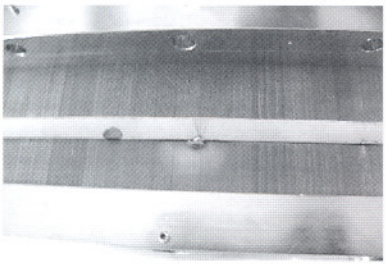
A.6: Machining of Septum Magnet Coils for Indus-2

Injection septum magnets are used to receive the electron bunch from booster synchrotron through Transfer Line-3 and inject the same into the Indus-2 Storage Ring after bending by around 21^0. These magnets have a parallel edge type core housed in a split stainless steel body.



FigA.6.1: Damaged coil-electrically shorted with core

In the year 2009, the magnet core was found to be electrically shorted with coil due to failure of alumina insulation on the coil (Fig. A.6.1). These coils are having intricate shape and size. Old coils were fabricated by brazing its independent parts. But this time we attempted to fabricate these coils by machining in single piece. This has reduced path resistance remarkably. 25 mm thick OFE copper (C10100) plate was used to machine all types of coils. There are two septum magnets in Indus -2 injection section, one (thick) of 19 degree, another (thin) of 2 degree. The effective length of thin septum magnet is 250 mm with bending radius 7162 mm, whereas the effective length of thick septum magnet is 860 mm with bending radius 2593.40 mm. The thin and thick septum coils are having septa of 1.5 mm and 3.00 mm at very large radius with dimensional accuracy of 0.10 mm

As the material of construction is OFE copper, machining of thin septa with large radius was a challenging job with conventional/ traditional machining process. OFE copper is considered to be the most difficult among copper and its alloys to machine. Multilayer coated carbide tools with high rake angle and built-in chip breaker geometry were used to obtain surface finish of better then 0.8 µm. Non-traditional machining (Electrical discharge machining-EDM wire cut machine with flush mode) was used for profile cutting to avoid distortions. The machining process was planned in such a way that the coil was machined in two settings on CNC milling machine for scooping as well as profile cutting for various thickness. Proper references were generated on top of plate before machining its bottom side. Both the ends (entry and exit) of septum coils have webs of 18 mm thickness with pocket opening for electron beam passage. End connection terminals are intricate in shape and size. EDM wire cutting machine was used to create small gap between their surfaces. Due care was taken to accommodate maximum numbers of coils in minimum size of copper plate. First, 4 nos. of coils (2 nos. thick and 2 nos. thin) were machined on CNC machining centre using G-code generated by UG Nx CAM software to get desired shape and size. Profile cutting was performed using flush type CNC wire cut machine. Proper fixtures were used to avoid deforming of coil due to internal stresses getting relieved. Another type of 2 nos. of thick septum magnet coils was machined with 2mm corner radius on septa. Manual part programming was used for machining of desired shape and size on CNC milling machine. Tailor made tools were used to machine the corner radius of 2 mm. A fixture was fabricated for alumina coating of these coils. It was observed that coating results were better when fixture was used during coating process. Special bending fixture was developed and used to achieve proper radius at end connections of coils. Use of proper cutting fluid invariably increases the level of possible cutting speed/feed, increases productivity, improves surface finish, enhances accuracy and lengthens tool life. Normally a light mineral oil or mineral oil containing 5% to 20% lard oil is used to get very fine surface finish. But to avoid straining, pre-final and final cuts should be cooled with kerosene or petrol. We have used M/s. Hougton make Hocut-B-60 semi synthetic cutting oil with anti bacterial agents. It has pH value of 9.5 @ 5% emulsion and mineral oil <50%. This was helpful in getting better surface finish without strains.

High Speed Steel (HSS) and tungsten carbide are normally used as tool materials for machining of OFE copper. Good surface finish along with high dimensional accuracies can be achieved using polished tool with correct rake angles. Feed of 0.02 mm/revolution with cutting speed of 35 to 40 m/min is normally used to achieve high precision. Tool wear in case of HSS tool is very high, which requires frequent re-sharpening of tool and this leads to inaccuracies. We have used ISO grade TiN coated carbide standard tools with built-in chip breaker geometry except for machining of corner radius of 2 mm, where HSS was only option available with us. The surface finish achieved was of the order of 0.8 microns (R_a) with stringent tolerances on all dimensions (Fig. A.6.2).

Fig. A.6.2: Machined septum magnet coil. Inset shows machining of end connections on EDM wire cut

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