

ACCELERATOR PROGRAM

A.1 Assembly and test of beam transfer line-3 meant for electron injection into Indus-2

Beam transfer line 3 (TL-3) is the extension of beam transfer line 2. Electrons extracted from the booster synchrotron are transferred to Indus-2 through these lines. This line starts after the second bending magnet of TL-2 and ends at the injection septum of Indus-2 as shown in fig. A.1.1. It has been designed keeping in view the beam optics requirements and the location of the Indus-2. As the length of the line is around 68.2 m long, the optics has been chosen in order to keep the number of magnetic components and their power supplies to a minimum while keeping the beam sizes within acceptable values. This line has 3 bending magnets and 18 quadrupoles. To cover major length of the line with a symmetric structure, a FODO cell has been selected as it satisfies all the necessary requirements. Driven by a single power supply, this cell has been repeated four and half times. As it is necessary to change the direction of the beam after crossing the Indus-1 wall, while suppressing the dispersion, a double bend achromat has been introduced in the line. Six quadrupoles at the end of lines are used to match the twiss parameters at the injection point of Indus-2. These six quadrupoles are all independently powered and can be varied in a wide range to change the beam parameters at the injection point as per the injection requirements. A bending magnet has also been used at the injection point to suppress the dispersion generated by the septum magnet. In order to keep the beam well aligned along the design path, there are 11 horizontal and 12 vertical steering magnets. Besides, the line also has eight beam profile monitors and four wall current monitors to observe the beam profile/position and intensity respectively.

While the installation work was going on in the Indus-2 ring, to crash the time required for commissioning, it was decided to carry out trials to transport the electron beam through TL-3. In order to pursue this activity, the line was

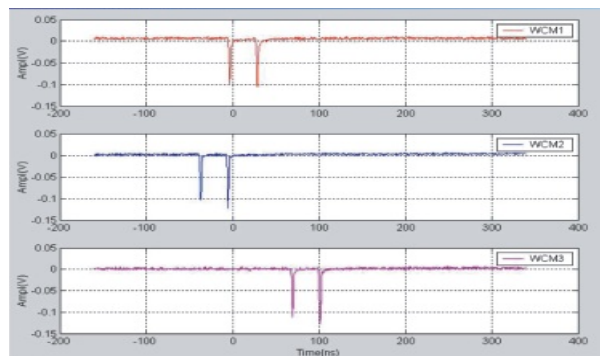


Fig. A.1.1 A schematic giving layout of components in the Transfer beam lines 2 and 3

terminated near the injection point at a beam dump as shown in fig. A.1.1. On May 4, 2005, a 450 MeV electron beam was injected into the TL-3. The electron beam was transmitted up to the beam dump easily. The magnet currents were close to the fitted values based on the measured field data for various magnets. Three Wall Current Monitors measured the intensity of the beam. The equal heights of the three current pulses as shown in fig.A.1.2 indicate that almost entire beam was transmitted through the line. Vacuum in the line was of the order of 10^{-9} mbar.

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A.2 Estimation of elastic couplings in the short straight section of LHC during alignment involving jack movements

Six meters long, twin quadrupole short straight section (SSS) of the Large Hadron Collider (LHC) may suffer from elastic coupling between its cold mass and cryostat during the alignment involving jack movements. The forces responsible for this relative displacement stem from finite stiffness of interconnection bellows and metal hoses of the internal piping of the jumper connection and from relatively flexible 'glass fibre reinforced epoxy' (GFRE) composite supports of the cold mass. In addition, the vacuum jacket of the jumper connection and the large sleeves attached to both ends of SSS produce elastic deformations of the cryostat vessel. A unified finite element model consisting of cryostat, large sleeves, vacuum jacket of jumper, interconnection bellows, internal piping of jumper, composite cold supports and alignment jacks using beam, link, shell and solid elements and constraint equations was developed at CAT under

