BEAM DIAGNOSTIC COMPONENTS FOR SUPERCONDUCTING CYCLOTRON AT KOLKATA

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Abstract

VEC Centre Kolkata has constructed a K500 superconducting cyclotron (SCC). Several beam diagnostic components have been designed, fabricated and installed in SCC. In the low energy beam line, uncooled slits, faraday cup, beam viewers, and collimators are used. The inflector is also operated in a faraday cup mode to measure the beam inside SCC. The radial probe and viewer probe are respectively used to measure beam current and to observe the beam size and shape inside SCC. The magnetic channels, electro-static deflectors and M9 slit are also used to measure beam current at the extraction radius. Water cooled faraday cup and beam viewers are used in the external beam line. The radius of curvature of the radial probe track was reduced to align the internal and external track during its assembly. It was observed that the probe did not functioning properly during beam trials. Different modifications were incorporated. But, problem with the probe persisted. The paper describes the beam diagnostic components used in the cyclotron, discusses the problems faced in operating the radial probe, modifications tried and outlines the future steps planned to operate the beam diagnostic components.

INTRODUCTION

Beam diagnostic components are used to detect various parameters of the beam of charged particle as it is transported from the ion source to the superconducting cyclotron, accelerated within it and finally extracted from the cyclotron.

BEAM CHAMBER DIAGNOSTICS

The charged particles are axially injected at the centre of the cyclotron and an electrostatic filed is applied across the electrodes of a spiral inflector to inflect the particles at the horizontal median plane of the cyclotron. The inflector can also be used in diagnostic mode to detect the beam injected at the cyclotron centre by measuring the beam current on the electrodes.

Main Probe

The main probe is the most sophisticated diagnostic instrument used for tuning the internal beam from central region up to extraction radius. It consists of a vertical array of three electrically isolated probe segments which measures the distribution of charged particles across the median plane and a differential wire which provides information on the centering of beam. The probe is inserted within the beam chamber along a curved path through the 27 mm aperture between liners along the center of the hill. The probe is a 1100 mm long assembly of several carts and links connected end to end using hinged joints and flexible enough to follow the slotted track. Two guide wheels are mounted at the bottom of each cart which are inserted into the 3.2 mm deep slot of the track so that the probe can follow the track contour as its rear end is pushed to and fro with a linear drive system [1]. The track consists of a curved and straight segment connected together with a transition track. Curved track is brazed on the liner and straight portion of track is laid through the radial penetration of the beam chamber. Probe carts are provided with a spring loaded top wheel which is kept in contact with the upper liner. The downward force due to compression of the spring prevents any upward movement of the probe from the track.

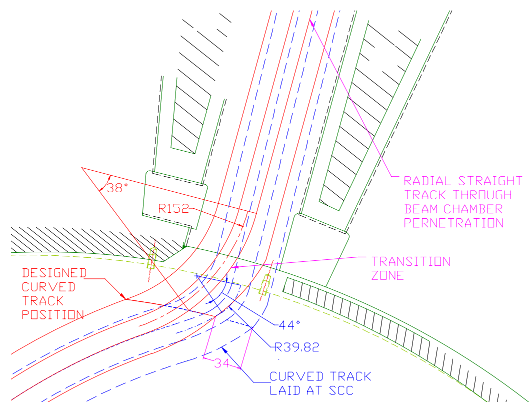

Figure 1: Change in main probe track

It was observed during assembly of magnet with cryostat that the curved track was shifted by 34 mm from the straight track (Fig.1). In order to accommodate this error, the radius of curvature of the transition track was reduced to 38 mm instead of its designed value 152 mm. It was found during initial operations of the probe that the guide wheels were severely worn and finally dislodged on track causing malfunction of probe. Design modifications e.g., change of material of the guide wheel shaft from phosphor bronze to stainless steel and use of larger circlip (6 mm) to clamp the guide wheel shaft with the probe carts were implemented to resolve the problem of disintegration of probe components. The modified probe used to go out of track (see Fig. 2) near the small curvature zone as it is pushed from the rear end and ultimately get trapped between the liners. The problem of derailed movement persists even after the probe was reconstructed with smaller link length so that it can negotiate smaller bend radius. The solid height of the probe was increased such that the space available in

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Figure 2: Main probe in derailed condition within the beam chamber.

between upper liner and probe top would not be sufficient for upward movement and subsequent failures. The modifications could not succeed due to variation of track height, varying inclination of the track and unevenness of the liner gap along the complete length of the track.

