

New progress of ITER-PF strand production in WST

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Abstract. ITER Poloidal Field (PF) systems consist of 6 independent coils with different dimensions and require NbTi superconductor and copper strands. Western Superconducting Technologies Co.,Ltd.(WST) will supply PF2-5 NbTi strand for ITER, and over 14,000 km of NbTi strands have been produced in the past two years. Main performance of NbTi strands, including critical current, n value, wire diameter, Cu/non-Cu ratio, hysteresis loss and RRR are reported and analysed in this paper.

1. Introduction

The ITER magnet coils are wound from Cable-In-Conduit Conductors (CICC) made up of superconducting and copper strands assembled into a multistage, rope-type cable inserted into a conduit of butt-welded austenitic steel tubes. The conductors for the Toroidal Field (TF) and Central Solenoid (CS) coils require about 500 tons of strands while the Poloidal Field (PF) and Correction Coil (CC) conductors need around 250 tons of NbTi strands [1].

CN contribute to ITER project includes PF conductors, TF conductors and CC/Feeder which requires about 170 tons NbTi strand and about 30 tons Nb₃Sn strand. In the past two years, WST has produced over 50 tons NbTi strand for PF conductor.

2. Strand Performance

Figure 1 shows a cross section microphotograph of NbTi wire with 0.73mm and the enlarged microphotograph of NbTi filaments area. The niobium barrier is used between NbTi filament and copper matrix to avoid intermetallic of Cu and Ti which can't be co-deformed with the strands or stabilizer matrix [2].

The main specifications of PF NbTi strand including critical current (5T, 4.2K), n values, strand diameter, Cu/ non-Cu ratio, hysteresis loss and RRR values are listed in Table 1. The main strand performance of WST is shown in figure 2 to 7, and satisfied the ITER requirements which marked as dash line in each figure.

The implementation of Statistical Process Control (SPC) calls for the identification of key process parameters and of sound methods for relevant statistical sampling in order to reduce and control manufacturing process variability, prevent defects and ensure suitable and reproducible performance.



SPC methods rely on the monitoring of mean values of key process parameters, and the evolution of these mean values, to detect deviations in production and assess their potential impact on performances.

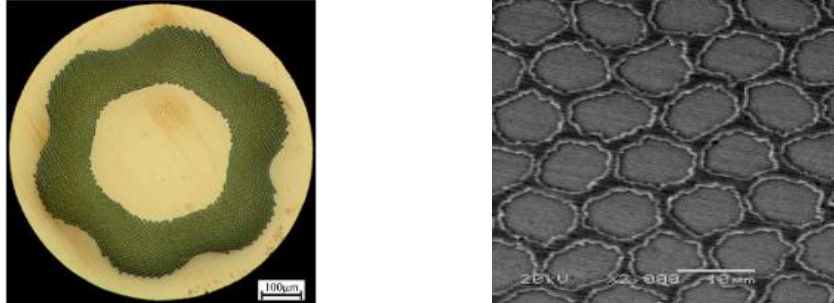


Figure 1 Cross section of NbTi strand (left) and filament area (right) made for ITER-PF conductor

Table 1. Main Strand Specification

	NbTi strand
Minimum critical current	339A
n-Value ^a	> 20
Strand diameter	0.730 ± 0.005 mm
Cu-to-non-Cu volume ratio	2.25- 2.45
Maximum Hysteresis loss	45 mJ/cm ³
Residual Resistivity Ratio of plated strand	> 100

^a This value is defined in the 0.1-to-1 $\mu\text{V}/\text{cm}$ range at 4.22 K and $B_{\text{ref}} = 5.0\text{T}$ for minimum critical current

The critical current and n value has the similar trend and a large distribution along with the mass production yield increased.

The diameters of nickel plated NbTi strand data which shown in figure 4 are with small range and well controlled. The Cu/non-Cu ratio points are spread from lower limits to upper limits and within the specification and some of the data near lower limits because of the intended cuts.

