A.11: Development of rotating coil based magnetic measurement system at RRCAT

A rotating coil based measurement setup has been developed at RRCAT for the characterization of quadrupole and sextupole magnets. This report presents successful development of the measurement setup showing a comparison of measured results of multipoles of a quadrupole magnet with those found from a DANFYSIK made rotating coil based harmonic bench (model 692), obtained from ESRF on loan basis for the characterization of Indus-2 magnets.

The measurement setup shown in Fig. A.11.1, comprises of a rotating coil assembly, a DC motor to rotate the coil assembly connected with an incremental encoder at the other end and a digital integrator (PDI-5025) for flux measurement. For the alignment of the magnet, six strut system attached to the magnet base along with five dial indicators are used.

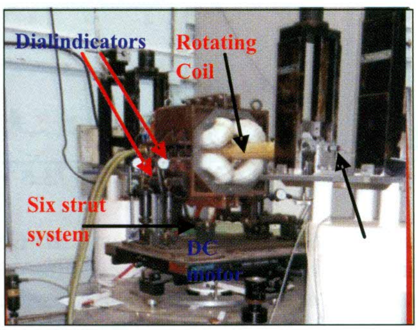

Fig. A.11.1: Harmonic bench setup

When the coil assembly is rotated inside a magnet bore, the induced voltages are measured and integrated (flux) as a function of rotation angles using the integrator. The measured data are then analysed by performing a Fourier analysis.

$$\int V dt = NLR_{ref} \sum_n \left(\frac{R_{coil}}{R_{ref}}\right)^n (a_n \cos(n\theta) + b_n \sin(n\theta))$$

where N, R_{coil} and L are the number of turns, radius of the coil and effective length. R_{ref} is reference radius, $a_n=nR_{ref}^{\,n-1}A_n$ and $b_n=nR_{ref}^{\,n-1}B_n$ are the skew and normal harmonic coefficients respectively. $n=1,2,3..$ are the dipole, quadruple and sextupole ...etc. components. The rotating coil assembly was developed and calibrated in collaboration with CERN and it consists of 4 long and 3 short coils. Four long coils are used in various combination to compensate the main component to improve the accuracy of the higher order multipoles which are typically $<10^{-3}$ of the fundamental component. Two end short coils and one center short coil are used for the axis alignment and strength estimation at the centre respectively.

A transfer line-3 (TL-3) quadrupole magnet was first measured in ESRF bench and the measured data were compared with the measurement done in RRCAT bench. The integrated strength ($gl=2B_2$) of the magnet is 3.45 T @ 150 A. In Fig. A.11.2 and Fig. A.11.3, the ratio of the higher order multipoles to the main strength (b_n/b_2 and a_n/b_2) Vs n (n=1,2,3,….) measured in ESRF bench and in RRCAT bench ($R_{ref}= 32$ mm) are shown at two different excitations (b_2/b_2=1 not shown). The results of the higher order multipoles measured in RRCAT bench are found in very good agreement with those obtained using ESRF bench.

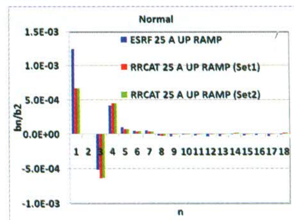

Fig. A.11.2a: bn/b2 at 25 A up ramp.

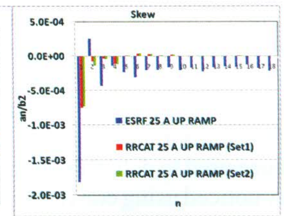

Fig. A.11.2b: an/b2 at 25 A up ramp.

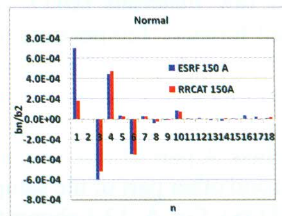

Fig. A.11.3a: bn/b2 at 150 A up ramp.

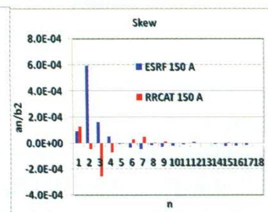

Fig. A.11.3b: an/b2 at 150 A up ramp.

The absolute differences in the ratios of normal higher order multipoles to the main strength found from the two measurement setups is $\leq 1 \times 10^{-4}$ at all excitation levels up to 150 A except at 25 A (up ramp) and 75 A (down ramp) where the measured results of RRCAT bench differ by $<1.5 \times 10^{-4}$ for b_3/b_2 and b_4/b_2 from measured results of ESRF bench. The magnet can be aligned (with the axis of the rotating coil) easily with precision of Δx and Δy (center deviation) < 10μm and rotation angle deviation of $\Delta\theta \leq 0.2$ mrad with the use of the six strut system and dial indicators. In the present case, at 150 A, the magnet was aligned with deviations of Δx and Δy < 5 μm and $\Delta\theta \sim 0.02$ mrad in RRCAT bench and in ESRF bench (with automated alignment system) it was aligned with deviations of $\Delta x \sim 24$μm, $\Delta y \sim 1$μm and $\Delta\theta \sim 0.075$ mrad.

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