DEVELOPMENT OF HIGH TEMPERATURE SUPERCONDUCTOR MAGNET FOR DIFFERENT APPLICATIONS

My PhD project is inserted in the project named BISCOTTO born from the collaboration between INFN and CNR-SPIN.

The project BISCOTTO is focused on the development of superconducting canted solenoids involving HTS conductor. There are several important motivations and interested application fields, from the particle physics to medical to electrical applications, and the development of a cosine theta canted (CCT) solenoids based on HTS conductors would open new horizons in those areas. It can be also considered that the basic structure of the magnet is the same in all cases, even if geometrical dimensions and the magnetic field could be different depending on the application. As a consequence, the development of specific CCT has more general value.

The BISCOTTO's general aim is the development of key technologies to be involved in the design and construction of a superconducting cosine theta canted solenoid using HTS conductors. Since the present technology of HTS conductors shows that two types of promising conductor could be used (BiSCCO 2212 and MgB2 wires) and since the development of the magnet cannot be separated from the conductor, both a canted solenoid with BiSCCO wires and with MgB2 wires will be studied. It is worth mentioning that the development of technologies for HTS magnet has a more general value also beyond this specific objective because the use of HTS material for any kind of magnet layout (solenoid, toroids, …) would have a big impact in much wider fields.

In particular, in this collaboration the activities to be carried out within the BISCOTTO project are:

1) Development of a BiSCCO 2212 superconducting wire;
2) Design of a superconducting CCT involving both a BiSCCO wire and MgB2 wire;
3) Construction and test of small models for supporting the design choices.

The first year of my PhD was mostly focused on improving the transport properties of BiSCCO wires and became familiar both with the production technique and with the I_C measurement systems at CNR-SPIN laboratories. BiSCCO wires are made with the Powder in Tube (PIT) technique, which consists mainly of three steps: 1) filling of a metallic sheath with the precursor superconducting powder; 2) cold deformation of the so obtained composite tube down to a wire; 3) final heat treatment, the so called partial-melt-process in 1 bar Oxygen atmosphere for the formation of well-connected superconducting Bi-2212 phase. In the Bi-2212 case the metallic sheath has to be made by Silver, which is ductile and permeable to Oxygen. Moreover, PIT technique is easily scalable to large scale and industrial production. In the last years, evidences show that the main mechanism for limiting the critical current density J_c is related to bubbles formed during the heat treatment (HT) in the melting phase, whose diameter might be compared with the one of the superconducting filaments.

The cause of this problem is the low density of the powder and different approaches have been developed to increase it. In the last decade, at National High Magnetic Field Laboratory in FL (USA), the researchers started to apply a very high overpressure (OP) during the HT on commercial wire produced by Oxford Superconducting Technology and, applying a pressure between 50~100 bar pressure during the OP process, they reached an engineering critical current density J_e of about 1000 A mm^{-2} 15 T, rising it up the by 8 times.

The researcher at CNR-SPIN succeeded in inducing a higher powder compaction simply by acting on the deformation technique trough a suitable alternation of groove-rolling and drawing processes (GDG process) in certain stages of processing the wire. In these months we tried to optimize both the fabrication and the heat treatment of Bi-2212 wire. We explored different geometries of the wire, aiming to improve its filling factor and achieving maximum compaction, and we changed the alternation in the GDG process. We also studied how the whole melting time of the powders changes both the transport properties of the samples and affects the bubbles issue.

We achieve some transport properties improving, thanks to these works and thanks to the use of finer BiSCCO powders, rising up J_e by a factor 2 from ~300 A mm^{-2} to more than 600 A mm^{-2} at 7T. Therefore, we achieve the realization of wires with a J_E far beyond the minimum application requirements, set at 500 A mm^{-2} at the operative magnetic field.

Thank to this work, I become independent in all the phases of the wire iter: from filling the sheath with powders to the deformation process to the I_C measurements. I also continued to use cryogenics liquids, necessary for the transport measurements, getting more confident with them.

Due to the worldwide great difficulties in obtaining liquid helium supply, in the last months I also started to develop a pre-conceptual C++ code at INFN laboratories. Being intrinsically three-dimensional, the modelling of a double helical coils is very complicated and the development of such kind of code is necessary to understand how the magnet works. The magnetic field produced by two concentric helical coils cannot be analytically determined, but the problem can be approached by a numerical integration of the Biot-Savart law. The code I wroteis focused on solving the magnetostatic problem calculating the magnetic field in the centre of the CCT magnet, its dependences from the number of the windings and from the number of points used to do all the integrations. Being based on B-S law, the magnetic field calculated with this code diverges along the helices, so we expect a good accuracy in the magnetic field calculation far from the conductors themselves and a likely approximation by excess, due to the mentioned divergence, near the conductor surface.

Course attended with exam (all given):

1)Advanced Computational Physics – Ferrando
2) Electronics and Data acquisition – Musico, Fontanelli
3) A hands-on crash-course on theoretical condensed matter physics – Cavaliere, Traverso Ziani

Event attended:

1/9/2019 – 5/9/2019: European Conference in Applied Superconductivity (Glasgow, Scotland)

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