Design of PF-1 coil helium inlet and dummy joint samples for fatigue tests at T=77 K

ICEC/ICMC
25th International Cryogenic Engineering Conference & International Cryogenic Materials Conference 2014
July 7-11, 2014
University of Twente, Enschede, The Netherlands

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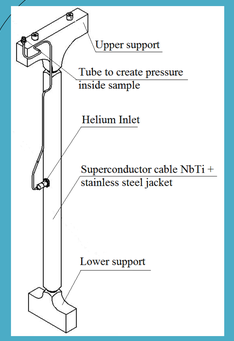
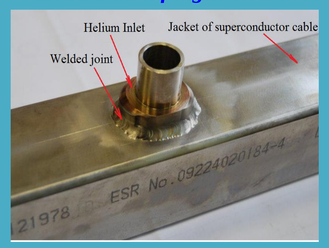
Background

Helium inlet and electrical joint between conductors are critical elements of double pancakes of ITER PF-1 coil. Helium inlet is a part of the PF-1 coil used to inject the liquid helium into PF1 conductor channel. The full-scale sample of helium inlet and mechanical loading facility have been designed and manufactured to perform a fatigue tests at 77K under required strain and to check leak tightness of the helium inlet sample. Thermocycling (296K-77K-296K) was carried out before fatigue tests; leak tightness test of helium inlet was carried out before and after fatigue tests. The low ohm electrical joint is used to connect two lengths of NbTi CICC into a single electric circuit, to qualify the technique and equipment for electrical joint manufacturing the dummy joint qualification sample has been designed to simulate required strain of fatigue tests. The main feature of the sample design is the symmetric combination of two dummy joints to compensate the bending moment. The helium inlet sample passed fatigue test successfully in 2013 year. Fatigue tests of dummy joint sample will be carried out in 2014. The article includes the results of helium inlet and dummy joint designs stress analyses under required test conditions, the facility description for fatigue tests at 77K, helium inlet sample fatigue tests, leak tightness tests and thermocycling results.

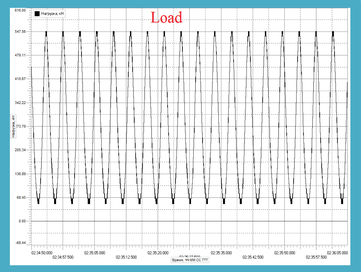
Helium inlet fatigue tests at 77 K

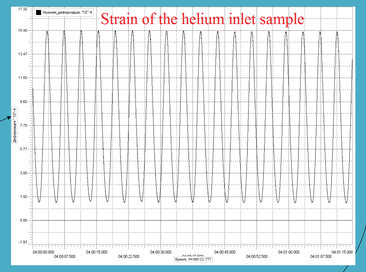


Full-scale helium inlet sample



Welded part of helium inlet and jacket of superconductor cable

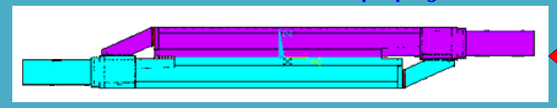




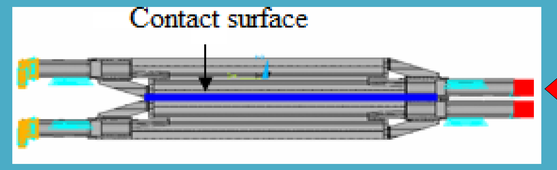
In 2013 on the premises of JSC TsNIITMASH (Moscow) which is a subcontractor to JSC NIEEFA, the fatigue tests of a full-scale helium inlet sample at T=77 K were conducted in the result of which has been obtained:

- *The load on the sample is varied in the range of Fmin = 49.8 kN, Fmax = 547.56 kN;*
- *Strains of the helium inlet is varied in the range of εmin = 1.4x10-4 to εmax = 15.4x10-4;*
- *The sample withstand 30,000 cycles;*
- *Frequency of cycling was 0.3 Hz;*
- *Temperature of the helium inlet sample was T=77 K.*

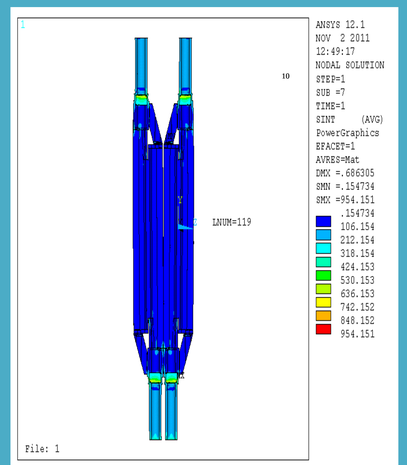
Structural analysis of the the stress-strain state of a dummy joint symmetrical model for fatigue tests at 77K

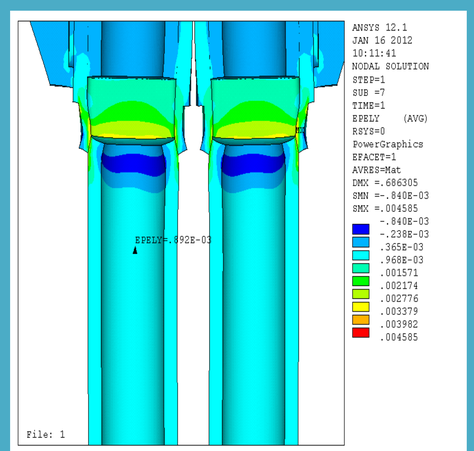


PF-1 coil dummy joint sample



Symmetrical finite element model of dummy joint sample

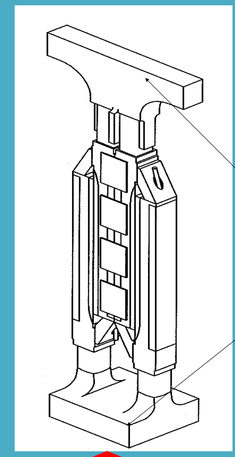




During fatigue tests of a dummy joint sample the strain of the conductor jacket should be in the range of 4x10-4 to 9x10-5 . According to the calculations, the force of F=640 kN should be applied to the dummy joint sample. Following figure represents the distribution of the strain in a dummy joint sample under this force, analysis was made by the help of ANSYS software.

Practical needed strain ε = 0.9e-3 is achieved in the jacket of the conductor. Thus the main aim of the dummy joint sample sample creation is achieved.

Full-scale dummy joint sample for fatigue tests at 77K



Tails for load transfer from testing machine

Design of full scale dummy joint sample for fatigue tests at 77 K

Bimetallic (Cu-316L) plates for manufacturing of dummy joint sample termination boxes.

Conclusion

- A symmetrical model of a full-scale dummy joint sample for fatigue tests has been designed and verificated by ANSYS software;
- The full-scale helium inlet sample for fatigue tests has withstood all test stages and is in full conformity with the requirements of the technical specification for PF-1 coil; therewith the operability of the helium inlet design has been validated;
- The fatigue tests of the full-scale dummy joint sample at T=77 K will be carried out in 2014.