Jacket Material Selection for CFETR Central Solenoid Model Coil

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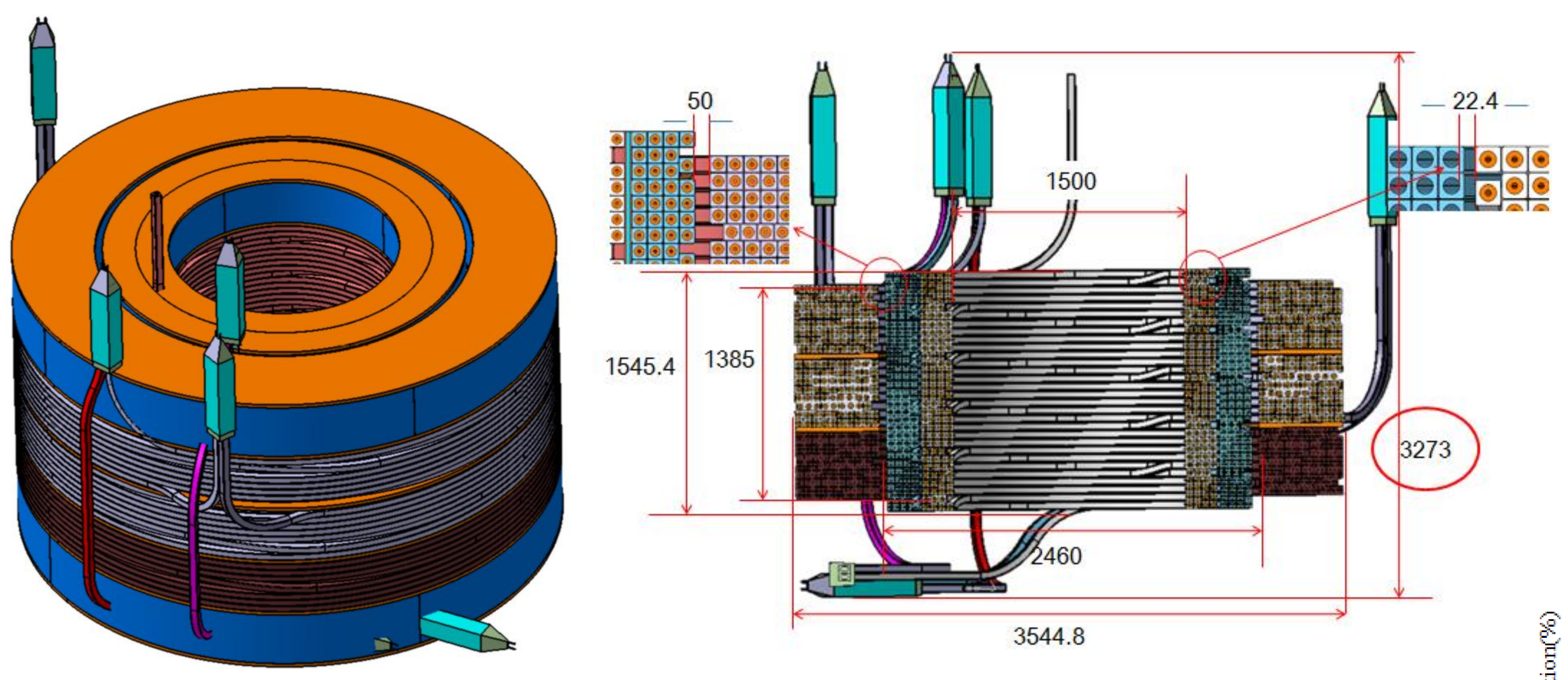
I. ABSTRACT

CFETR central solenoid model coil is the first R&D trial carried out in ASIPP for widen the technologies of CICC coil manufacturing. The coil is designed as a hybrid magnet, inner Nb_3Sn coil for providing high magnet field and the outer NbTi coil for magnet field compensation. For the outer NbTi coil, there is no dispute of using the SS316L as the jacket material. For the inner Nb_3Sn coil, both the SS316LN and the high Mn steel were considered. The jacket material for the Nb_3Sn coils must retain good mechanical and fatigue performance after undergone the coil manufacturing steps, such as conductor compaction, coil winding and exposure to the Nb_3Sn reaction heat treatment. In this paper, the 4K mechanical and fatigue properties were compared for the manufactured circular in square SS316LN and high Mn steel conduits after exposure to the representative coil manufacturing steps. Finally, the SS316LN is selected as the jacket material for the inner high field Nb_3Sn coils.

II. CFETR CENTRAL SOLENOID MODEL COIL DESIGN

a. Coil design

The CFETR central solenoid model coil is composed of two Nb_3Sn coils and three NbTi coils. The two Nb_3Sn coils are designed in a nested pattern with a height of about 1.5 m. The three NbTi coils are stacked, each height is about 0.45 m. All five coils are connected by the superconductor joints.



