SEPTUM MAGNET FOR ELECTRON SLOW EXTRACTION FROM THE YEREVAN SYNCHROTRON

A.Z.Babaian, G.B.Bagdasarian, V.Ts.Nickogosian, A.R.Toumanian, A.G.Zacharian
Yerevan Physics Institute, Armenia, USSR
E.A.Ludmirsky
Serpukhov, USSR
J.Rummler
DESY, German

1. Septum magnet for electron slow extraction

Electron extraction from Yerevan synchrotron is carried out by the buildup resonance of the circulating beam about the maximum of the magnetic guidfield [1].
The accelerated electrons by the buildup resonance are thrown behind the thin current sheet (of the septum magnet), which is located in the focal space between blocks 14 – 15. The spaces between synchrotron magnet blocks are about 0.7 m and it is not enough to extract 6 GeV electron beam within one space. That is why the extracted electrons after septum magnet get into the working region of the bending magnet, set into the defocal space between blocks 17 – 18. The bended part of the beam is extracted outside of the accelerator magnetic field to the beam transport channel.
The Yerevan synchrotron modernization program foresees the increase of the slow extraction time first from 2 to 10 msec and then up to 20 msec for the 6 GeV electrons. Increasing of the extracted beam time requires more reliability of the septum magnet, because of the release of heat on the thin current sheet.
The following technical points have been used in the operating septum magnet, which ensures extracted beam time only up to 2 msec. Magnetic circuit, current sheet and cooling system as well as horizontal tuning device are installed in the vacuum chamber of the accelerator. In this case magnet is becoming bulky, with a large number of communications in the vacuum chamber. The main feature of the recent developed septum magnet (Fig.1) is that the magnetic circuit return conductor of excitation winding as well as the water communications are put out of the accelerator vacuum chamber . The tuning device is out of vacuum chamber too. The above mentioned technical points used in the given construction ensure high reliability, low gas emission into the vacuum chamber and simple operation [2].
The main parameters of the magnet line are given in the Table 1.

Table 1. Main parameters of the septum magnet

Physical parameters

Extraction energy, GeV	6
Deflection, mrad	4
Magnetic strength, T m	0.08
Magnetic field, T	0.16
(at the magnet center)	

Electrical parameters

Exitation current, A	13
Septum copper cross-section, mm^2	5.95
Return conductor cross-section, mm^2	50.29
Septum current density, A/mm^2	218.5
Return conductor current density, A/mm^2	25.9
Septum impedance, mΩ	1.62
Septum voltage, V	21

Mechanical parameters

Gap height, mm	7.4
Septum thickness, mm	0.7
Gap width, mm	30
Magnet iron length, m	0.5

2. Magnetic circuit

Magnetic circuit of septum magnet consists of a C-shape (1) and kovar plate (2). C-shaped part is made of electrical sheet steel and is laminated of sheets of 0.35 mm thick. The laminations are isolated with radiation resistant mica type of 20 μm thick.
The poles are parallel with the 0.05 mm accuracy. Magnet is laminated into the 500 mm length package in the special device ensuring the accurate assembling. For making the package the device having the parallel base surfaces of 0.05 mm all over its length is stacked up by the alternating ferromagnetic laminations and mica type and is fixed by two sides. Afterwards the fixed package is installed into the frame and filled in with epoxy resin. The frame is fixed to the vacuum tank by the screws 4 and 5.

