Multi-Mode Beam Forming for FMC Inspection of CANDU Reactor Fuel Channels

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Zirconium-Niobium 2.5 (ZrNb2.5) alloy tubing is used in the design for the entire fleet of CANDU nuclear reactors. The ZrNb2.5 tubes, frequently referred to as Pressure Tubes (PT), are the pressure boundary element in the reactor core and as such perform the critical function of nuclear containment. Routine inspection of select PT is mandatory as a licensing condition for continued operation of the nuclear units. Current PT inspection methods are founded upon conventional ultrasonic and eddy current testing principles and have been deployed for over 40 years. Aging of the ZrNb2.5 PT material and in-situ conditions have adverse effects on the inspection quality and productivity. Changes in technology over that 40-year period further complicate system operation and maintenance. A new inspection system has been proposed. The new system is based upon Full Matrix Capture (FMC) data acquisition and Total Focus Method (TFM) beamformers. Multiple FMC apertures acquire data in immersion mode, passing through the ID surface and then insonifying the body of the PT material with ensuing reflections from the OD surface in longitudinal and shear wave modes. The beamformer is required to first image the ID surface as to provide the coordinates of the ID. An iteration of the TFM beamformer is applied to image of the material on the first skip inclusive of the OD surface. Subsequent iterations of the TFM beamformer are used to image the material volume via combinations of wave modes. Wave modes selected for imaging are a function of the distribution of ultrasonic energy and the requirements of the Inspection Specification. Other material characteristics are inferred from metrics derived from the time domain signals in the FMC data set. This paper describes the work performed to date and provides the beamforming results achieved on both laboratory samples and ex-service PT material.