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HTS CroCo - a Strand for High Direct Current Applications

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High temperature superconductors (HTS) are discussed as energy-efficient solutions for applications needing high direct currents beyond 10 kA e.g. for large high-field magnets or busbar systems in industrial electrolysis plants. *REBCO* coated conductors are promising materials due to their excellent electrical performance at both, high fields and high temperatures. A number of high-current cable concepts based on REBCO tapes were developed such as the Roebel cable, co-axially wound tapes and several stacked-tape arrangements, among them the HTS CrossConductor (HTS CroCo), a stacked-tape conductor with high current density developed at KIT.

In this presentation, the conceptual design of high-current HTS cables based on HTS CroCo strands is discussed and the realization of a 35 kA demonstrator made from twelve HTS CroCo strands is presented. The demonstrator was tested successfully at $T = 77$ K, reaching the target performance 35 kA DC current at 77 K and even for a constant-current operation at 36 kA for more than 30 minutes limited by the copper connections, not the superconducting cable. Currents and voltages were measured over all twelve strands individually during the parallel operation in the cable. The measured data allow the experimental validation of the modeled current distribution calculated, based on the individual characterization of the twelve strands. The use of such cables for example in aluminum electrolysis will be discussed as a potential application.

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Development and Perspectives of HTS Cable-In-Conduit Conductor with Al-Slotted Core for Fusion Applications

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In the recent years, due to the increasing performances of the High Temperature Superconductor (HTS) REBCO-based conductors, i.e. *coated conductors*, the development of HTS based technology for extremely high field generation applications is emerging as one of the most favorable opportunities in nuclear fusion sector.

Pushed by this application perspective, new concepts of conductors incorporating HTS coated conductor tapes have been designed and implemented. Among them, a Cable-In-Conduit Conductor comprised of an Aluminum-slotted-core has been developed. In this cable the HTS tapes are stacked and inserted into helical ducts formed in an extruded Aluminum cylindrical core mostly studied in the 5-slots configuration (5 ´ 20 tapes – or 5 ´ 30, depending on tape thickness). The cable layout, designed aiming at the industrial feasibility of the manufacturing process, has shown promising electrical, thermo-hydraulic and mechanical properties assessed in several experimental studies of cable samples.

In this contribution, the status of the art of the Aluminum-slotted-core CIC conductor development will be presented. In particular, the manufacturing process, the electrical and mechanical behavior of the cable will be discussed based on the experimental results obtained in cable prototypes and numerical simulations with implemented cable FEA codes. On this basis, the most advanced concept of the cable with 6 slots and square jacket made of high strength Al – alloy has been developed. First results on the jacketing process and mechanical behavior will be provided showing how this solution is particularly suitable for fusion magnets. In this perspective, the road map of the cable development activities will be described. The layout and manufacturing details of the sample (sub-size conductor rated for 15 kA at 4.2 K and 12 T) for quench experiments to be performed in the next months at the SULTAN facility will be illustrated. In particular, preliminary experimental results of the electrical behavior and termination concept will be presented and the expected behavior of the cable described. These results supported by thermal-hydraulic/electric 1D multi-region conductor model implemented by PoliTo contributed to predict the quench propagation in HTS conductors.

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Development of Large-Current HTS Conductors for the Next-Generation Helical Fusion Experimental Device

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The Large Helical Device (LHD) has been successfully operated at National Institute for Fusion Science. Deuterium experiments, having achieved the ion temperature of 10 keV, proves the effective plasma confinement by the heliotron magnetic configuration. The design study of the LHD-type helical fusion reactor FFHR-d1 has also progressed. Presently, extension of the LHD project is proposed and discussed, with the main target showing the steady-state discharge capability under high heating power. In parallel, discussion for the post-LHD project has also been initiated, as one of the candidates is to build a new device employing a similar but more optimized heliotron magnetic configuration with magnetic field produced by the High-Temperature Superconducting (HTS) magnet system. A large-current capacity HTS conductor is required, and three candidates are now being developed: STARS, FAIR, and WISE. Firstly, the STARS conductor has been developed since 2005 to be applied to FFHR-d1. The REBCO tapes are simply stacked, imbedded into a copper stabilizer and stainless steel (SS) reinforcement jacket. A 3-m long 100-kA-class conductor sample, having a SS jacket sustained by bolts, was formerly fabricated and tested successfully. A bridge-type mechanical lap joint technique with low joint resistance has also been developed to make the "joint-winding" feasible. A 20-kA-class conductor is now being developed to meet the new target by selecting a suitable welding method for the SS jacket. Secondly, The FAIR conductor has a stack of REBCO tapes imbedded in a circular aluminum-alloy jacket. The stacked tapes are twisted together with the aluminum-alloy jacket, which is welded by Friction Stir Welding (FSW). A number of ~1-m long short samples, having different pitch length of twisting, are fabricated and tested, presently in liquid nitrogen. Thirdly, the WISE conductor is formed by inserting a stack of REBCO tapes into a flexible metal tube. Then, after the coil winding, the winding package is impregnated by filling a low-melting temperature metal. The advantage of this conductor is its flexibility during the winding process. Two prototype coil samples were fabricated and tested in liquid nitrogen. In this presentation, the design concepts and progresses of these large-current HTS conductors are reviewed.

Keywords: Large-current HTS conductor, LHD, helical / heliotron, fusion magnet