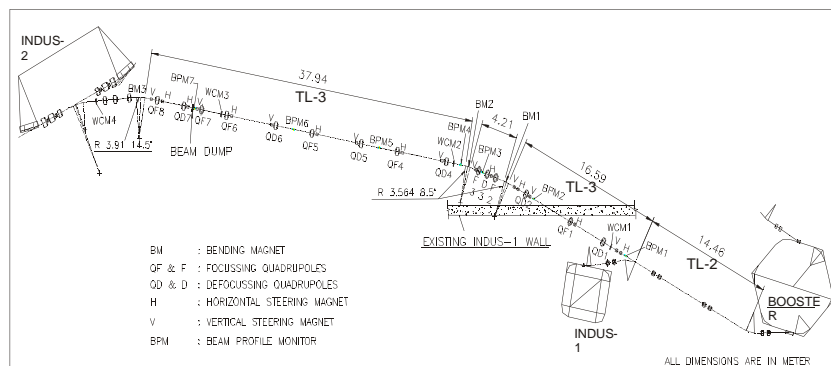


Fig. A.1.1 A schematic giving layout of components in the Transfer beam lines 2 and 3

DAE-CERN collaboration. To validate this complex model, dedicated experiments at CERN were carried out.

The tuned FE model gives out a relationship between the individual jack movement and cold mass positions (fig. A.2.1). The results are being used during the installation phase of LHC (fig. A.2.2).

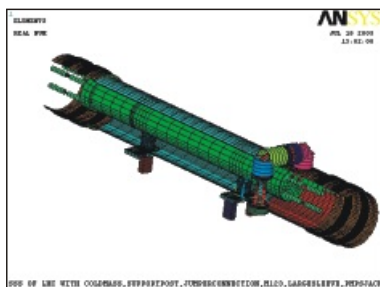


Fig. A.2.1 Finite Element Model of SSS



Fig. A.2.2 A picture of SSS in string-2 of LHC

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A.3 Motorizable high precision motion adaptors and jacks for inner triplets of LHC

After successful development and supply of compound motion alignment jacks for LHC arc magnets, CERN and CAT agreed to extend the work for the inner triplets of the LHC under DAE-CERN collaboration. The inner triplet system provides the final focusing of the proton beams before collision at four locations in the machine. Each inner triplet consists of 3 quadrupole optical elements. The quadrupoles of the inner triplet focus the beams to small spot sizes, about 0.016 mm. The alignment resolution (horizontal / vertical axis) required is less than 0.01 mm for these 18 ton magnets. In addition, the alignment has to be done remotely during small beam-on maintenance intervals.

The added requirements for the inner triplets jacks were the higher setting resolution of 0.01 mm, development of adaptors for motorization of jacks in vertical and transverse

directions, and short mounting and dismounting time for the adaptors due to high radiation environment.

The work done includes enhancing the setting resolution of 0.05 mm of the arc jacks to the inner triplet requirement of 0.01 mm, development of a compact mechanical adaptors and developing the interfaces for motorization.

The vertical adaptors are extremely compact precision lifting devices having a high load capacity of 10 tons and setting resolution better than 0.01 mm. Three different concepts based on wedges-on-rollers, screw driven by gear train and using a polyurethane block as hydraulic fluid were developed. A pre-series of eight adaptors were made after thorough testing of adaptors based on different concepts and selection of polyurethane based concept for implementation. These adaptors are assembled with the jacks, and two-stepper motors- one each for vertical and transverse movement- is coupled to these adaptors. Three such jacks support each magnet. The integrated alignment system consisting of jacks, pre-series vertical & transverse adaptors (supplied by CAT, and motors and its control unit provided by CERN), was successfully tested on a dedicated test set-up under a CAT-CERN joint test campaign in June 2005 at CERN.

A total of 74 of the 80 modified jacks required for the inner triplets have been supplied to CERN (fig. A.3.1- A.3.2). Series adaptors, numbering 130 units will be sent by the end of November 2005 to CERN.

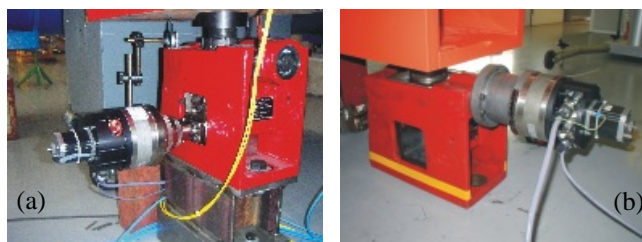


Fig. A.3.1 Vertical (a) and transverse (b) motorized jack with adaptor, under the triplet magnet during testing



Fig. A.3.3 Inner triplet magnet Q3 on its jacks

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