SOME ASPECTS OF THE SUPERCONDUCTING MAGNETS DESIGN FOR HIGH ENERGY PROTON SYNCHROTRONS

Alexeev V.P., Meshcherov R.A., Mironov E.S. and Vasiliev A.A.
Radiotechnical Institute of the USSR Academy of Sciences, Moscow, USSR.

Abstract

The RTI superconducting program related to proton synchrotrons and the present situation of this work are described. Some problems of the pulsed superconducting magnet design are discussed in this paper.

The study of the high energy cybernetic accelerator has been carried out for some years at the Radiotechnical Institute of the USSR Academy of Sciences[1,2,3,4]. The use of the automatic control techniques allows to decrease orbit deviations from the vacuum chamber axis and thereby to decrease the magnet cross section. The automatic control methods along with the advanteges given by superconducting magnets could result in building high energy small aperture accelerators with the reduced cost in future.

The objective of the program being currently effected at the Radiotechnical Institute is the feasibility study of a superconducting cybernetic accelerator for the energy exceeding 1000 GeV. It is planned to design superconducting dipole and quadrupole magnet prototypes to study questions concerned with ensuring the low level ac losses, the construction simplicity and structural dimensions stability in time, provided the magnet is affected by dynamic forces and thermal cycles.

It is supposed to have a very long rise time of the magnetic field in the superconducting high energy accelerator (accelerating time - tens of seconds). The long rise time of the field not only decreases losses in superconducting windings but also simplifies the cryostat, the vacuum chamber and the iron screen surrounding the superconducting coil.

The pulsed dipole magnet not longer than 6 m with the aperture not larger than 6 cm is the main magnet element of the superconducting accelerator. The adopted research program provides for the design of its models. The starting experiments were carried out with pulsed solenoids yielding fields of up to 45 kG[5]. Then a 40 kG 70 cm long dipole magnet with a 8 cm diameter winding aperture was designed[6]. It is intended for the comparison of the calculated field in the dipole and the actually obtained one. The magnet construction provides a cosine distribution of 2-mm-diam conductors arranged in grooves on the thin walls of stainless steel cylinders. Such a construction makes it possible to locate winding conductors with a precision of 0.1 mm which is needed to obtain the desirable field homogeneity. One of the cylinders holding winding conductors is shown in Fig.1. A number of the magnet cylinders has been made for the present.

The magnet is placed horizontally in a cryostat (Fig.2). The cryostat design enables one to adjust the magnet inside

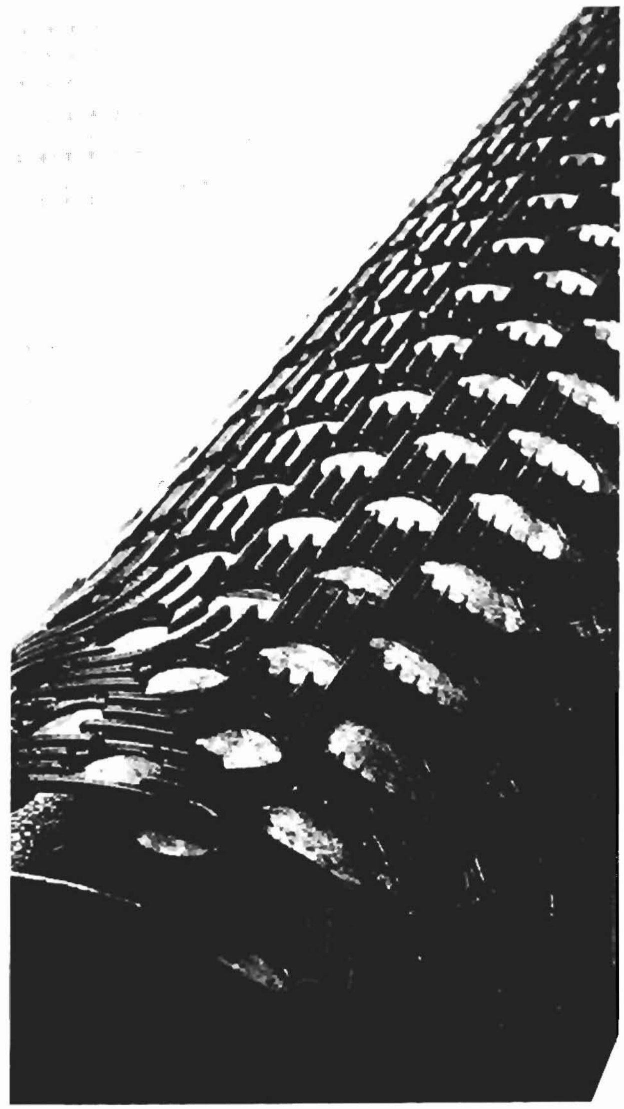

Fig.1. One of the dipole cylinders with grooves for the superconducting cable.

the cryostat with a precision of 0.1 mm. The cryostat peculiarity is that it is fully demountable with indium flanged tight joints. In spite of a great number of joints it displayed a good hermeticity in testing and proved to be quite suitable for tests of various experimental magnets.