Two Nb_3Sn coils

The inner one:

Total layers: 30 layers
Total length: 619.4m

The outer one:

Total layers: 30 layers
Total length: 782m

Three NbTi coils

From bottom to top:

Layers: 8 for each, totally 24
Length : 746m, 746m, 739 m respectively

Fig.1. The profile map and dimensions of the CFETR central solenoid model coil
(All of the marked dimensions are in mm and the insulations dimensions are included)

b. Conductor design

The Nb_3Sn and NbTi conductors' design are based on the knowledges learned from ITER CS and PF conductors. The configuration and parameters are as follows:

Item	Nb_3Sn conductor 		NbTi conductor 
Jacket material	316LN or JK2LB		316L
Sectional dimension before compaction (mm × mm)	□51.3 × Φ35.3		□54.2× Φ38
Sectional dimension after compaction (mm × mm)	□49 × Φ32.6		□51.9× Φ35.3
Radius（mm）	6±1		4±1
Operation current (kA)	48.3	48.3	48.3
Maximum magnet field (T)	12	8.39	5.84

III. JACKET MATERIALS PREPARATION

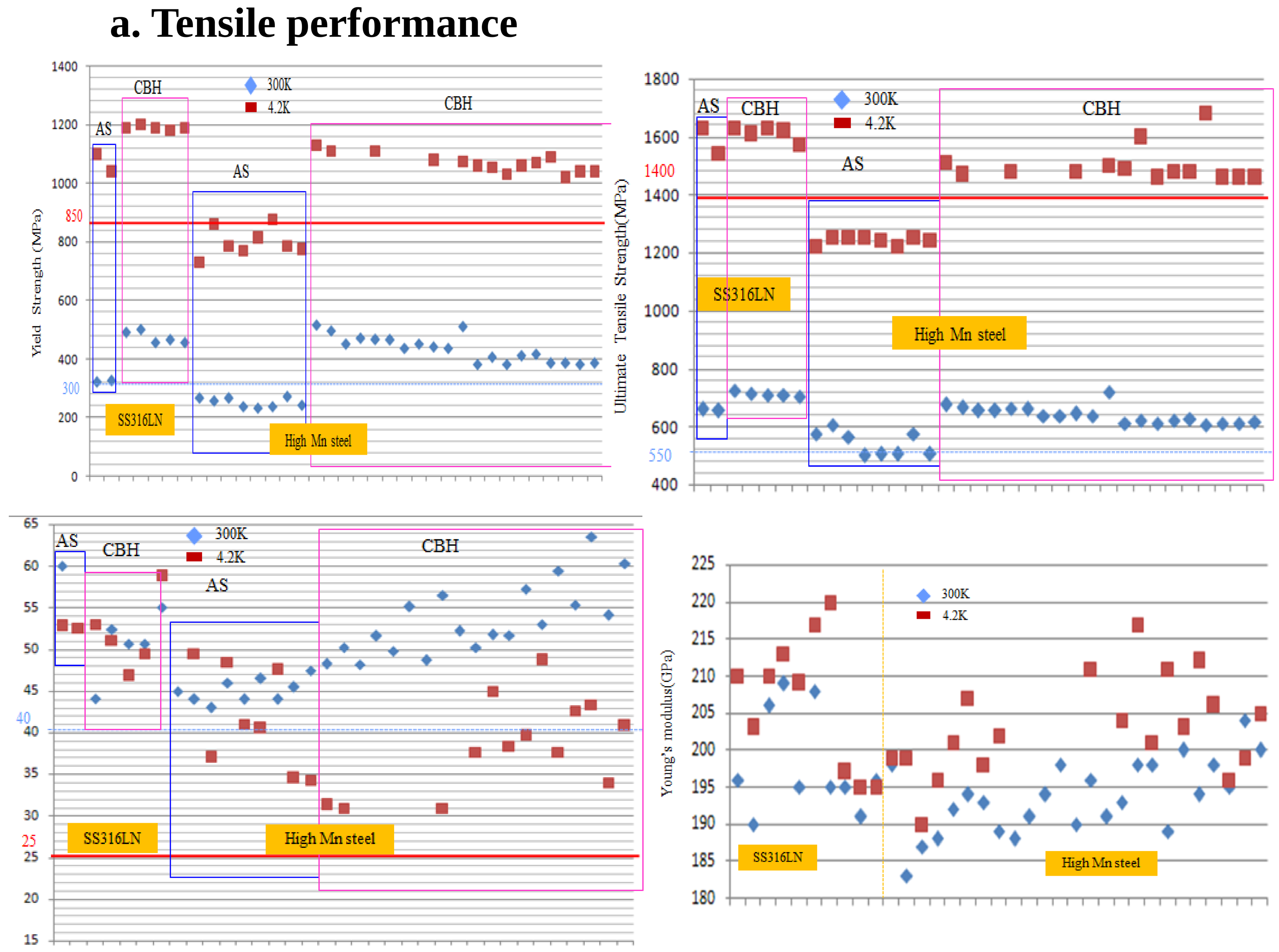
Both SS316LN (low carbon) and high Mn steel have been trial manufactured for Nb_3Sn coils for mechanical and fatigue properties evaluation. Sections were prepared and have undergone the coil manufacturing processes:

Conduit compaction to the final dimension
Bending with a radius of 2 m
Aging treatment: 575 ℃/ 100hours and 650 ℃/ 100hours

Fig.2. Nb_3Sn coil jacket samples preparation

IV. MECHANICAL AND FATIGUE PERFORMANCE COMPARATION

a. Tensile performance



The first trial manufactured SS316LN and High Mn steel circular in square conduit have similar tensile properties in the cold worked and aged conditions both at room temperature and 4.2K.

Fig.3. Tensile properties (mean value) comparison for SS316LN and the developed high Mn steel at RT and 4.2 K (SA: solution annealed; CBH: compacted, bended and heat treatment)

b. Fatigue performance

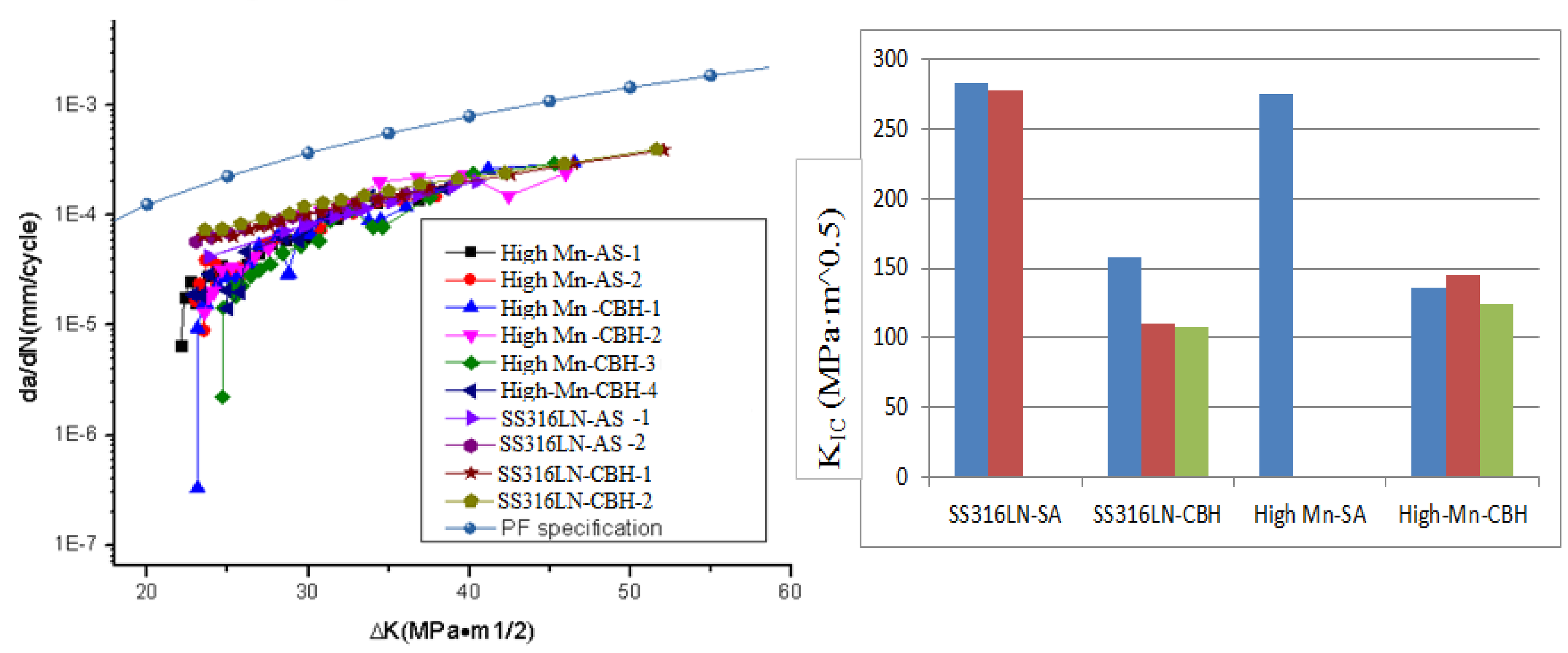


Fig.4. FCGR and fracture toughness of SS316LN and high Mn steel at 4.2K

V. CONCLUSION

From the tested results, it can be concluded there is no significant advantage of using the developed High Mn steel, at least based on our current state of knowledge. Conclusions can be drawn from comparison the tested fatigue properties of SS316LN and High Mn steel conduit with the ones used for ITER, optimization on the conduits manufacture technology should be proposed for improving the fatigue properties after cold working and aging.

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