A theoretical analysis has also been carried out to assess the effect of lateral thrust on the probe near the transition zone. Lateral thrust would result in increase of frictional resistance against the probe motion and as it is pushed from rear end, the whole train tends to buckle and finally comes out of the track. The link angles are obtained corresponding to different position of link at the transition zone. The cosine components of this angle are multiplied to obtain the transmitted force (F2) and the remaining part causes lateral thrust only (Fig. 3). The lateral reaction force imparted by track on the probe links becomes significantly high as the radius of curvature is reduced (Table-1).

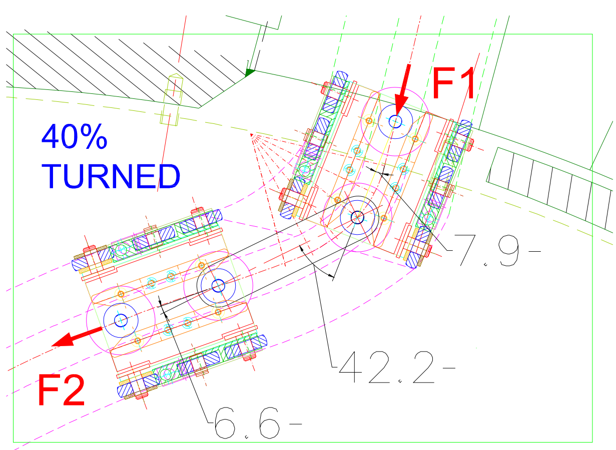

Figure 3: Component of link forces near transition zone

Viewer Probe

The viewer probe is used to observe the shape of the charged particle beam inside the cyclotron from 350 mm radius to extraction radius. A fluorescence is produced as the accelerated particles hit the zinc-sulphide (ZnS) screen of viewer probe and the illumination is brought out to the CCD camera placed out side the beam chamber using a small aperture borescope.

Table 1: Comparison of Thrust on Main Probe

Link Rotation	**Thrust component of driving force (F_1)**	
	At design curvature R = 152mm	At as built curvature R = 38mm
0% turned	0.19	0.24
20% turned	0.18	0.28
40% turned	0.15	0.27
60% turned	0.15	0.24
80% turned	0.15	0.23
100% turned	0.18	0.25

Magnetic Channels and M9 Slit

The electro-static deflectors, passive magnetic channels no. 1 to 8 are placed along the extraction path of the accelerated beam. These devices can be moved radially within a short span and current due to hitting of beam on these components can be measured to detect the beam trajectory.

M9 slit along with active magnetic channel no. 9 is placed within the yoke of the superconducting cyclotron magnet just before the external beam line. The gap between the slits determines the width of the beam to be delivered through the external line. The beam current measured from the electrically isolated slits can be used for optimising beam transport. M9 slit (Fig 4) is operated using a non conventional pneumatic circuit, since it is placed within a strong magnetic field. The slit opening can be varied from 2 mm to 26 mm through a closed loop control circuit consisting of a pneumatic cylinder, a current to pneumatic pressure converter, linear potentiometer and a control modules [2]. A pair of double acting pneumatic cylinders is used to move both slit jaws in either direction. Each cylinder is actuated by two current to pneumatic converter, which varies cylinder pressure according to the current input. The position of the slit is sensed by a linear potentiometer and fed back to the control module. The control unit compares the slit position with the set one and sends the forward signal to current to pneumatic converter.

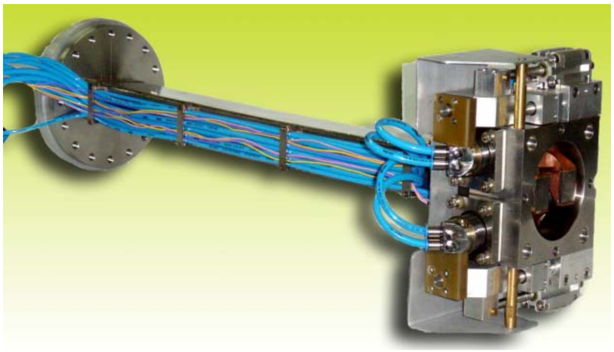

Figure 4: M9 Slit.