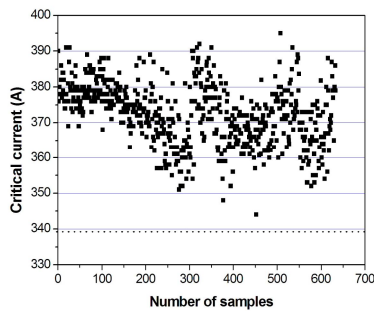
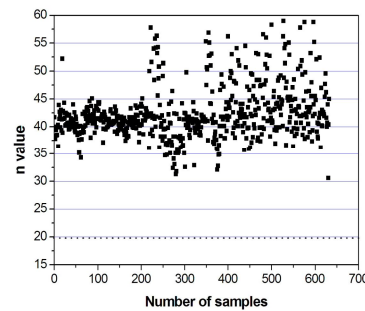
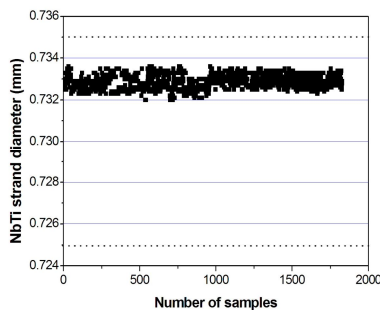
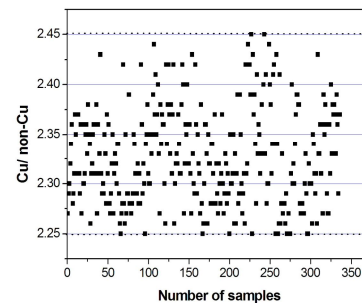
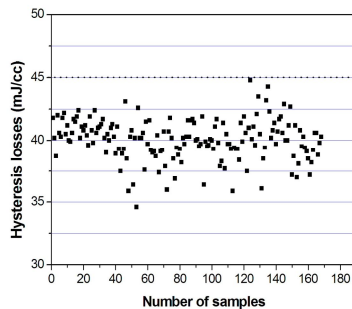
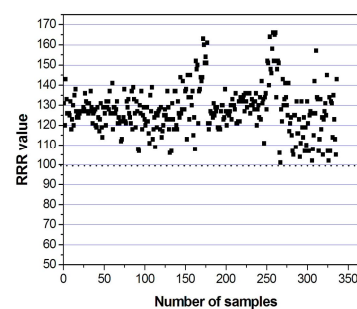
The hysteresis loss and RRR values appeared within specification, and large variation of RRR values compared with other parameters was primary attributed to different oxygen free copper suppliers and temperature control.

3. Production Yield

Figure 8 shows the overall production yield of PF NbTi strand up to now. A stable production yield has been achieved for PF NbTi production. The highest average piece length of batch is around 90000 meters which above 300 kg.

4. Qualification Test

Full-size ITER conductor qualifications are carried out at the SULTAN facility, located at CRPP, in Villigen, Switzerland [3]. Nb-Ti conductor samples are single lengths mounted in a hairpin configuration at the bottom. SULTAN samples are instrumented with voltage taps and temperature sensors at various locations. The measurements are carried out at fixed temperature and field (B_{ref}) and increasing current to obtain critical current (I_c) or at fixed current and field and increasing temperature

**Figure 2.** The critical current of PF NbTi strand**Figure 3.** The n value of PF NbTi strand**Figure 4.** The diameter of PF NbTi strand**Figure 5.** The Cu/non-Cu ratio of PF NbTi strand**Figure 6.** The hysteresis loss of PF NbTi strand**Figure 7.** The RRR value of PF NbTi strand

to obtain critical sharing temperature (T_{cs}). The runs are the most relevant to assess conductor performance.

The required values of I_c , B_{ref} and $T_{Cs,min}$ for the various PF coils are summarized in Table 2. For a strand design to be qualified its current sharing temperature at I_{op} and B_{ref} must be greater than the value specified in Table 2.

Two sultan samples named PFCN1 (PF2-4) and PFCN2 (PF5) have been tested in CRPP. The test results of PFCN1 and PFCN2 samples showed that the performance of the PF conductor satisfy the ITER requirement. The test results of the samples are shown in the Fig 9 (a) and (b).

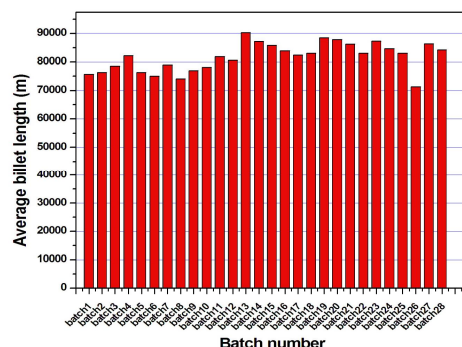


Figure 8 The average piece length of PF NbTi strands

Table 2. Minimum current sharing temperature of ITER PF Strands

Coil	Current (A)	Field (T)	Min. Current Sharing Temp.(K)
PF1&6	33	6.4	5.9
PF2-4	69	5.0	6.1
PF5	45	5.7	6.1

5. Conclusion

WST have produced PF2-5 NbTi strand successfully and will finish the PF strand production in the next year.

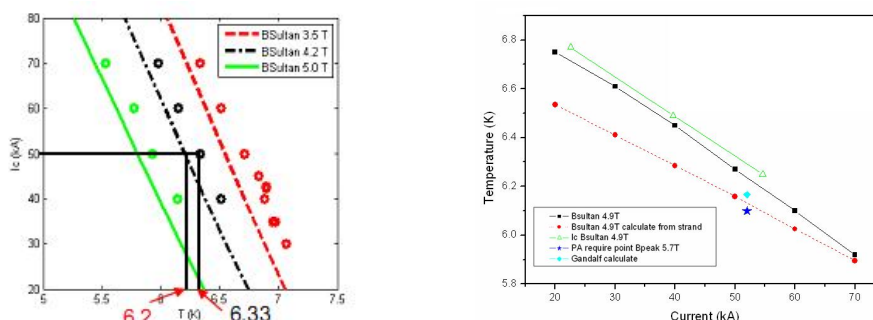


Figure 9 Test results of PFCN1(a, left) andPFCN2(b, right) sultan samples(Courtesy of Vostner A, IO)

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