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Automation in Ultrasonic Gauging & Imaging of Tubes and Pipes

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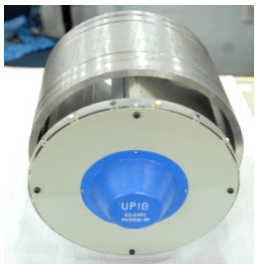

Inspection head assembly inside pipe

ABSTRACT

Automated ultrasonic imaging and gauging systems are employed for the inspection of tubes and pipes in strategic applications due to systems automated operation without the intervention of an operator; repeatability in measurements and better measurement accuracies. This article provides brief details of the two systems namely the in-house developed Water-immersible 2-channel ultrasonic pipe inspection and gauging system for inspection of long length pipes and the water-immersible system modules can float along with the flow of fluid. Another system is, the Automated 5-Channel Ultrasonic Gauging System (UGS) suitable for inspection of pressure tubes of PHWR, where the system was interfaced to the automated 2-axes mechanical precision scanner.

KEYWORDS: *Ultrasonic Gauging System (UGS), Water-immersible, Pressurised Heavy Water reactor (PHWR), Post-Irradiation-Examination (PIE), Tubes/pipes*

Introduction

Metallic Tubes/pipes play an extremely important role in strategic and critical applications like defence, nuclear and petrochemical industries. Tubes and pipes are employed in these industries to work under high temperature, high pressure, high flow rates, radiation and/or gas-liquid environment. Metal loss, corrosion and erosion cause wall-thinning of such tubes and pipes. The tubes and pipes are also inspected for volumetric and planar flaws which are hidden inside the material of tubes and pipes. To provide a high level of safety, reliability and quality assurance, there is a need to inspect flaws and to measure the ID, OD and WT of such tubes and pipes. There are some references available from national and international researchers and manufacturers who have developed automated ultrasonic inspection systems for tubes and pipes[1-5]. A water-immersible 2-channel IP 67 grade water-immersible ultrasonic pipe inspection and gauging instrumentation system (UPIG-250) is suitable for gauging and imaging of long-length metallic pipes and an automated 5-channel Ultrasonic Gauging (UGS) system suitable for post-irradiation examination of pressure tubes of 220MWe PHWR have been designed and developed by Electronics Division (ED) of BARC[6,7].

Water-immersible 2-channel Ultrasonic Pipe Inspection and Gauging System (UPIG-250)

The water-immersible 2-channel Ultrasonic Pipe Inspection and Gauging System (UPIG-250) has been designed & developed, as shown in Fig.1 (a). The system operates on the principle of Pulse-Echo mode and consists of water-immersible IP67 grade two modules comprising of ultrasonic instrumentation hardware. The modules of UPIG-250 system are namely the 2-Channel Ultrasonic Spike Pulser module, Fig.1 (b) and the DAQ module, Fig.1 (c). The DAQ module comprises of 2-Channel wideband Pre-amplifier, 100MSPS/8-Bits Digitizer, Artix-7 FPGA and USB controller modules. UPIG-250 hardware enclosures are mounted inside the inspection head assembly and the inspection head assembly is designed at Workshop, ED, BARC. The inspection head has 8+8 spring-loaded Teflon balls at the front & rear sides for proper centring of the inspection-head inside the 12" diameter sample SS pipe, having 12.75mm wall-thickness. The inspection-head has been mounted with spherically focused ultrasonic immersion two transducers placed 180 degree apart for the measurement of WT, ID and OD of the pipe under testing[8]. 2KB of A-Scan 1D data Fig.1(d) is stored per transducer with a time latency of 200 msec between two channels. Considering the transducer diameter of 10 mm, the UPIG-250 can provide acquisition for a fluid velocity of 100 mm/sec inside the pipe. At present, the two modules have been tested inside the pipe, filled with water, for a period of five hours and more than 180MB of data has been stored in a static condition. A time slot of 10 minutes has been provided before the actual acquisition starts inside the pipe to complete the installation of UPIG-250 system inside the water-filled pipe. Once the data acquisition of five hours is completed, the DAQ module will be opened and the USB board is connected externaly to the PC via USB 2.0 cable. At present the water-immersed UPIG-250 system has been tested for five hours inside the pipe. The modules are operated by Li-ion batteries that are mounted in another IP67-grade two enclosures. Subsequently, the entire water-immersible UPIG-BARC system will be tested inside the pipe with a fluid velocity of 100–500 mm/sec. Such system is one of the first kind of indigenously designed & developed battery-operated system available for the inspection & gauging of pipes and tubes. For inspection & gauging of tubes, customised inspection-head is inserted inside the tube under test and system hardware will remain outside the tube.

