## §5. HTS Coil Option for the LHD-Type Fusion Energy Reactor FFHR

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High temperature superconducting (HTS) conductors are being considered as an option for the LHD-type fusion energy reactor FFHR, which is being designed at NIFS. HTS conductors will be used in the layer-wound helical coils of FFHR with conduction cooling. The details of the proposed 100 kA-class YBCO HTS conductor for FFHR, coil cross-section, and cooling concept are described in [1,2].

Several analyses, such as, thermal, structural, quench detection and protection, ac losses, have been carried out to examine the feasibility of the HTS conductors for FFHR. Simple structural analyses suggest that the strains due to electromagnetic forces are less than 0.25%. Therefore, the total strain in the windings, including the bending strain (~0.05%), is ~0.3%, which is less than 0.7%, the allowed strain for YBCO tapes. The hoop stresses are also well below the yield strengths of the considered materials as shown in Fig 1. More details of this analysis can be found in [1,2].

Due to the low thermal diffusivity of materials at elevated temperatures, the quench propagation in HTS conductors is very slow and therefore quench detection is not easy [3]. According to the quench detection analysis, longer conductor lengths at higher initial hot-spot temperatures are required to observe detectable voltages. After quench detection, the magnetic stored energy should be dumped safely to protect the magnets. Figure 2 shows the initial and final hot-spot temperatures before and after dumping the magnetic energy into an external dump resistor with a time constant of 20 s. Analyses suggest that a little higher initial hot-spot temperature before dumping could be allowed with stainless-steel jacket of the conductor compared to Al-alloy jacket, which is helpful in quench detection as discussed above.

Though HTS conductors have many advantages, there are still many issues associated with HTS wires, such as, higher ac losses, large shielding currents, and inherent mechanical brittleness. To realize HTS magnets, more developments are required such as for cabling techniques of conductors, winding techniques of magnets, and low resistance joints. A technique to realize low-resistance joint between HTS conductors having stacked HTS tapes is proposed as shown in Fig 3. The tapes of two conductors are cut in stair-like structure and then soldered together individually. A joint resistance of ~0.01 nΩ might be achievable. Having low-resistance joints, high stability margin of the conductors, and less required refrigeration power, the segmented helical coils option for FFHR might be possible [1,2].

The feasibility studies suggest that the HTS coil option is viable for FFHR.

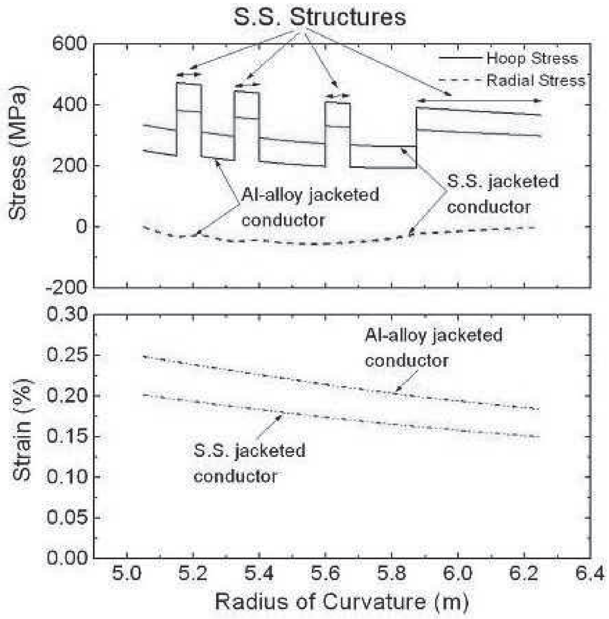


Fig 1: Calculated electromagnetic stress and strain in the helical coils of FFHR.

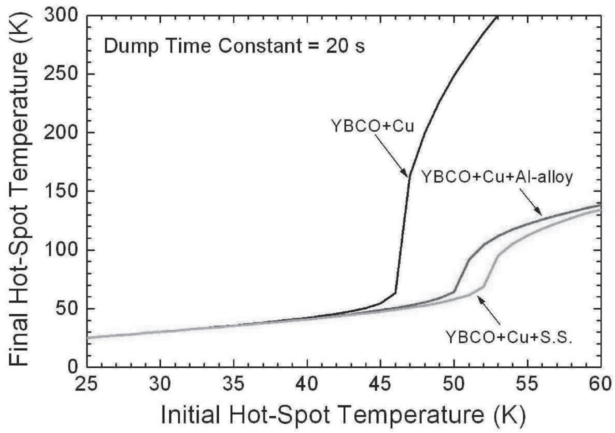


Fig 2: Calculated final hot-spot temperature as a function of initial hot-spot temperature with different conductor jacket materials. A case of no jacket (only YBCO and Copper tapes) is also shown for comparison.

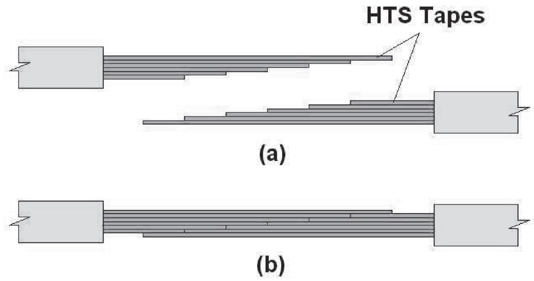


Fig 3: Schematic views of a joint between two HTS conductors. (a) Stair-like structure of the tapes; (b) overlapping of tapes and then jointing.

[1] Bansal, G. et al., to be published in Plasma and Fusion Research, (2008).
[2] Bansal, G. Ph.D. thesis (Sokendai), 2008.
[3] Hemmi, T. et al., NIFS Annual Report (2007).