FERROMAGNETIC INSERTS INCREASING THE FIELD OF A SOLENOID

P. Genevey, G. Neyret, A. Sagniez, B. Turck

To cite this version:


HAL Id: jpa-00223641
https://hal.archives-ouvertes.fr/jpa-00223641
Submitted on 1 Jan 1984

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
FERROMAGNETIC INSERTS INCREASING THE FIELD OF A SOLENOID

P. Genevey, G. Neyret, A. Sagniez and B. Turck

C.E.A./Saclay, DPhPE/STIPE, 91191 Gif-sur-Yvette Cedex, France

Abstract - During the last ten years, lots of test facilities providing fields up to 7 or 8 T have been built. The present development of superconducting devices needs short sample measurement in field up to 9 or 10 T. The use of 2 ferromagnetic inserts in the bore of the solenoid allows a cheap, simple and reliable increase of the field in the gap up to 2 T. This increase depends on the used material, the width of the gap and the diameter of the inserts. Our system consists of a set of two cylindric pieces of a 25% Cobalt alloy, 149 mm in diameter providing a 10 mm gap, which results in a increase of the field in a 190 mm useful bore coil, from 7.2 to 9.2 T. The so modified coil allows two hairpin samples to be measured in the same run.

In most laboratories, superconducting magnet (bubble chamber, accelerator magnets) have been generally designed to generate fields up to 7 T. The test facilities have been designed accordingly to qualify conductor by short sample tests in the field range. Fusion programs (Tore Supra, M F T F) require magnets working at 9 T. or more. The construction of test facilities in this range is expensive. It seems interesting to use available test facilities by introducing ferromagnetic concentrators to increase the field in a gap where the short sample is located.

The possibility to increase the magnetic fields by ferromagnetic concentrators is well known but has seldom been used at liquid helium temperature /1/. Using two iron cobalt alloy blocks put in the inner part of a solenoid, we have increased field from 7.2 to 9.2 T in a 20 mm gap.

A simple theory shows that, for two identical flat poles uniformly magnetized along the axis of symmetry, the magnetic field in the middle of the gap between the two poles can be enhanced by $\Delta B$.

$$\Delta B = M (\cos \theta_2 - \cos \theta_1)$$

* Work supported by the Association Euratom - CEA.

In most laboratories, superconducting magnet (bubble chamber, accelerator magnets) have been generally designed to generate fields up to 7 T. The test facilities have been designed accordingly to qualify conductor by short sample tests in the field range. Fusion programs (Tore Supra, M F T F) require magnets working at 9 T. or more. The construction of test facilities in this range is expensive. It seems interesting to use available test facilities by introducing ferromagnetic concentrators to increase the field in a gap where the short sample is located.

The possibility to increase the magnetic fields by ferromagnetic concentrators is well known but has seldom been used at liquid helium temperature /1/. Using two iron cobalt alloy blocks put in the inner part of a solenoid, we have increased field from 7.2 to 9.2 T in a 20 mm gap.

A simple theory shows that, for two identical flat poles uniformly magnetized along the axis of symmetry, the magnetic field in the middle of the gap between the two poles can be enhanced by $\Delta B$.

$$\Delta B = M (\cos \theta_2 - \cos \theta_1)$$

* Work supported by the Association Euratom - CEA.
Where $M$ is the magnetization of the material (2.1 T for a fully saturated iron and 2.4 T for a fully saturated iron-cobalt alloy) $\theta_1$ and $\theta_2$ are shown on figure 1.

![Diagram](image1)

Figure 1

This value gives a good approximation of the field enhancement. The main characteristics of the solenoid of the test facility are given in the table below:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful internal diameter</td>
<td>206 mm</td>
</tr>
<tr>
<td>Internal diameter</td>
<td>220 mm</td>
</tr>
<tr>
<td>Winding external diameter</td>
<td>300 mm</td>
</tr>
<tr>
<td>Length</td>
<td>390 mm</td>
</tr>
<tr>
<td>Central field</td>
<td>7.2 T</td>
</tr>
</tbody>
</table>

A cryostat is inserted in the bore of the solenoid which allows to introduce and remove the test assembly (see fig. 2, photo 1) (3 current leads, 2 ferromagnetic blocks, 2 short samples) without warming up and recooling the coil. Its useful aperture is 189 mm.

![Diagram](image2)

Figure 2 - Test assembly


Photo 1 - Test assembly
The magnetic material is an iron-cobalt alloy (AFK1 from Metalimphy). Its composition is: iron 74.2%, cobalt 25%, chromium 0.3%, manganese 0.5%. When fully saturated its magnetization is 2.4 T.

In our system, the upper block is not exactly axisymmetrical to provide room for the sample holder itself. The diameter of the blocks is 149 mm. The field has been calculated by a computer code. The depth of the gap has been chosen to obtain the 2 T enhancement and the best field homogeneity in the plane where the sample to be measured is located. Figure 3 gives the field homogeneity \( \frac{B(x) - B(0)}{B(0)} \) along the conductor axis, for a gap depth of 20 mm (\( B(0) \) being the field on the axis and \( B(x) \) the vertical component at a distance \( x \) from the axis). In the useful part \( x \leq 2.5 \, \text{cm} \) the field homogeneity with the ferromagnetic insert is the same as the one without. The use of shims can improve this homogeneity if needed.

The field has been measured by a small integrating coil and an integrator voltmeter with a low drift (photo 2). The device has been calibrated using coils whose field have been calibrated by N.M.R. The value of the field in the midplane is given in figure 4. The precision on the field is better than 5 \( \times 10^{-4} \). One problem is the remanent field \( B_r \), since integrating method can only measure the field variations and not the absolute value. We have observed that \( B_r \) is the same at 4.2 K and at room temperature and does not vary when the two blocks are taken apart and put again together in order to change the sample. The \( B_r \) value with a 20 mm gap is 0.004 T. In a 9 T field such an error becomes negligible.
Another problem arises from the magnetic forces when the insert is not exactly at the magnetic center. The insert is first put a little lower than the magnetic center with its mechanical support being free to move. When increasing the field the insert moves up to the good position, then the support is clamped.

A sample holder allows two hair pin samples to be measured in the same run. Two samples of the "tore supra" conductor have been measured in the 10 T test facility and then in this (7 + 2) T facility. The results are identical. (conductor: 2.8 x 5.6 mm², critical current at 9 T and 4.2 K: 1400 A).

As far as the short sample measurements are concerned this technique allows to increase the magnetic field of a test facility by about 2 teslas avoiding the use of an insert coil which decreases the useful bore of the test facility.

REFERENCES:


2 - S. Shimamoto and H. Desportes. 5th I C M T Roma 1975 p. 579