Key features of the 2-Channel ultrasonic inspection and gauging system of for tubes and pipes:

- Transducer frequency: 2MHz/ 5MHz/ 10MHz (focused & damped)

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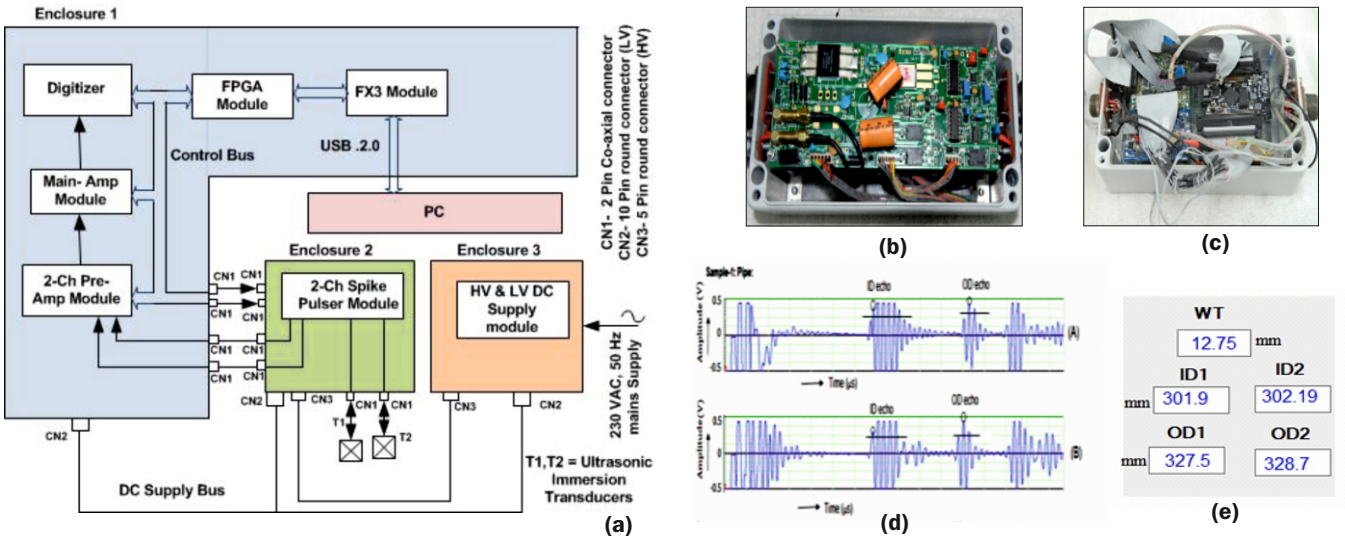


Fig.1: (a) Schematic Diagram of UPIG -250 system (b) Pulser module (c) DAQ Module (d) 2-Channel A-Scan waveforms received by 5 Mhz immersion transducers of EEC make, Mumbai (e) Gauging Data of sample pipe.

- 2-Channel Pre-amplifier (individual) Gain: –66dB (maximum)
- Temporal averages: – 32 (fixed) (To enhance SNR)
- Operating mode: Pulse Echo (PE)
- 2-Channel Spike Pulser: -100V@ 100nsec[9]
- Digitizer: 100MSPS @ 8-Bits, 2Kbytes/A-Scan Data
- Interface to Computer: USB 2.0
- Mech. Dimensions of IP67 grade modules: Pulser Module: 120x220x91mm; DAQ Module: 160x260x90mm: Battery Module-1: 120x220x91mm (DC supply for FPGA) and Battery Module-2: 160x260x90mm (DC supply for DAQ module)

