Considerations concerning the use of HTS Conductor for Accelerator Dipoles with Inductions above 15 T

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Abstract

The use of high temperature superconductors for accelerator dipole has been discussed for about twenty years and maybe a little more. Conductors that can potentially be used for accelerator magnets have been available for about fifteen years. These conductors a REBCO tape conductors that can be wound into coils with no reaction after winding and BISSCO cable conductors that require reaction after winding and insulation after reaction in a process similar to Nb3Sn cables. Both conductors are expensive and the process after reacting is expensive. Some unknown factors that remain: Will either conductor degrade in current carrying capacity with repeated cycling like Nb3Sn cables do? The other two issues are problems for both types of HTS conductors and they are; 1) quench protection in the event of a normal region run-away and 2) dealing with the superconducting magnetization inherent with HTS cables and tapes. This paper will discuss the last two issues and maybe will provide a partial solution to these problems.

Why is Shield Current Magnetization a Problem?

1) Magnetization circulating currents usually produce unacceptable multipoles within the magnet good field region. This is worst at low fields at injection.
2) At high magnetic fields the circulating currents can cause delamination and fracture within the coils.

Why is quench protection difficult in HTS Magnets?

1) Quench propagation velocities are low for HTS coils.
2) Heaters and quench back don't work because of the high specific heat at higher temperatures.
3) Run away quenching is hard to detect when there is a lot of copper in the conductor

How can one Reduce Dipole Magnetization?

1) Avoid Cosine Θ Coils which have the fields oriented perpendicular to the conductor flat face.
2) Block coils should be designed to that the fields are oriented parallel to the conductor flat face. A Vobly dipole moves the superconductor magnetization away from the beam region.

A Vobly Dipole and where it came from

The Vobly dipole was developed at BINP in Novosibirsk Russia in the 1980's. This type of dipole is well suited for large angle bending magnets used in electron storage rings. This magnet was designed for 7 to 8.5 T short dipoles for electron storage rings. This magnet has the iron saturation controlled so the field drops off quickly at the ends and the field is uniform over a large region. The flux in the coils goes in one direction in most of the magnet coils within the magnet gap, which will reduce the effects of magnetization. This type of magnet could be suitable with REBCO tape dipoles.

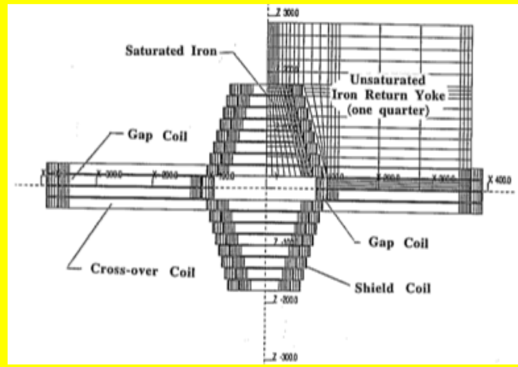

Fig. 1 Cross-section of a 7.5 T Vobly Dipole

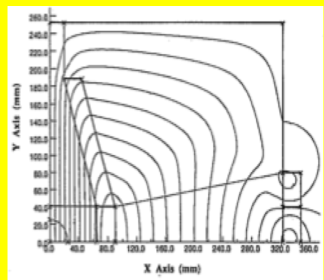

Fig. 2 Dipole Flux lines

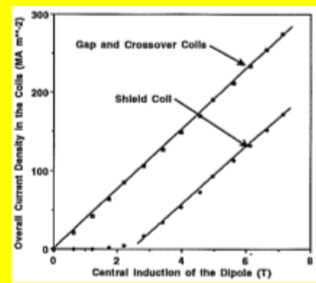

Fig. 3 Dipole Coil Currents

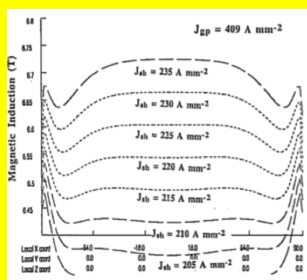

Fig. 4 Field uniformity Versus Shield Current

Parameter and (units)	Value
Design Induction B_P (T)	15.0
Maximum Iron Width W_{FE} (mm)	900
Maximum Iron Height H_{FE} (mm)	795
Radius of the Good Field Region (mm)	20
Gap between Iron Poles G (mm)	45
Pole Width between the Coils W (mm)	70
Gap Coil Height (mm)	44
Gap Coil Width (mm)	~40
Number of turns per Gap Coil	320
Gap Coil Current (A)	~938
Average Coil Current Density (A mm^{-2})	~170^
Stored Magnetic Energy (MJ m^{-1})	~2.6*

15 T Dipole Parameters

Further work needed to develop the Design

The Vobly dipole is inefficient in its use of conductor, but this can be improved by eliminating the crossover coils and reducing the height of the shield coils. This will reduce the stored energy of the magnet somewhat.

The coil package is over 80 % copper, but only 2.5 % is within the REBCO conductor. The rest of the copper is the shorted secondary circuit used for protection from quenches in conjunction with varistors put across the magnet coils. The iron in the poles with also absorb some of the magnets stored energy during a quench.

The field errors due to conductor magnetization should be lower at injection than for other dipole magnet designs. More work is needed to prove this.

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