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Development of Vision System for Dimensional Measurement for Irradiated Fuel Assembly

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1. Introduction

In order to develop an advanced nuclear fuel, a series of poolside examination (PSE) is performed to confirm in-pile behavior of the fuel for commercial production. For this purpose, a vision system was developed to measure for mechanical integrity, such as assembly bowing, twist and growth, of the loaded lead test assembly. Using this vision system, three(3) times of PSE were carried out at Uljin Unit 3 and Kori Unit 2 for the advanced fuels, PLUS7^{TM} and 16ACE7^{TM}, developed by KNFC.

Among the main characteristics of the vision system is very simple structure and measuring principal. This feature enables the equipment installation and inspection time to reduce largely, and leads the PSE can be finished without disturbance on the fuel loading and unloading activities during utility overhaul periods. And another feature is high accuracy and repeatability achieved by this vision system.

2. System Architecture

The vision system consists of three main parts, such as measuring instrument, camera and video recording, and data processing part described in Figure 1.

In measuring instrument part, a ten-meter tape ruler and an encoder are used for measurement of assembly length and grid altitudes. The temperature detector is applied for the thermal compensation between the ruler and encoder to get more accurate data. Two plumb lines regarded as ideal vertical guides are used to measure the assembly bowing and twist. The shoulder gap (denoted distance between bottom of top nozzle and upper of fuel rod) and rod spacing are recoded their images on the video tape and then evaluated by means of the video micrometer which generates horizontal and vertical lines on the monitor screens. All images are recorded on the tape for documentation. The computerized data evaluation program built in the PC processes all measuring data.

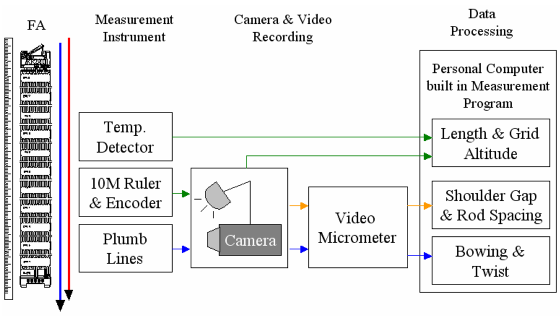


Fig. 1. Block Diagram of Vision System

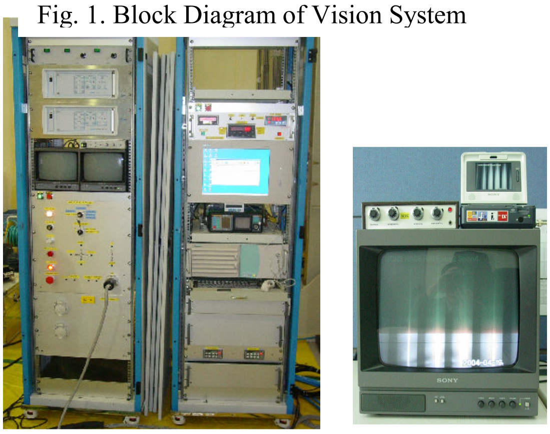


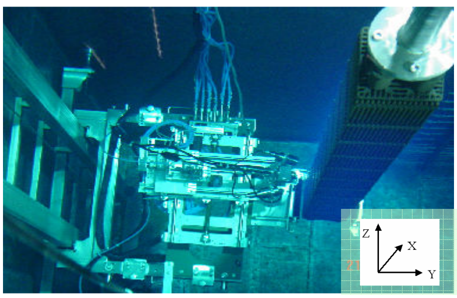
Fig. 2. Vision System Controller and Video Micrometer

2.1. Camera Stand

The camera stand is designed to be install on the UT elevator or fresh fuel elevator in the fuel spent pool. The camera is mounted on a Z mast enabling precise vertical displacements, which is mounted on a horizontal X-Y table by air motor controlled by programmable logic controller (PLC). The assembly is positioned in front of the camera stand, and suspended freely from the spent fuel-handling tool during the examination.