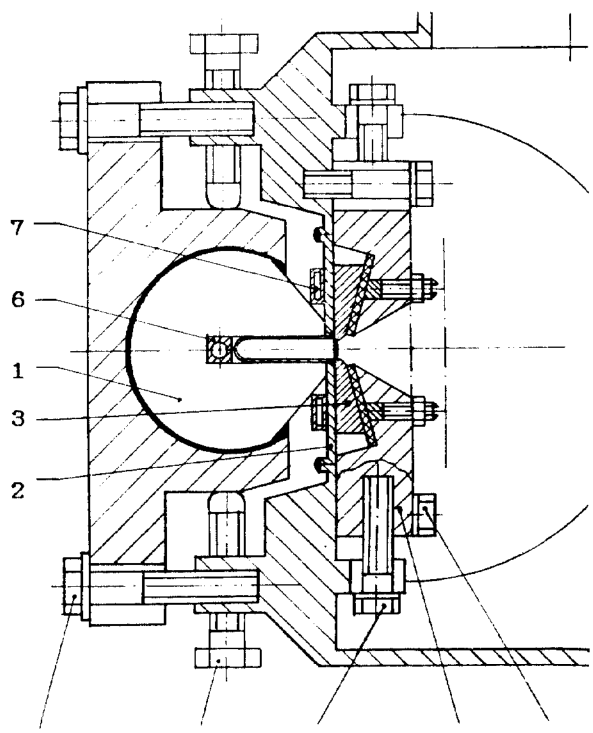


Fig.1 Septum cross-section
1 - Magnetic circuit
2 - Kovar plate
3 - Septum
4,5 - Frame fixing screws
6 - Return conductor
7 - Cooling tube
8,9,10 - Transverse stretcher

0-7803-0135-8/91$01.00 ©IEEE

Kovar plate carries out double function. On the one hand it is continuation of the magnetic circuit due to its good magnetic characteristics. On the other hand kovar is well welded to the stainless steel. Kovar plate is preliminary straightened then after soldering a cooling copper tube (7) to it is ground from the outer side. The deflection of the plate from the ideal plane is not more than 0.05 mm after welding.

3. Excitation winding

One turn excitation winding consists of two parts: thin septum part (3) and return conductor (6), which is out of the vacuum chamber. These two parts are connected into one turn with a special connector out of the vacuum chamber.

The thin current sheet is made of copper perforated strip. The thin part of it has 0.7 mm of thickness and 8.5 mm of height. The perforated part has the shape of rectangular trapezoid. The sides of the current sheet are in the thermal contact with kovar plate, which is soldered to the cooling copper tube. The shape of the current sheet ensures the conductive transition of the heat from the central part to the periphery parts. Besides, the thin sheet is being stretched transversely by the holding plate (8) and screws (9,10). That compensates the thermal deformation of sheet to reduce its effective thickness. The analogous longitudinal stretching of the septum during its installation eliminates its longitudinal deformation.

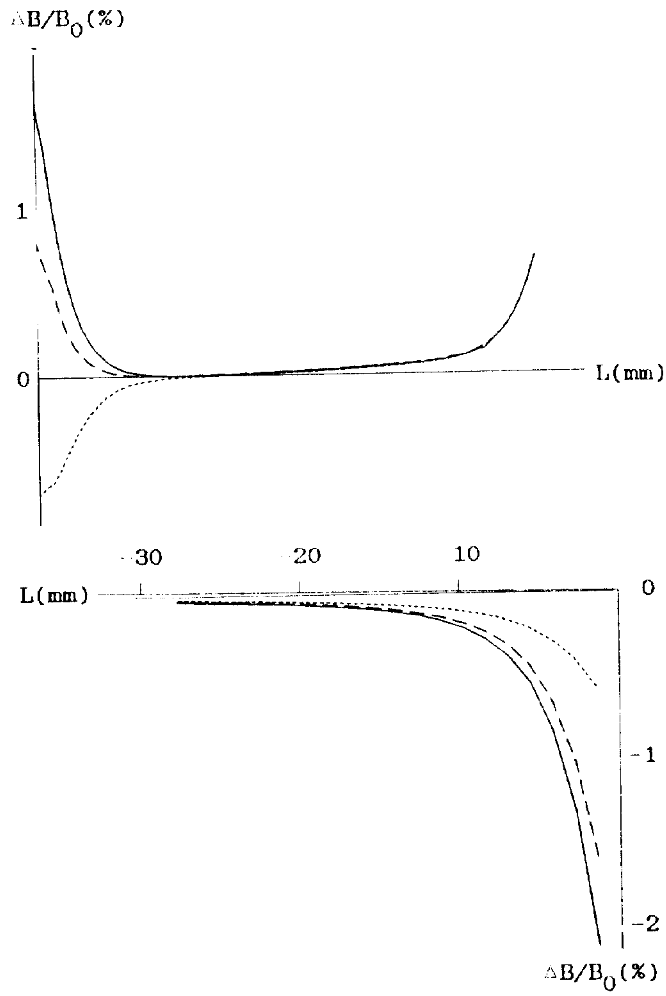
In Fig. 2a is shown the dependence of the magnetic field distribution in the septum magnet aperture. In Fig. 2b are shown the scattering fields from the outside of the sheet for the different values of the sheet height h . Calculations were carried out for different values of h within 8.5 - 8.9 mm. The best value of h, at which the magnetic field uniformity in the working region is 0.5% and the field value outside the septum sheet is minimal, is 8.5 mm.

