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Development of a 3-D Measurement Apparatus for Measuring Cell sizes, Spring and Dimple pitches of Grids for PWR's Spent Fuels

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1. Introduction

A nuclear fuel bundle burns for about 3 cycles in the core of a reactor in general. During irradiation in the core of a reactor, the fuel rods of a bundle are swelled and cooled down by coolant. At this time, some of the springs and dimples of the grids are deformed, and the surface of the fuel rod could be shinny and damaged as a result, however so far the deformation quantities hove not been measured exactly in country.

To measure the deformed quantities such as cell sizes, spring-to-spring pitches, and dimple-to-dimple pitches of various kinds of grids, a remotely controlled 3-dimensional measurement apparatus is required.

In this paper, the design requirement as well as conceptual design and characteristics of this apparatus are introduced, and test results are shown after installation in the hot cell at IMEF [1,2,3].

2. Experimental & Results

2.1 Conceptual design for a remote-controlled apparatus

As the grid of a nuclear fuel bundle is irradiated by neutrons in the core of a reactor, it could be a highly radioactive substance during operation, and therefore, the examination and measurement apparatus must be designed to control it remotely from the operation area of the hot cell facility.

As shown in Fig. 1, a 3-dimensional measurement apparatus consists of a measurement part, a controller part, and a PC & DB system. A measurement part has a working table, which is moved about 250 mm in both a longitudinal direction (X-direction) and a transverse direction (Y-direction), and two arms, which are moved about 250 mm in the vertical direction (Z-direction) and equipped with a touch sensor tip and a camera, respectively. In particular a touch sensor tip should be able to measure the depth up to 100 mm under conditions of 10 mm x10 mm in cell size because both springs and dimples of a grid are located at 40 or 60 mm below the top of it. It should also be designed with clockwise and counterclockwise rotation (U-direction) of 360 degrees. The grooves for various kinds of clamps are machined on a working table.

The measurement accuracy is ± 0.001 mm, and the tolerance of both perpendicularity and horizontality are ± 1.0 mm. The function of an emergency stop is also considered for the designs.

In addition, coordinators for each axis were installed on the rails of each axis later to compare the moved value between the controller (CP-3) and coordinators.

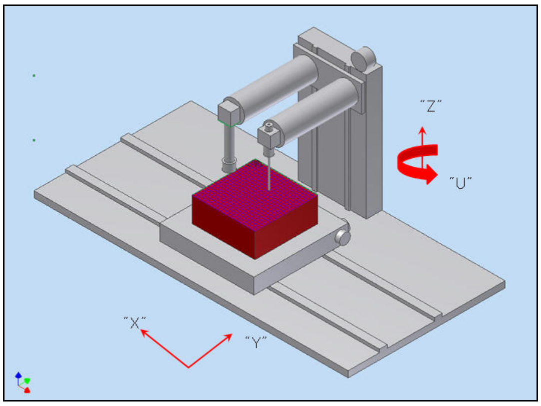

Fig. 1. The Conceptual drawing of a 3-dimensional measurement apparatus.

2.2 Definition of directions

The definition of directions for movement is designed as shown in Fig. 2 for easy and correct programming to control the apparatus exactly.

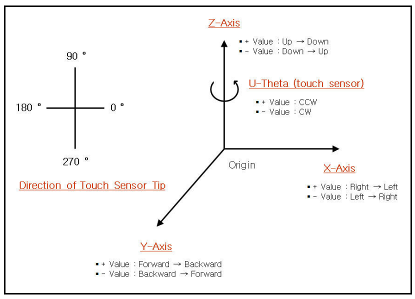

Fig. 2. The definition of directions for movement (three-axes and a touch sensor tip).

2.3 Examination flow

The examination flow is also reviewed to handle the measurement results of DB correctly as shown in Fig. 3. The measurement results are stored as an to MS-Excel file (*.xls) for easy access.

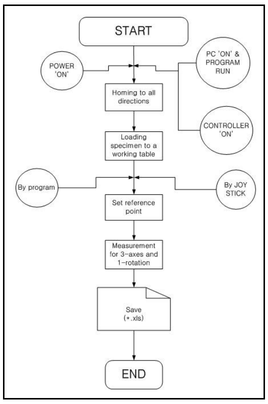

Fig. 3. Examination flow chart.

2.4 Trial test

This 3-D measurement apparatus consists of three parts, i.e. a measurement, a controller, and a PC & DB system as shown in Fig. 4. To check for interference between the software program and hardware parts, a test block (100 mmW x 100 mmD x 100 mmH) is used at the fabrication shop as well as at the cold laboratory of IMEF.

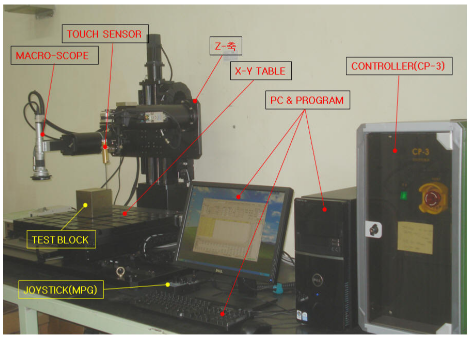

Fig. 4. The overview of a 3-dimensional measurement apparatus.

2.5 Installation

A measurement part is installed in the M5a hot cell of IMEF through the roof door, and the other parts are installed in the operating area of IMEF as shown in Fig. 5. After installation, a trial test is also performed by a test block previously used.

2.6 Performance test

On the basis of the test results obtained from a fabrication shop and the cold laboratory, a final performance test was carried out. The test results of the measurement accuracy, perpendicularity, and horizontality were well satisfied with the requirement and specification, as shown in table 1.

Fig. 5. After installation, (left) the picture of the whole system of the 3-D measurement apparatus, (top-right) a photo of in-cell parts, (bottom-right) a photo of out-cell parts.

Table 1 The measured maximum value of each directions after installation in M5a hot cell of IMEF

Axis	Measured maximum value (um)		Remarks
X	+ 200.976	- 89.123	>250 mm
Y	+ 202.033	- 95.480	> 250 mm
Z	+ 258.400	0	> 250 mm
U	0 – 330 degrees		0-360 deg.
* '+' means upper direction. '-' means lower direction.			

3. Conclusions

The 3-dimensional measurement apparatus for measuring cell sizes, spring-to-spring pitches, dimple-to-dimple pitches of grids for PWR spent fuel is developed, designed, manufactured, and installed successfully in the hot cell of IMEF. In addition, to raise the confidence of measurement results, a coordinator is also attached to the rails of each axis. The test results are all satisfied with a specification of a conceptual design.

Acknowledgement

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