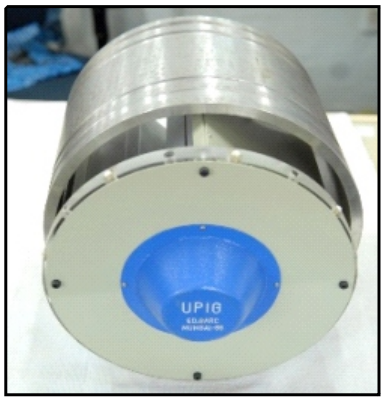
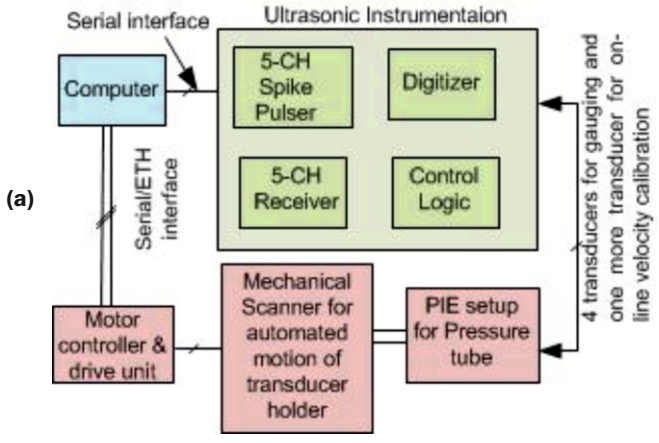


Fig.2: Inspection-Head inserted inside Pipe.

Automated PC-Based 5-channel Ultrasonic Gauging (UGS) system

There are two major aspects related to the accurate measurement of ID and WT of Pressure Tubes (PT) of Pressurised Heavy Water reactor (PHWR). Firstly, it is very important to assess the remaining life of the coolant channels of the PHWR while in-service and secondly, it is to analyse the post-service i.e. post irradiation dimensional variations in a PT due to fatigue and stresses[6]. Automated scanning mechanisms are widely employed for ultrasonic imaging and gauging of tubes due to automated operation without the intervention of an operator with repeatability in measurements and minimization of measurement inaccuracies. To meet the requirements of the Post-Irradiation-Examination (PIE) activity of PHWR, an automated ultrasonic-based X-Theta scanning mechanism has been designed and developed at ED, BARC for Post-Irradiation Examination (PIE) of pressure tubes of 220MWe PHWR, as shown in Fig.3 and Fig.4. The 5-Channel Ultrasonic Gauging System (UGS) H/W and 'Control & DAQ' S/W are major constituents of the system. The Z-Theta, 2-axes scanning mechanism could measures the ID, OD and WT of a sample PT of 5100mm length and the system also performed automated profilometry of the sample PT as shown in Fig.4(b). UGS comprises of 5-channel ultrasonic spike Pulser-Receiver,



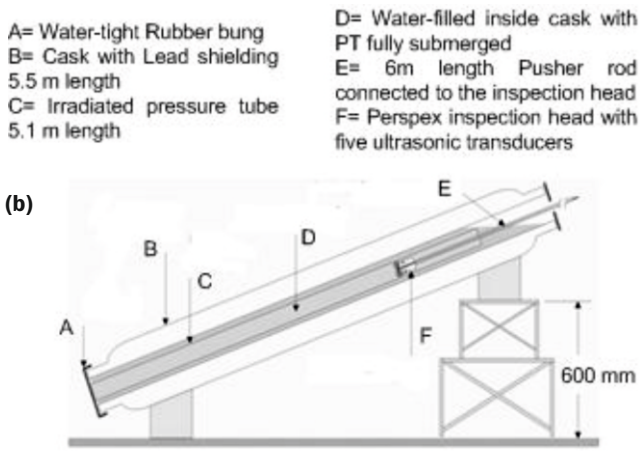


Fig.3: (a) Schematic Block Diagram of Automated 5-Channel Ultrasonic Gauging System(b) Dummy Cask filled with water which contains 5.1 mtr long sample Pressure Tube and X-Theta motions are imparted to inspection head for Gauging and profilometry.

