Tensile and Fatigue Testing of the Iter-Central Solenoid Conduit Alloy

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Introduction

The NHMFL's magnet material science and engineering capabilities catalyze the collaboration between NHMFL and the US-DOE's ITER program. One of the US-ITER project responsibilities is the design and construction of the ITER Central Solenoid (CS) modules that utilize cable-in-conduit conductor (CICC) design. A special conduit alloy (JK2LB) was developed for use in the CS which has a carefully controlled chemistry and microstructure in order to obtain the desired cryogenic mechanical properties. The production grade version of the alloy (and its welds) was supplied to NHMFL for qualification testing to confirm the strict requirements for strength, toughness and fatigue resistance. The conduit alloy must retain the required mechanical properties after the addition of coil fabrication steps such as welding, winding strain and heat-treatment,that influence material properties. The coil fabrication steps are simulated in the NHMFL Mechanical and Physical Properties Lab by subjecting the 1 m long conduit sections to 3 point bending strain and long term heat treatments at 650 C for 200 hrs. Tests of specimens removed directly from the conduit are used to measure the 4 K tensile, fatigue, and fracture properties, before and after the additional manufacturing steps. Evaluation of the properties is accompanied by metallographic and fractographic analyses to support the results and conclusions.

Experimental

Test samples are EDM manufactured to minimize the effect that conventional machining could have on the material condition. ASTM style specimens and procedures are used whenever applicable. The test machine is equipped with a cryostat to enable the specimens and fixture to be immersed in liquid helium for the 4 K tests.

Results and Discussion

As shown in Table I, the tensile properties of the JK2LB easily exceed the 295 K and 4 K requirements. The fatigue performance of the material was evaluated in S-n fatigue tests and crack growth rate tests (Fig. 1) and the material behaved as expected also satisfying the design requirements.

Conclusions

The production grade JK2LB conduit material exhibits excellent properties that meet the strict ITER-CS requirements. The additional manufacturing steps known to change the material properties of conventional austenitic steels have been addressed and were found to have minimal effect on the specialty alloy conduit.

Acknowledgements

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References

[1] Walsh, R.P., *et al*., "Mech. Prop.'s of Mod. JK2LB for Nb3Sn CICC Applications", Adv. in Cryo. Engr., pp 17-24, **Vol. 56** (2010).

Table I: JK2LB Tensile test results.

Material	Condition	Temp K	Yield Strength (MPa)	Tensile Strength (MPa)	Elong. in 25 mm (%)	Reduction of Area (%)
ITER Req. Minimum	AC+CW+AG	295	300	550	30	
Base in Flats	AC+CW+AG	295	435	618	44	47
Weld in Corners	AC+CW+AG	295	466	619	34	54
ITER Req. Minimum	AC+CW+AG	4	850	1150	25	
Base in Flats	AC+CW+AG	4	1085	1458	41	32
Base in Corners	AC+CW+AG	4	1076	1456	42	47
Weld in Corners	AC+CW+AG	4	1031	1432	34	51

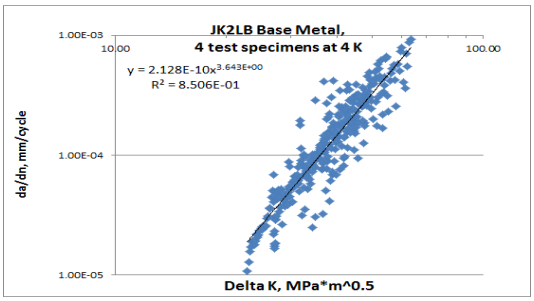

Fig. I: Fatigue crack growth rate data.