In the longitudinal direction the wide and narrow parts of the perforated section of the current sheet are alternating. In this case the impedance of the whole current sheet is defined not only by its length (which is equal to 8.5 mm) but also by the value of the additional ohms resistance of the transition, conditioned by the width and height of perforated part of the sheet [3]. The height of the perforation side is chosen with account of additional resistance value and effectiveness of its peripheral cooling.

4. Vacuum chamber

Vacuum chamber of the septum magnet consists of two parts. The separate stainless steel vacuum chamber with the wall thickness of 5 mm is installed in the gap of the electromagnet to extract the electron beam. It is welded all over the length with the kovar plate as well as to the stainless steel vacuum tank by the other end. The chamber by its edges is welded to the vacuum tank end faces, which shapes are identical to the transverse shape of the chamber. Vacuum chamber while pumping down is being deformed under atmospheric pressure. The maximal deformation value in its middle would not exceed 0.3 mm for the plate. I.e. the chamber vertical effective size is 7.4 mm. On the other side of the return conductor is the main vacuum chamber of the circulating beam which occupies inner volume of the vacuum tank. The rectangular shape of the tank allows to have rigid construction as well as an opposite wall removable which is very helpful in assembling and adjustment and in future it will be useful for operating septum magnet.

Vacuum pumping down is carried out by the pipe which is connected with the vacuum tank by the branch pipe. The vacuum tank is connected with the synchrotron vacuum chamber via elliptical bellows. That allows the move of septum magnet along radial coordinate for ± 5 mrad. The septum magnet is tuned by the remote control.



b

Fig.2. The dependence of the magnetic field distribution
a - in the septum
b - from the outside of current sheet
—— h = 8.5 mm,
- - - h = 8.7 mm,
.... h = 8.9 mm

5. Cooling of the current sheet

As it was mentioned above, the current sheet gets heated due to the big current density that`s why it is very important to have it cooled down. As the peripheral cooling system is used in the magnet the main requirement for extraction of the released heat is first - the transition of heat from its central part (effective conductor cross section for current flowing) towards the peripheral one (the perforated sides), and second - heat transition from the peripheral part to the cooling water. The first requirement is realized, as the whole septum conductor is made from one and the same material (copper), having high heat conductivity, the mass of its peripheral sides exceeds a lot of the mass of the current leader and the released heat is distributed uniformly all over the conductor.

For the heat transfer from peripheral sides to the kovar plate, a copper pipe is welded to its surface, it is necessary to have a good heat conduction contact. On the other hand it is required to have an electrical isolation of the septum magnet from kovar, otherwise there will take place a current spreading. To achieve that a thin mica type of 40 nm is installed between them.

References

[1] V.P.Belov, A.A.Makarov, G.A.Martirosian, V.Ts.Nickogosian, K.A.Sadoian, I.A.Shukalo - ННИЭФА П-Е-0776, М. 1988, (in Russian).

[2] J.Rummler, A.Babaian. In-and Ejection at the Yerevan Synchrotron and Stretcher. DESY M 90-93.

[3] Ju.M.Ado, E.A.Ludmirsky [illegible] 87 30, 1987, (in Russian).