2.2. Measurement of FA Length and Grid Altitudes

The video crosshair is generated and positioned it so as to view its horizontal line in the middle of the screen. Then the center of the upper edge of the grid is exactly positioned at this horizontal line by shifting the camera with the elevator and Z mast. The measurement is started from top nozzle without moving the camera with axis X, then for each grid until the lower grid and finally for the bottom nozzle. The values appeared on the encoder indicator are inserted into the data processing computer for calculation of the actual altitudes. These length measurements are applied for four faces of the assembly. The accuracy achieved by this method is less than +/-2mm.



2.3. FA Bowing and Twist Measurement

Fig. 3. FA Length Measurement

The assembly bowing is defined as the deviation of the assembly centerline from the line between top and bottom nozzle. The plumb line is approached to the right face of the assembly. The camera is moved with the elevator and/or Z mast, and by shifting the axis X and Y so as to detect the first two slots near the right edge of the grid and the close plumb line. In case the assembly is bowed, some difference distances of the plumb line to the assembly are measured by means of the camera and video micrometer. The measurement is achieved at each grid for the two perpendicular faces of the assembly.

The assembly twist is defined as the torsion of the different assembly cross sections against the top or bottom nozzle. Before the twist measurement, the calibration is conducted to set the angle corresponding to the graduation read on the horizontal ruler at the specified distance. The camera is placed on the calibration position and the middle of the top nozzle by shifting axis X and Y. Then the camera is shifted, while recording the image, along axis X at low speed until it moves past the two plumb lines and the latter converge. Repeat the operation for the bottom nozzle. This measurement is performed for only one any of faces of the assembly.

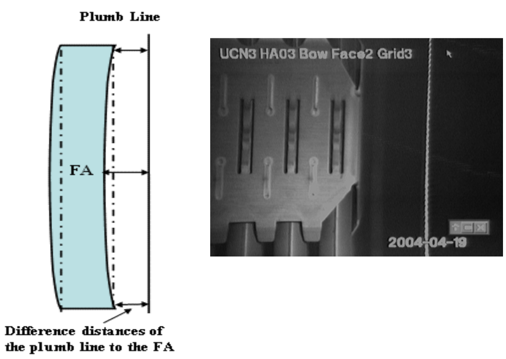


Fig. 4. FA Bowing Measurement

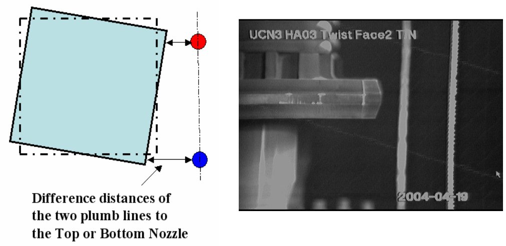


Fig. 5. FA twist Measurement

2.4. Shoulder Gap and Rod Spacing Measurement

For the shoulder gap measurement, the thickness of the top nozzle adapter plate is measured as reference value in number of pixels by video micrometer, and compared by the as-built data. The shoulder gap is detected successively between the two positions of horizontal lines generated by the video micrometer. Repeat the operation from the first row rod as far as last row rod. The EXCEL spreadsheet is used for calculation of the actual value of the shoulder gap.

In rod spacing measurement, the nominal outer diameter of a rod is denoted the reference value. The rod spacing is difference between the two positions of the vertical line generated by the video micrometer . for the compensation of the image tilt, a correction factor is calculated and applied by the measurement program. Repeat this operation at each span.

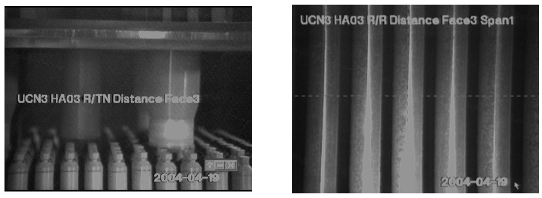


Fig. 6. Shoulder Gap and Rod Spacing Measurement

3. Conclusion

By using this vision system, three PSEs were successfully performed without troubles, and generated faster and more reliable test results enough the fuel performance evaluation. This system can be also applied the inspection of the assembly geometry to be used in the next cycle. And it is expected that the irradiation performance data collecting from these PSE activities would be usefully utilized for next advanced fuel developments.

REFERENCES

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[2] KNFC Technical Report, In-reactor Performance Evaluation Report for the 1st Cycle Irradiated PLUS7^{TM} LTAs, p1-62, 2004.