The further advance of the superconducting magnet design for accelerators depends to a considerable extent on progress in solving such main problems as reducing hysteresis losses, heat removal, field precision in space and time, and radiation effects.

An efficient heat removal from pulsed superconducting magnets can be achieved by means of thin insulated wires used as "drains" and made of pure aluminium which has considerably higher thermoconductivity at liquid helium temperature than copper. An experimental pulsed solenoid with the heat removing "drains" is under design now.

In air-core magnets the field topography at the magnet ends is of importance. In order to find the field distribution in the dipole magnet the influence of winding ends was calculated using a computer program[7]. It has been shown that if the winding ends are like that in Fig.3 the relative difference of the field integrals along the magnet for various distances from the magnet axis can be reduced to few hundredths per cent, provided the relation between the curve radius and the aperture is optimal.

An estimation of the residual field due to a superconductor magnetization in the dipole shows that this field is small enough for the conductors with thin filaments but has a rather nonlinear distribution in the median plane of the magnet shown in Fig.4. Calculations of losses in superconductors made for wide range of fields and different filament diameters demonstrate that the losses below the penetration field are not proportional to the transverse superconductor dimension. The losses in some speciments having the same diameter but different field dependence of critical current density also differ[8].

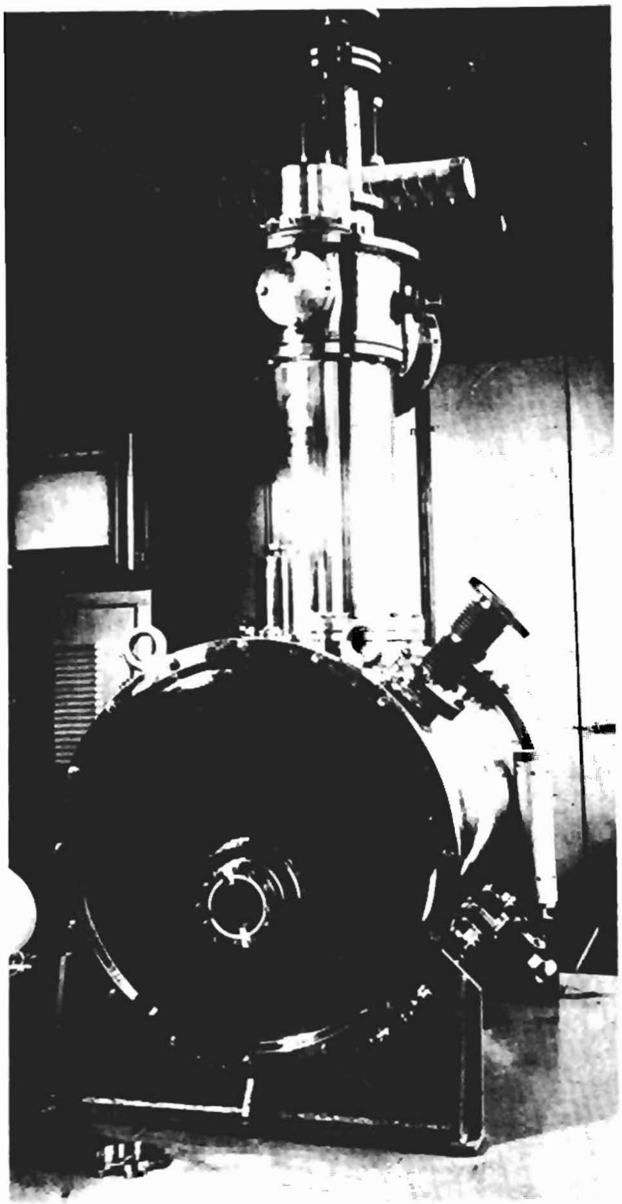

Fig.2. Cryostat with horisontal 5 cm warm bore.

