A.7: Impedance simulation of storage ring vacuum components: Benchmarking study

Beam coupling impedance in particle accelerators results from the interaction of a charged particle beam with electromagnetic fields induced in a vacuum chamber by the beam itself. The most significant effect is instability of longitudinal or transverse motion leading to deterioration of the beam quality or even loss of beam. Study of impedance is essential both for designing new accelerators and for understanding the beam dynamics in the operational facilities in order to improve their performance.

Before using the CST PARTICLE STUDIO software for upgraded Indus-1 component analysis, benchmarking of simulated results is required to ensure the reliability of the software. In this study, vacuum components of existing Indus-1 storage ring are considered for impedance analysis viz., circular and rectangular profile vacuum chambers and bellow. Indus-1 storage ring parameters considered for simulation are given in Table A.7.1.

Table A.7.1. : Indus-1 storage ring parameters.

Beam energy	450 MeV
Bunch charge	6 nC
Bunch length	0.120 m
Revolution frequency	15.8 MHz

Benchmarking of impedance simulation: Firstly, benchmarking of simulation results from CST was done for SS304 seamless Indus-1 rectangular (70 mm x 26 mm) and circular (69 mm ID) chambers with respect to analytical results as shown in Figure A.7.1.

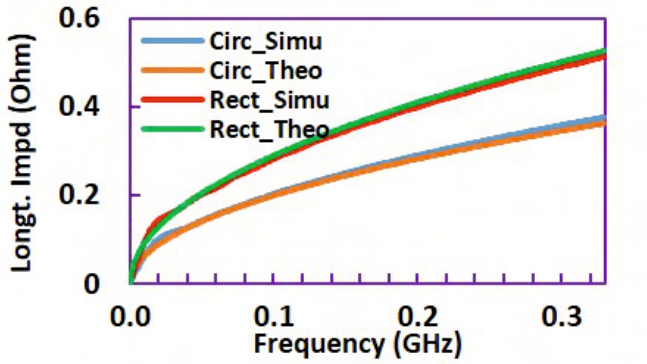

Fig. A.7.1: Benchmarking of CST wake field solver for Indus-1 rectangular and circular chambers.

A conventional stretched wire-method based measurement setup was used for the measurement of longitudinal coupling impedance of a bellow as shown in Figure A.7. 2(a). Copper wire of 3 mm diameter was installed on the axis of the reference (REF) chamber and device under test (DUT), which forms a coaxial transmission line with characteristics impedance of about 180 Ω. To match the vector network analyzer (VNA) and cable characteristic impedance to the 180 Ω, a series resistance Z_{match} was inserted at either ends of co-axial wire. Longitudinal beam coupling impedance (Z_{ll}) offered by one corrugation of an unshielded bellow (SS316L) similar to as shown in Fig. A.7.2(a) with corrugation depth of h=12 mm, width of g=3.8 mm and pipe radius of b=34.5 mm is given by:

$$Z_{ll} = i\omega L = i\omega \frac{Z_0 gh}{2\pi cb} \quad (1)$$

The S_{21} parameter of REF and DUT was measured in matching condition then longitudinal impedance was calculated by measured S_{21REF} & S_{21DUT}, which is given by:

$$Im[Z_l] = -2Z_c Phase\left[\frac{S_{21DUT}}{S_{21REF}}\right] \quad (2)$$

Impedance obtained from analytic expression, simulation and measurement were plotted together in Figure A.7.3. Simulated result shows a covariant behaviour with respect to the analytical as well as measured results over a large frequency range for Indus-1 stored beam. This completes the benchmarking of CST for further impedance analysis of upgraded Indus-1 components.

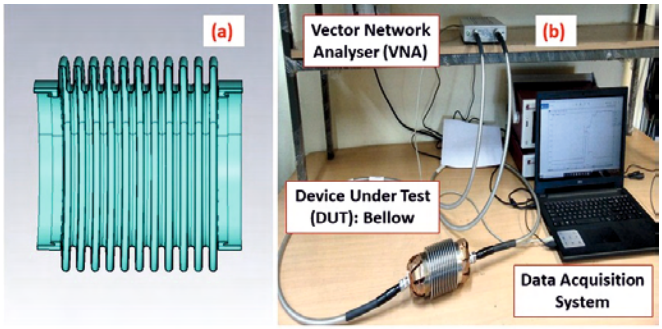

Fig. A.7.2: (a) Cutting plane view of Indus-1 bellow and (b) impedance measurement set-up for bellow.

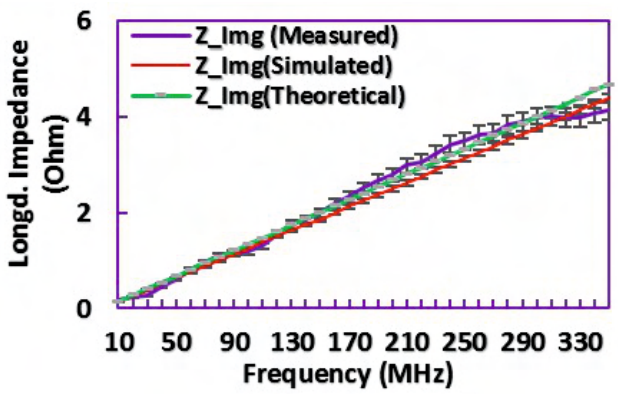

Fig. A.7.3: Comparison of CST simulation result with analytical and measured results.

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