Sequencial Abnormal Events in High-Temperature Superconducting MRI Magnet

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Introduction : Because of recent deficit of liquid helium, helium-free MRI magnets with high temperature superconducting (HTS) materials have been expected as one of the solutions. We have developed a 3T HTS-MRI system for human brain research with Bi-2223 tapes and showed its feasibilities at 1.5T [1]. However, in spite that we succeeded energizing to 1.5T more than sixty times and 3T three times, sequential abnormal events were happened for longer than ten minutes during the ramp-down at the third trial to 3T (fig.1). Here, we show these unique events specific to HTS magnets (in conventional MRI magnets, a quench process finishes immediately) in detail.

Abnormal events : The magnet was consist of five coils with diode clipping circuits and kept the operating temperature under 20K with a cryocooler with thermal conduction. As general HTS magnets, a super-stable power supply is necessary to maintain electric current because HTS tape joints have tiny resistance.

The abnormal events, loud noise and abnormal voltage changes, started about one minute after ramp-down start from 2.5T (intermission stage) and continued for more than ten minutes. Inspection of the decomposed magnet revealed three major damages (fig.2), a gap between coil #2 and the flange, melted electrodes at coil #1 and #2, and burned HTS tapes in coil #5. Recorded data of electric current, voltages and temperature indicated that sequential critical events had happened shown with eight arrows in Fig.3, that is, 1. abnormal events start (probably quench in coil #5), 2. thermal run away causing short circuits expanding in coil #5, 3. ramp-down halt by the operator, 4. ramp-down restart, 5. quench in coil #4, 6. power supply shutdown, 7. spark at the electrode of coil #2 and 8. spark at the electrode of coil #1.

Discussion : These sequential events show problems and a potential of HTS MRI magnets. Whole and immediate quench in conventional MRI magnet means it shares stored energy with whole coils and is difficult to be damaged, resulting in un-necessity of quench detection and protection, while HTS MRI must have the two to avoid fatal damages. In contrast, these events show a potential of HTS magnet because these are happened due to sufficient margins to its limits. Further development is necessary to achieve helium-free MRI in future.

Reference : Urayama, S., "Cryogen-free 3T-MRI system for Human Brain Research using Bi-2223 High-Temperature Superconducting Tapes",ICME, 2012, 376-381

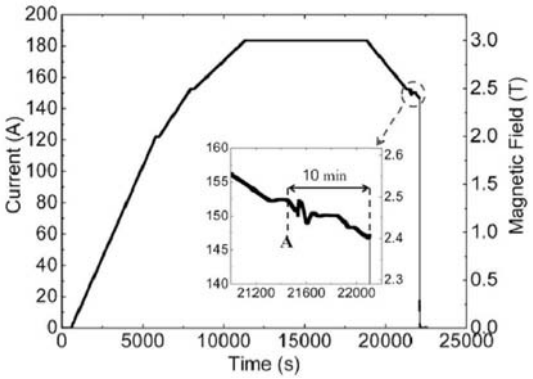

Fig.1 Electric current change at the third trial to 3T. The magnet was energised to 3T and the magnetic field was hold for longer than 2 hours successfully. The sequential abnormal events were occurred at the rise-down and 10 mins later the power supply was shutdown.

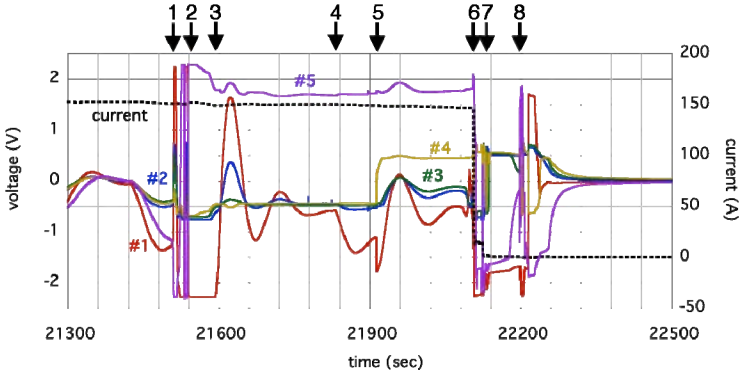

Fig.3 Changes of electric current and voltages of five coils during the abnormal events. Eight critical events, shown with arrows, were happened in the magnet (the details are written in the text).

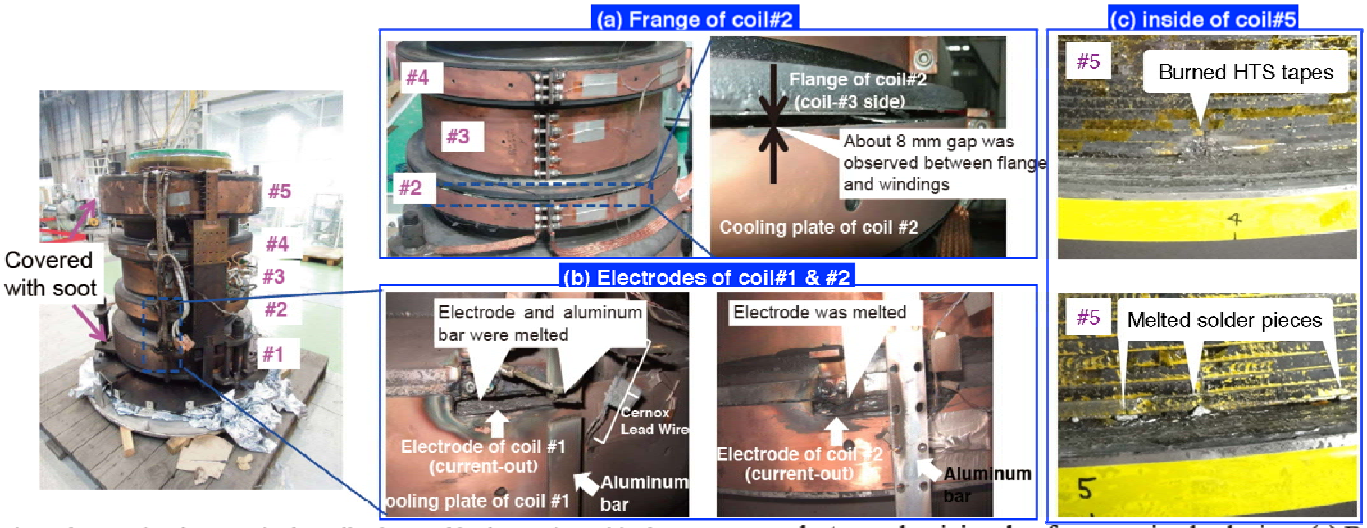

Fig.2 Three major damages in the coils observed by inspections. (a) There was a gap between coil #2 and the frange indicating strong force to the outer direction. (b) Electrodes of coil #1 and #2 were melted due to sparks to an aluminium bar for arranging lead wires. (c) By unwinding coils, burned tapes and melted solder pieces were found in the coil #5, supposed to be the trigger points.