L.1: LASMART - Laser based Apparatus for Sag Measurement Application of Reactor Tubes

Calandria tubes (CT) of pressurized heavy water reactor develops sag due to the stresses from the load of the fuel bundles and the heat produced from the fission reactions. Sag of these tubes is measured during *en-masse* coolant channel replacement activity, which is usually conducted after 10 to 15 years of operations. Monitoring the sag helps in achieving the desired life of the reactor and its safe operations. Sag measurements are currently done using inclinometer or LVDT probes. The high radiation levels in the channels lead to the failure of these expensive and imported probes. Laser based sag measurement has been developed as an alternate non-contact technique in high radiation environment. In this method, as shown in Figure L.1.1, an expanded-collimated laser beam is passed through the CT channel under test. The sagged region of the channel obstructs the part of the beam which is observed as a shadow on the screen.

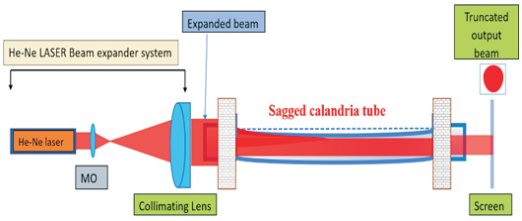

Fig. L.1.1: Schematic of the proposed principle.

The measurement comprises of three steps. The first step involves generation of an expanded and collimated laser beam, the second step involves alignment of the beam with the axis of the channel and the third step involves imaging and its processing to obtain the value of sag. Since the system has to be used in a radiation environment, components of the system are to be automated for remote operations. Figure L.1.2 shows the schematic of the CT sag measurement setup in the reactor vault.

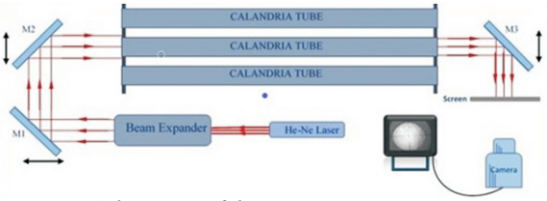

Fig. L.1.2: Schematic of the CT sag measurement setup.

Figure L.1.3 shows a developed collimated He-Ne Laser beam expander of beam diameter 110 mm which was aligned co-axially with the CT using a pair of highly polished stainless-steel beam steering mirrors. To align laser beam axis parallel to CT axis, alignment jigs with a small pinhole at centre (Figure L.1.4) were designed to exactly fit the internal diameter of the lattice tubes on either side of CT. The alignment is ensured by coincidence of the shadows formed by each jig on passage of collimated He-Ne laser beam.

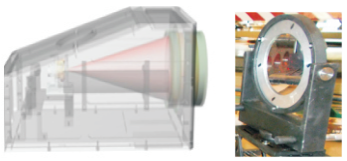

Fig. L.1.3: Laser beam collimator and a polished SS mirror.

Fig. L.1.4: Fabricated pin hole mounted on the liner tube protection sleeve (LTPS) alignment jig and monitoring of the beam alignment using camera.

For remote operation and automation, three motorized gimbal mounts were indigenously developed with the motion control. A shadowgraphic image acquisition and sag measuring software was developed in-house for the measurement (Figure L.1.5).

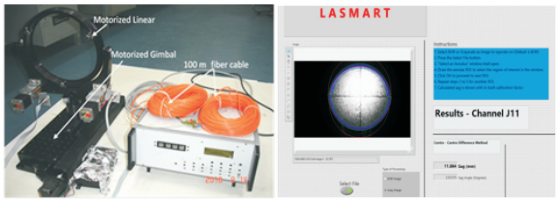

Fig. L.1.5: Motorized gimbal mounts and GUI of sag measuring software.

The developed system has been used on Q-11 and J-11 channels of KAPS-1, Kakrapar for the *in situ* measurement of maximum sag. The measured sag using LASMART and its comparison with the measurements done using inclinometer are shown in Table L.1.1. LASMART is probably the only non-contact sag measurement system in the world and can be used effectively in high radiation environment.

Table L.1.1: Comparison of the sag measured with LASMART and inclinometer.

Sr.No.	CT Channel	Sag Measured	Inclinometer readings
1	Q-11	11.75 mm	11.46 mm
2	J-11	11.86 mm	11.56 mm

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