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ITER超伝導導体の技術課題と取り組み
Technical problem and resolution of superconductor for the ITER magnet

布谷嘉彦, 名原 啓博, 高橋良和, 押切雅幸, 堤 史明, 高村 淳, 中瓶子 伸二, 渋谷 和之
Y.Nunoya, Y.Nabara, Y.Takahashi, M.Oshikiri, F.Tsutsumi, J.Takamura, S.Chuheishi, K.Shibutani

日本原子力研究開発機構
Japan Atomic Energy Agency

Introduction

Japan Atomic Energy Agency (JAEA) is responsible for Nb3Sn Cable-in-Conduit conductors (CICC) for the Central Solenoid (CS) and the Toroidal Field (TF) coil under the ITER project [1]. The CS conductor consists of 576 Nb_3Sn and 288 Cu strands which are cabled in five stages around the central spiral and then wrapped with stainless steel tape as shown in Fig.1 [2][3].

Full-size conductor test was performed to confirm performance using SULTAN facility at Switzerland, especially effect of electromagnetic load cycles on the current sharing temperature (Tcs), because CS is operated in pulse mode.

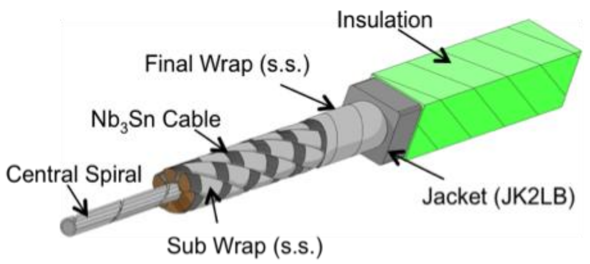

Fig. 1. Nb_3Sn cable-in-conduit type conductor for ITER CS conductor consists of 576 Nb_3Sn and 288 Cu strands. Outer dimension of jacket is 49 m

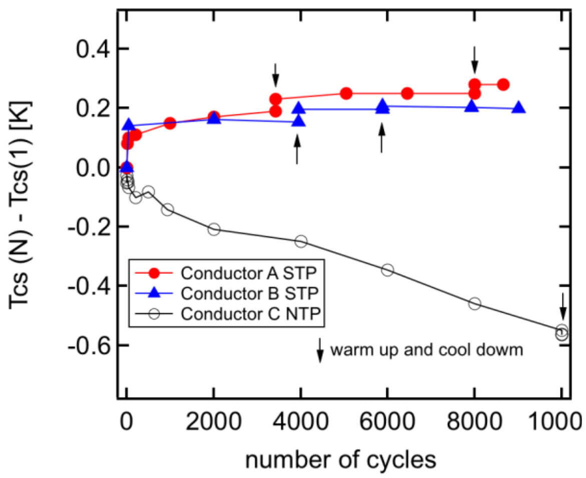

Fig. 2 Current sharing temperature vs. electromagnetic load cycles of full-size conductor samples, measured at experimental facility (SULTAN). Twist pitch sequence STP: 20-45-80-150-450 mm, NTP: 45-85-125-250-450 mm.

The original (reference) conductor which had relatively long twist pitch cabling design is called as the normal twist pitch (NTP) conductor. NTP conductor showed Tcs decrease with increasing the number of cycles as shown in Fig.2 with the notation “conductor C NTP”.

The destructive examination was performed on the sample after the cyclic test [4]. The photographs of the cable and the conductor cross section are shown in Fig.3. There observed strand deformation like bucking at the low transverse load side (“B” in the figure), where no deformation at the high transverse load side (“A” in the figure) was observed. Due to the electromagnetic load, the cable was moved toward “A” side, resulting in the void in “B” side. Consequently, the buckling of the strand was occurred by an axial compressive force that was induced by the difference of thermal expansion between strand and stainless steel jacket, because the supporting and the friction of the jacket and the cable on the strand changes by the induced void and then strand deformation was developing as increasing the number of cycles. This phenomena was also observed in TF conductors sample, however it was not so dominant because of the required number of cycles is much less (< 1000).

Cable Optimization

Although it is not clear whether the Tcs decrease

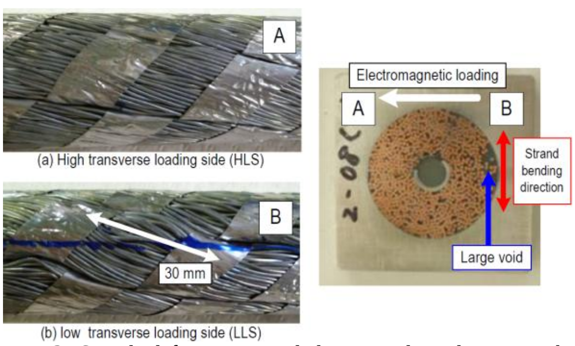

Fig. 3 Strand deformation and location dependence in the conductor cross section.

could happen in ITER CS, because SULTAN sample does not have the same environment condition such as field distribution along conductor length, conductor shape where SULTAN sample is straight and short, and so on. However in order to eliminate concern that this could happen to the ITER CS, cable optimization was planned in the view that improve of cable stiffness could result in registration of strand buckling. Therefore, the short twist pitch (STP) conductor was introduced.

Twist pitch sequence of both STP and NTP are listed in Table I. The twist pitch of STP conductor at the first stage that composed of a triplet cable is about half, assuming the triplet is most effective component that may change cable stiffness.

Table I Twist pitch of cables for CS conductors

Twist pitch [mm]			
Items	NTP	STP	
	Cond. C	Cond. A	Cond. B
1st stage	45	23	20
2nd stage	85	48	45
3rd stage	125	88	80
4th stage	250	155	150
5th stage	450	452	450

Test Result

Tcs of the STP conductor was tested at SULTAN facility and showed no Tcs decrease during electromagnetic cycles and warm up & cool down as shown in Fig 3 (Conductor A and B). It is understood that the triplet with a shorter twist pitch has better engagement among strands producing more stiffness resulting in less deformation of strand in "B" side. This result is acceptable for CS conductors.

Conclusion

By introducing short twist pitch conductor, performance during electromagnetic cycles was improved and concern of Tcs decrease in ITER CS is eliminated. Improvement is understood that shorting pitch of the triplet in the first stage make more engagement of strand providing more stiffness of the cable that prevent strand deformation like buckling observed in the destructive examination of the previous SULTAN sample

Reference

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