3T SUPERCONDUCTING DIPOLE MAGNET WITH A HIGHLY HOMOGENEOUS FIELD

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Abstract

The calculated characteristics of a superconducting dipole magnet are given. The construction of the magnet is simple and economical one and provides a highly homogeneous magnetic field up to 3 T.

Introduction

A superconducting synchrotron magnet has to meet rather strict requirements in production cost, mass production possibility, operational reliability and magnetic field quality.

At the Laboratory of High Energies, JINR, SC magnets, which production is simple and available for realisation in the laboratory conditions, are studied within the years. The magnets provide high quality pulse magnetic fields with an amplitude up to 2T[1,2]. In the paper the description of the magnet, in which the field amplitude reaches 3T and all the 2T magnet design advantages are conserved, is given.

The possibility to get fields in the conventional magnet remaining uniform up to the 3T level was shown by Umstatter[3], but is not yet realised.

Design features of the 3T magnet

The basic idea of the 3T magnet with an iron yoke is to leave the induction at the 2T level when the field in the aperture increases to 3T. Due to this fact the yoke saturation effects are excluded and the field remains linear in all the induction range. Let us excite mentally fields in two window frame magnets with square aperture oriented at angle $\pi/2$ relative to each other, and superpose one magnet on the other. As a result, the fields in the working aperture are summarized, the total field increases $\sqrt{2}$ times while the induction in the yoke conserves the former value. After the superposition, as shown in Fig. 1, the currents in the crossed coil parts are subtracted in the pair of the diagonally placed corners, which diagonal is oriented along the resulting field, and summarised in the other. The last fact is the main difficulty for the magnet realisation. The proposed decision of the problem[3] is to increase the area of the coil by two where the double current density is needed. Then the values of the third and fifth harmonics can be minimized by choosing a and b coil parameters (see Fig. 2). The decision is complicated in practice because the coil shape, made of a flat SC cable, has no median plane symmetry. Another coil form conserving its symmetry was proposed[4] (Fig. 3). This form permits to control the high harmonic values, but the complicated coil configuration makes difficult its mass production. By doubling the current density in the corner turn and shaping it to an isosceles right-angled triangle, one would get a symmetrical coil and at the same time reduce to zero the value of almost all the high harmonics. For this, it is sufficient to reduce by one half the current density in the rest of the coil turns by doubling the cross section area of the cable, of which the turns are made. This is possible by inserting in the SC cable the same number of conventional conductors as the number of the SC conductors in a triangle cable.

Magnetic field computation

The cross section of the magnet under discussion is shown in Fig. 4. Its coil contains 26 turns. The turns are made of a square SC cable of 4x4 mm^2, including insulation, that consists of 3 SC 1.5 o.d. conductors and 3 conventional copper conductors of the same diameter (Fig. 5b). There are also two turns of the triangle SC cable in the coil (Fig. 5a). The main magnet parameters are listed in Table 1.

Table 1.

Maximum magnetic field	T	3.0
Maximum coil current	A	6.8
Number of the coil turns		28
Aperture of the magnet	mm^2	55x55
External dimensions of the magnet	cm^2	25x15
Cross section SC cable area: square	mm^2	3.7x3.7
triangle	mm^{22}	3.7x3.7/2
Diameter of the SC filements	μm	16
Store energy of the magnet	kJ/m	11.9
Inductance	mH/m	0.53

The field in the dipole was studied with two computational programs permitting to find two- and three-dimensional field distribution. The comparison of the third harmonic relative values computed with the two-dimensional program POISCR[5] at 0.7 radius of the magnet aperture is shown in Fig. 6 for the magnet under discussion and the 2T one. The dependence $\mu(B)$[6] was used in computation for the Fe + 3.25% Si steel. As seen, the iron yoke saturation becomes noticeable when the field level exceeds 2.5T. The third harmonic value is 0.2% at 3T and the values of the highest harmonics are lower than 0.01%. The field distribution in the magnet working aperture and the distribution of the induction in the yoke is given in Fig. 7. There is also shown the coil geometry as it is represented by the program POISCR. The high resolution of the representation is evidently insufficient, especially for the triangle turn. Namely, the last fact causes some trouble at a three-dimensional computation with the program MAGSYS[7]. The results of the computation are given in Fig. 8. It is seen that the field is uniform enough inside the magnet and there are considerable nonliniarities only at the magnet ends. These computations were performed for the simplest one-layer coil geometry and several values of radius R of its bend at the magnet ends. The further optimisation of the end coil geometry permits to decrease the nonliniarities.

Conclusions

The given results of computation show that the highly uniform magnetic field is attainable in the proposed magnet and simultaneously the magnet retains all the design advantages of the 2T one.

Literature

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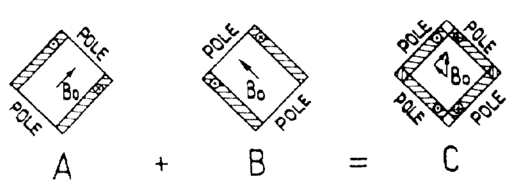


Fig. 1.