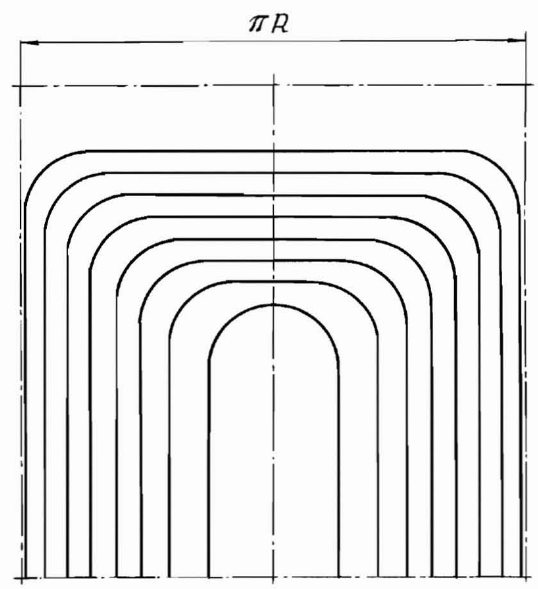

Fig.3. Schematic diagram of conductors distribution at dipole end.

In spite of the fact that there exist theoretical schemes of the ac losses calculation one can not design superconducting magnets without loss measurements. The cryostat designed for this purpose at the Radiotechnical Institute enables to measure the losses in magnets with a diameter of up to 160 mm and up to 30 cm long by means of a helium boil-off method. The cryostat has a dielectric inner enclosure connected with an outer one through a remote controlled valve opened in cooling down and closed in measuring. To diminish the device inertness the volume in which the gas temperature changes from 4.2°K to the room one was minimized.

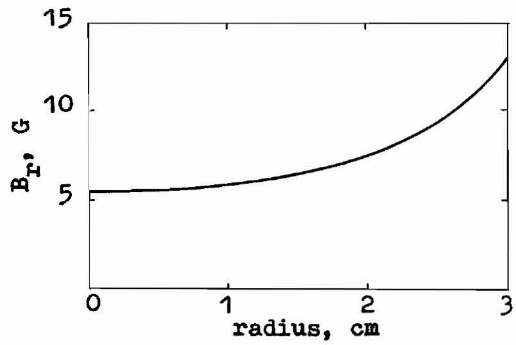

Fig.4. Residual field distribution in magnet median plane. Calculation has been made for 3.2 cm-thick winding, inner radius of 3.7 cm, superconductor packing factor of 0.2, superconducting filaments diameter of 3 μ.

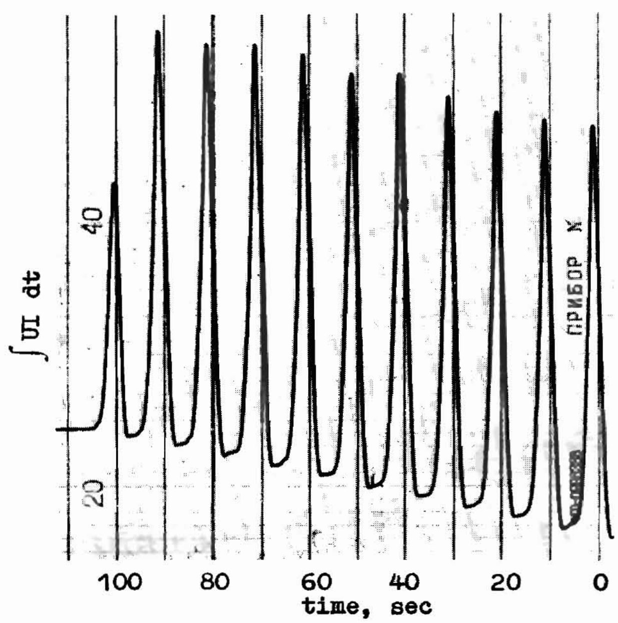

Fig.5. Output signal of electrical device for loss measurements.

It is reasonable to use an electrical loss measuring device with a Hall probe as a multiplier to have two independent measurement methods. An output signal of the electrical device obtained in measuring losses in one of the superconducting solenoids is shown in Fig.5.

Our future program provides for some extention of the research work. Particularly it is proposed to design the 2 m long pulsed magnet prototype.

The development tendencies of both ac and dc superconducting magnets display promising prospects of the magnets for accelerators. But there exists a number of important problems concerned with both construction of the magnets themselves and manufacturing high current superconductors to be solved.

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