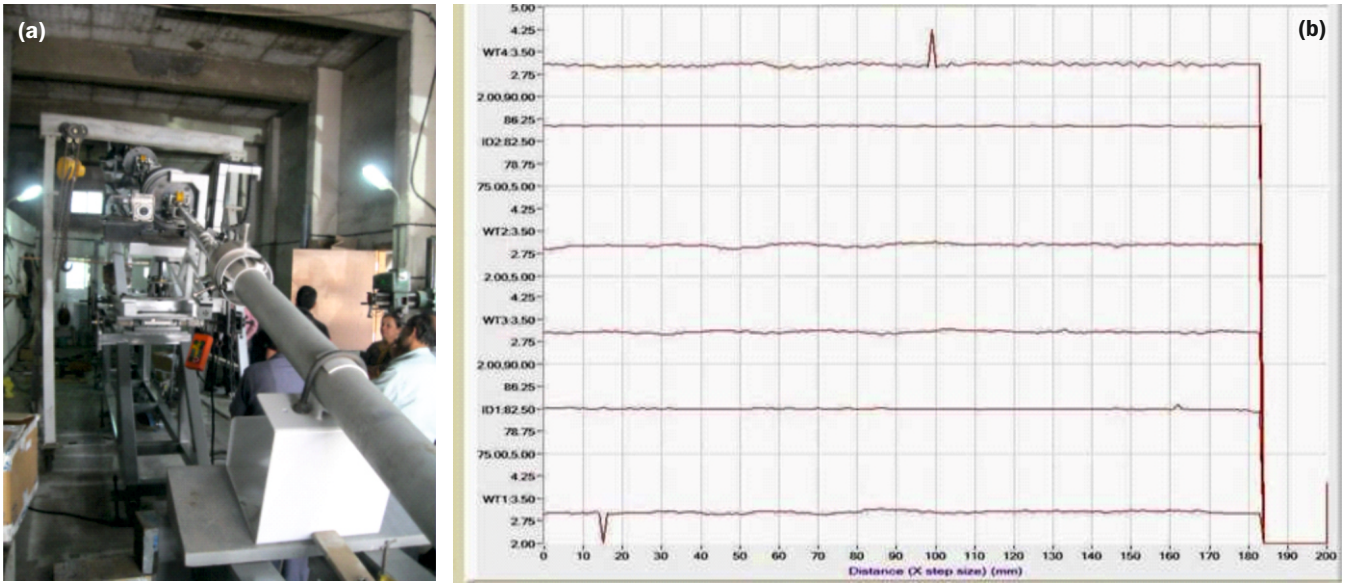


Fig.4: (a) Automated X-Theta mechanical Scanner (b) ID and Wall-Thickness Profilometry of 5.1mtr long sample Pressure Tube.

PCI-based 500 MSPS, 8-bits digitizer and control & data acquisition GUI software, for measurement & analysis of gauging data. Each Pulser channel provides a spike type pulse of 300V for excitation of high frequency spherically focused 10 MHz ultrasonic transducers of Roop Telsonic, Mumbai make, and user selectable HV pulse amplitude &amplifier gain and sampling rate and depth range in Pulse-Echo mode. Each receiver channel has user programmable gain and the digitizer provides sampling rate up to 500MSPS. Gauging and profilometry data are stored and displayed for on-line computation of ID, OD and WT of the PT, as well as to acquire and display profilometry. i.e., a cross-sectional view of the PT in terms of variation in ID and WT over a length of 5100 mm of the sample PT.

Conclusions

A water-immersible IP 67 grade 2-channel Ultrasonic Pipe Inspection and Gauging System (UPIG-250) has been designed and developed for the gauging and imaging of long-length metallic pipes utilized petrochemical and other strategic industries. Another system is a an automated, 5-Channel Prototype Ultrasonic Gauging System (UGS) was developed for the profilometry of the pressure tube (PT), using 10MHz focused transducers and water-immersion technique. A technique was developed which can be adopted for the Post-Irradiation-Examination (PIE) of irradiated Pressure tubes of 220MWe PHWR, inside a hot-cell. ID of 82.55mm of PT was measured with an accuracy of 100 microns, using X-Theta automated mechanical scanner and 5.1-meter-long dummy pressure tube. The technique established by using the prototype development, is suitable in a hot-cell area for the PIE of an irradiated Pressure Tubes of PHWR.

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