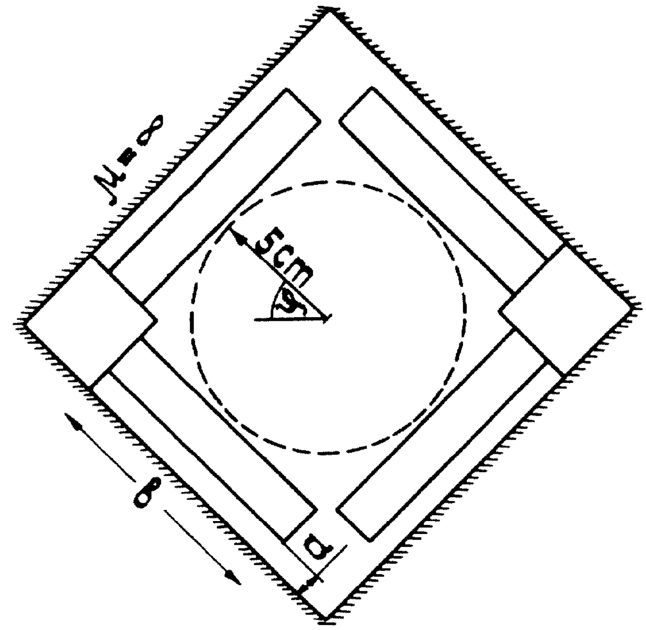


Fig. 2.

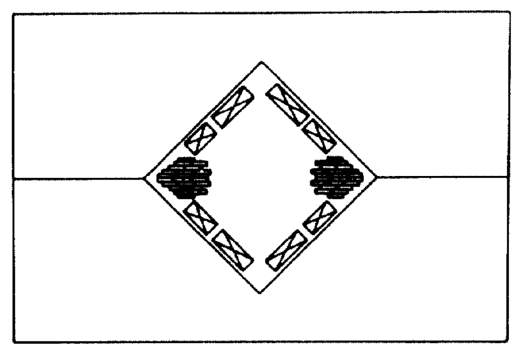


Fig. 3.

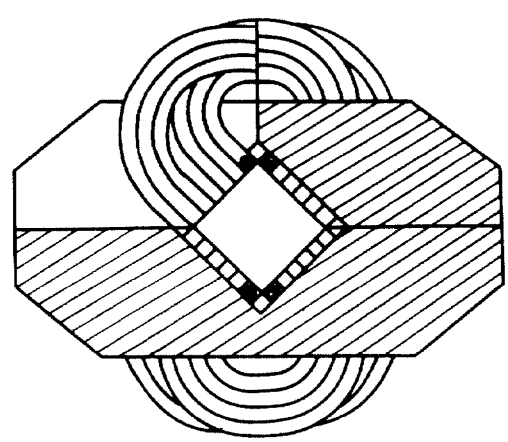
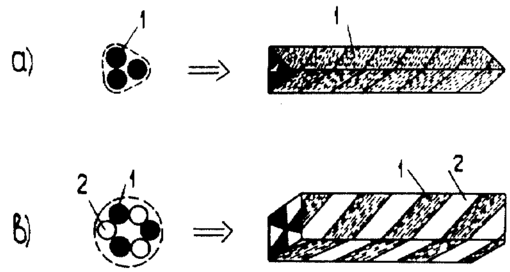


Fig. 4.



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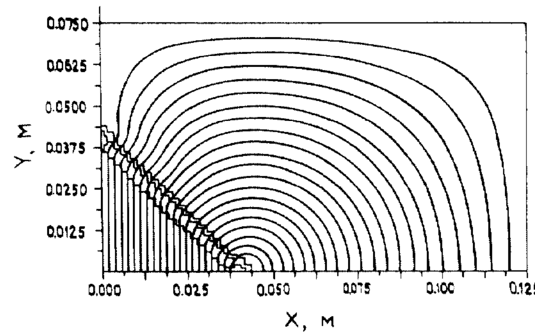

Fig. 7.

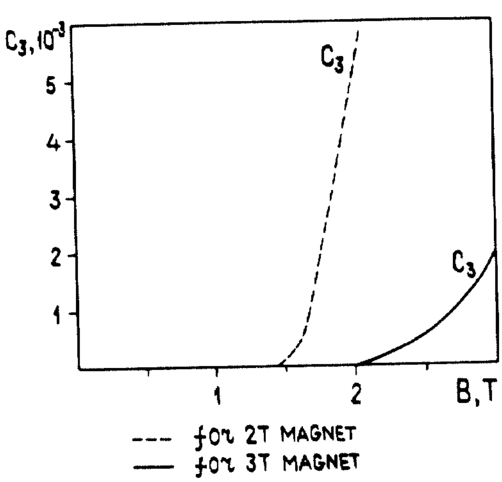

Fig. 6.

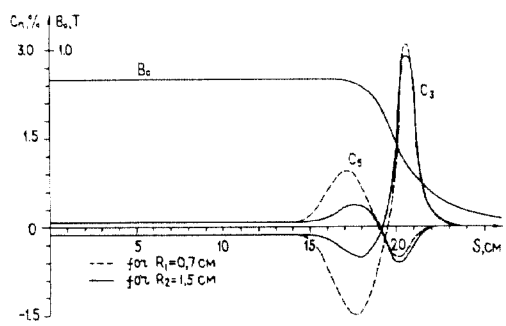

Fig. 8.