L.3: Nuclear fuel metrology system developed for FBTR fuel pin inspection

Laser based instruments developed at RRCAT have been extensively used in various stages of the nuclear fuel cycle. The non-contact inspection and metrology of the mixed carbide fuel for the Fast Breeder Test Reactor (FBTR) fuel pin has been carried out for the first time. The FBTR pin comprises of mixed carbide fuel pellets assembled inside a thin SS tube clad. The top and bottom plugs are welded to the thin SS tube and a SS wire of 0.76 mm diameter is tightly wrapped helically after which it is welded at the end point. From the reactor physics point of view, it is very important that the wire is wrapped tightly as per the specifications. The pre and post irradiation data of the various attributes of the FBTR pin viz. bow, pitch of the wrapped wire, weld orientation at the end point, diameter and length are of interest for post irradiation examination (PIE). A completely automated system has been developed which is capable of measuring these parameters without any human intervention thus minimizing radiation exposure to operation personnel. Using optical non-contact based shadowgraph technique and image processing tools, dimensional measurements have been carried out on the shadowgraph of the FBTR pin and geometrical data has been generated.

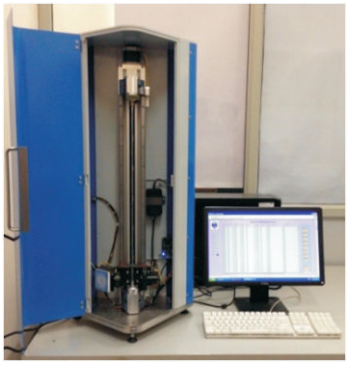

Fig. L.3.1: FBTR fuel-pin inspection system

A collimated source is used to project a parallel beam of light on the FBTR pin and the shadowgraph of the pin is imaged using a tele-centric lens on a CMOS camera. Using the optical alignment, positioning of the FBTR pin is carried out to achieve a focused image on the CMOS sensor. The image processing software was used to detect the edges, contours, dents, peaks and a list of various other features which carry information of the important parameters of the pin. A ring LED source is used for front illumination used for taking front illuminated photographs for visual inspection tool. The machine vision software also generates several triggers for the motion control of the Z-Theta stage. The completed system is as shown in the Fig. L.3.1.

The optical system is mounted on a translation stage with position accuracy of 0.05 mm in Z direction. The FBTR pin is held in a rotatable chuck with a very precise stepper motor for pin rotation with angular accuracy of 0.4°. This Z-Theta stage is controlled by a two axis precise micro-stepping motor driver card developed in-house. The software code written in LabVIEW carries out a high speed measurement of the shadowgraph images to calculate the various parameters viz.,bow, wire weld orientation, wire wrap pitch, pin diameter and pin length. Several images are acquired and automatically processed at different orientations for e.g. to calculate the bow the pin is rotated around in 360° to get about 100 images and the value is displayed in 20 seconds. Measuring the orientation requires angular micro-positioning the FBTR pin and acquiring another set of 100-200 images in 40 seconds. Similarly measuring the wire wrap pitch requires measurement of the distance between two consecutive shadow peaks which is done in an auto loop in a continuous fashion along the length of the pin. Figure L.3.2 shows shadowgraph of the top plug and bottom plug weld region showing wire wrap starting and end points.

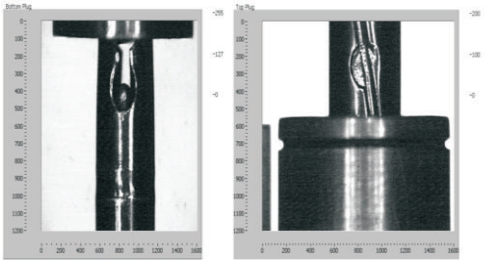

Fig.L.3.2: Shadowgraph of the top plug and bottom plug weld region showing wire wrap starting and end points.

Acceptable range and accuracies for FBTR Pin are as follows:A. Bow measurement: < (2/1000 mm) ± 0.05 mm, B. Wire wrap pitch: (86-94)±0.5 mm, C. Weld orientation: (223°-283°) ± 1°, D. Length: (530.3-531.9 mm)±0.1mm, E. Diameter:(<6.02) ± 0.05 mm

The user interface developed for the system is capable of directly indicating whether the pin inspected is acceptable and within the desired limits and hence does not require any human intervention. It also gives the summary of values of all the measured data in a report generated to be used for pre and post irradiation dimensional studies. Several campaign of measurements on dummy pins supplied by Radio Metallurgy Division (RMD) have been carried out and the data has been generated for statistical analysis. The system has been tested for round the clock operations and is able to reliably measure fuel pins with the desired accuracy and is ready to be installed at RMD, BARC.

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