0.03~0.15

2 kinds of case studies were carried out to find the optimal control variables. At first, tooling time was checked with various feed rate and step feed. Then, the limit of step feed was checked according to the rotational speed.

2.1 Influence of feed rate and step feed to the tooling time

At first, drilling experiments was carried out at various feed rate and step feed to check the influence to the tooling time. As shown in Table II, feed rate does not affect the tooling time. However, as the step feed increases, tooling time is drastically decreased.

Table 2. Drilling experiment at various feed rates and step feed (rotational speed: 18000 rpm)

Step feed \ Feed rate	3mm/min	5mm/min	7mm/min	9mm/min
0.03mm	165min.	163min.	163min.	162min.
0.05mm	101min.	99min.	99min.	98min.
0.07mm	74min.	72min.	72min.	71min.
0.09mm	58min.	57min.	56min.	56min.
0.11mm	48min.	47min.	46min.	46min.
0.13mm	42min.	40min.	40min.	39min.
0.14mm	X	X	37min.	X

To instrument a thermocouple in a fuel rod, 5 fuel pellets should be drilled off. And, a hole needs to be drilled off in 96 minutes including waiting time to drill off 5 pellets in a day. So, the step feed should be larger than 0.07mm.

2.2 Limit of step feed according to the rotational speed

The 2nd experiment is checking the limit of step feed according to the rotational speed. At each rotational speed, drilling experiment was carried out by increasing step feed by 0.01 until the drill bit is broken. Fig. 3 shows the limit of step feed at each rotational speed. At low RPM, the drill bit is broken at small step feed because cutting force is not enough. At high RPM, the drill bit is also broken at small step feed because a high friction is induced due to lack of coolant as shown in Fig.4. So, stable drilling is available between 8000 rpm and 13000 rpm at a high step feed.

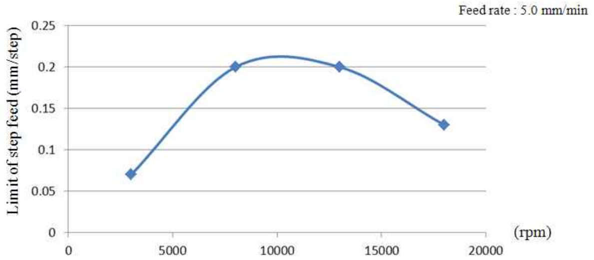

Fig. 3. Limit of step feed according to the rotational speed

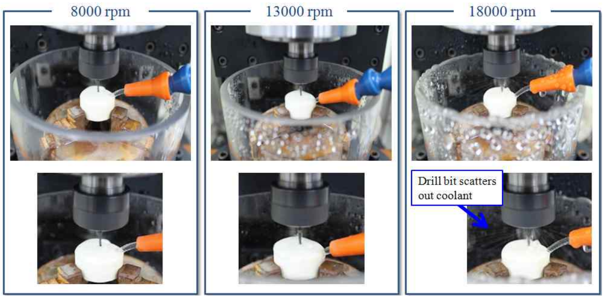

Fig. 4. Scattering of coolant at each rotational speed

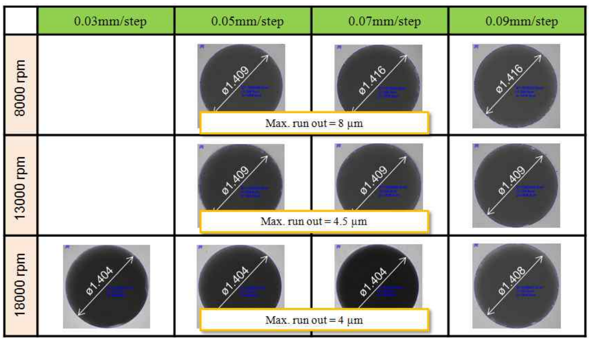

Fig. 5. Diameter of drilled hole at various rpm and step feed

Fig. 5 shows the diameters of drilled hole at various RPM and step feed. As shown in Fig. 5, the amount of run out is decreased as the rotational speed increases. That is, the spindle shows a good performance above 13000 rpm.

According to the above results of experiments, optimal drilling condition is set as 13000 rpm, 0.07mm/step and 5mm/min.

3. Maximum number of drilling hole

Using the optimal condition obtained in the previous paragraph, the maximum number of holes with a drill bit was checked. As shown in Fig. 6, at 8th hole, the neck of a drill bit is broken and stuck in the hole. So, it needs to inspect the status of drill tip at least after drilling 6 holes. Statistically, the average diameter of drilled hole is 1.413mm and it satisfies the design spec (1.4±0.05). And, the standard deviation is 0.004mm and the maximum run out is 0.007mm.

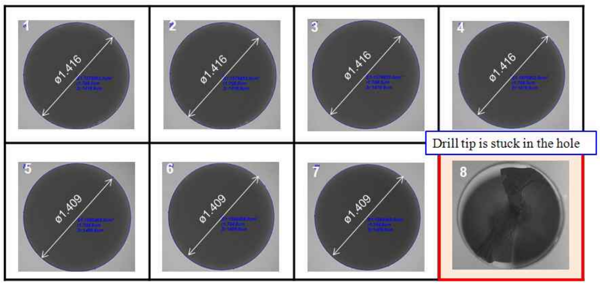

Fig. 6. Diameter of drilled hole with a drill bit

4. Conclusions

In this study, optimal drilling condition to drill off 5 fuel pellets in a day is decided according to the case experiments with sintered alumina blocks. Using the optimal condition, it is verified that a drill bit can drill off at least 7 holes in the sintered alumina blocks.

Acknowledgements

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