BEAM LINE DIAGNOSTICS

Beam diagnostic components installed at injection and external beam line are similar in principle except the addition of cooling circuit in the external line components to cater to the cooling required for higher beam energy.

Faraday Cup and Beam Viewer

Faraday cup is used to measure the beam current as well as deviation of beam from the center. when it is transported along the beam line. A nine segment disc with eight angular sectors and central one is used to detect the distribution of the beam in the injection line (Fig. 5).

Beam viewer is used to visualize the shape and size of beam at different locations of the beam transportation line. Fluorescence is produced when the beam strikes the zinc-sulphide disc. A camera placed at the view port helps to view the image in the control console

Faraday cup and beam viewer uses similar drive system comprising a double acting pneumatic cylinder of 100 mm stroke actuated by a two-way direction control valve. The diagnostic element is mounted on the carriage of linear drive system comprising three parallel guide shafts. It is inserted at the center during diagnostic mode and kept away from beam line during transportation of beam. End position feedbacks are obtained from two limit switches.

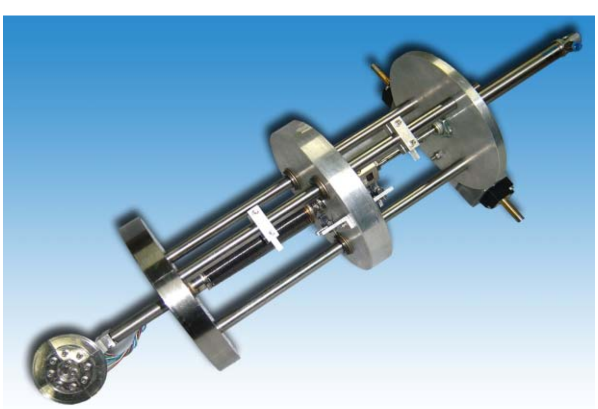

Figure 5: Faraday Cup used in low energy injection line.

Slit

Slits are installed at various locations of beam line to trim the beam width. Two electrically isolated copper jaws are mounted on two lead screws which are constrained to rotate but free to move axially (Fig. 6). The lead screw nuts are rotated by two independent motor drive and the lead screws along with the jaws slide over span of 20 mm from the mean position. Two rotary encoders are used to obtain the position feedback for each slit.

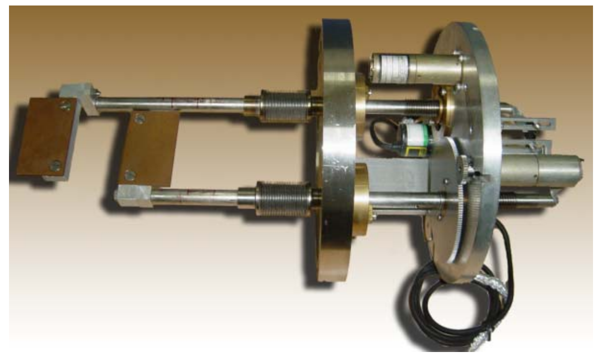

Figure 6: Un-cooled Slit.

CONCLUSION

- Problems were faced in operating the main probe. The following alternatives are planned.
  - ➢ A new cart has been designed, where welding has been completely eliminated and the downward spring force has been increased to restrain upward movement of the probe.
  - ➢ It is proposed to convert the open slot of the track in to a 'T' slot and design a new cart with its lower guide wheels moving inside the slot. The slot would not allow the probe to come out from the track.
  - ➢ Partial modification of contoured track on liner is also suggested. Feasibility of removing a part of curved track from the liner and reinstallation of the track with larger radius of curvature is also being studied.
- Viewer Probe having similar design as the main probe but without a track, M9 Slit, Faraday Cup, Beam Viewer and Slits are all functioning properly.

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