NON CONTACT PROFILE MEASURING TOOL FOR
END FITTING & FEEDER TUBES
AT
CANDU BRUCE REACTORS

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During reactor operation, pressure tubes grow in length primarily due to the radiation. Each fuel channel assembly grows at different rates, which presents challenges with managing the feeder pipe gaps between adjacent fuel channel assemblies. Fuel channels are periodically repositioned based on their growth rates to ensure that they remain on their support bearing and there are adequate gaps between feeder pipes to prevent contact with each other. This project involved the collection of data for each fuel channel using a non-contact profiling tool.

- For Bruce Unit 3, there were several measurements required:
  - Measuring the spacing of feeder pipes
  - Profiling of end fittings relative to the spot face and calculation of:
    - Length of the thickened portion of the stop collar
    - Position of the remnant weld
    - The distance from the E-Face to the spot face
    - Most inboard feeder to spot face distance
  - Feeder proximity to the end fitting

This work was a joint effort by Techno Scientific Inc. (TSI), Babcock & Wilcox Canada Ltd (B&W) and Bruce Power. The concept is based on a non-contact measurement by lasers mounted on an absolute linear encoder slide.
System Design

The concept is based on non contact measurement by lasers mounted on an absolute encoder slide.

Two lasers are used to monitor the profile. The operator moves a testing head fitted with lasers on mechanically guided encoder slide, which provides the real time position of the head. The lasers provide the distance from the object reflecting the beam. Up to thousand samples per second are collected from both lasers together with corresponding positions.

The profiles are calculated from collected samples. An advanced calculation routine is used to calculate the diameter and the centre of each feeder pipe.

The spacing between feeder pipes is derived from the centre position and diameter of each tube. Three colour cameras monitor the placement of the tool against the spot face and the scanning process. All the control cables from the control box are run through a high flex conduit which is approved for nuclear application (Figure 1).
Figure 1: WSP Testing Tool
Electronics and Computer

Main components are listed below:

- Two displacement laser sensors, one with sensing range 20-45 mm i.e. Keyence IL 030 and the second Optex CD33-250 with sensing range 250 (+-150) mm, output signal 4-20mA or serial output RS422.
- Mechanically guided magnetic length measuring system or absolute position encoding, length: 1550mm (60”).
- Control Box with a microcontroller, 12 bit A/D converter and counter for capturing the data and sending them to laptop computer over Ethernet.
- Laptop computer with 15.6” screen, dual core processor, 4GB RAM, min. 250 GB HDD, Windows 7.
- Three colour cameras C-cam8AN monitor the placement of the tool and lasers before and during the measurement cycle and the image is superimposed with measured data by B&W.
Software

Custom software for this application is written in VC++ under Windows XP/7. The user interface allows for easy set up of all parameters. All captured raw data are stored on the hard drive and are used in advanced calculation to determine the feeding pipe diameter and centre position (Generation of a semi circle with pipe diameter). The pipes diameter and centre position are then used for calculation of spacing between feeder pipes. End fitting profile data is used for determining the length of the stop collar and the distance from the spot face to the first step on the end fitting. It also calculates the E-face to spot face dimension by adding 51.75 inches to the spot face to first step dimension for the West or 52.25 inches for the East.

All required input data like end fitting ID are entered to the computer through User Interface. These data, all calculated diameters and distances, date and time of inspection are saved to the computer hard drive.

Calculated diameters and distances are stored as a table in a text file that can be exported to Excel. Raw data are saved in proprietary format as well.

The data can be transferred through local area network via Ethernet link.

Some data are used by B&W software for superimposing on video signal. The end fitting number, data from encoder and lasers are sent to B&W computer over the ethernet in real time.
Calibration

Part of the software is Calibration Mode for system calibration. This is a dedicated module. A calibration stand was provided to TSI for this purpose by B & W to establish system constants. The testing device is attached to the stand and secured in the defined precise position. The stand provides two defined distances for both lasers. A defined step for profile laser is used for checking the calibration of profile laser to be sure that the length of the stop collar and the position of first step in the end fitting is measured correctly. Two short samples of feeding tubes are used on calibration stand to check that the feeding tubes spacing and diameters are calculated correctly.

Each calibration tool has its own I.D. with mechanical values precisely defined. Ten (10) tools were manufactured and calibrated.
Figure 2: Offset Calibration
Measurement window opens after pressing *Measurement* button in main mode. This window has three main sections: Profile Graphs on left side, end fittings list and distances list on right side and some controls and indicators.

Figure 3: Measurement Window
To control the operator’s movements a speed indicator was devised. The Speed Indicator has four lights: two green, one yellow and one red. Lights glow according to the tool speed in testing direction. The setting for this indicator is done in Controller Calibration. There are two different settings in Control calibration: one for End Fitting Profile and another for Feeders Profile measurement. The speed can increase as soon as the End Fitting profile is finished.

If orange light turns on, the warning message is sent to Status window. If red light turns on, an Error message is generated and the test is stopped.

It is recommended, keeping to the speed when only first two green lights are glowing.

The software checks the actual speed, not average speed. The speed warning or error can appear even when the average speed is slow and the testing tool jerks.

Operators learn after some attempts to move the tool within the speed limits allowed.
Mechanics

The fixture is manually operated.
The tool has three levels:

• Base with stabbing wedge on one end and mounting collar on the other and T slot for the second level.
• Absolute magnetic linear encoder with tip on one end, and locking handle on the other mounted on a T profile.
• Measuring tool, which slides on the encoder bar during testing.

An absolute slide encoder is mounted on a bar with profiled delrin shoe on one end and a stainless steel band with two latches on the other. Operator will insert the fixture inside the clearing next to the feeder tube flange and press hard against the spot face plate groove (which is the datum point). The head will be in the most inner position. The band is secured by moving the latches to fix the bar in position. Operator then pulls back a telescopic push rod and pulls the measuring head with two lasers to the outer most position. Data collection is initiated by the absolute encoder and data is collected by the computer. When the optical signal indicates successful data collection, the telescopic push rod is returned to the original position, latches released and the fixture pulled out.
Figure 4: Mock-up of End Fitting with Feeder Tubes
Figure 5: Detail of speed indicator

Figure 6: Close up of measuring head
Figure 7: Detail of the stabbing tool
Figure 8A:
View from the camera indicating no gap (A) vs gap (B) between the tool & spot face (B)

Figure 8B:
Figure 9: Placement of the tool on mock-up
Figure 10: Close up of inserted tool
Figure 11:

Operator handling the tool.
Figure 12: A close up of the tool against the spot face
Figure 11: Close up of the mounting ring
Conclusions

As the systems were operating in low radiation environment (< 10 mR / hr) a large team of operators had to be hired. While some other tests were performed by them the three hundred operators finished the job successfully.