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

The Joint Stock Company D.V. Efremov Institute of Electrophysical Apparatus (JSC “NIEFA”), 3 Doroga na Metallostroy, Metallostroy, Saint Petersburg 196641, Russia.e-mail: nas3188@yandex.ru


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 NITI 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.

Full-scale helium inlet sample

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 = 1.4х10^{-4} to εmax = 15.4х10^{-4};
- The sample withstand 30,000 cycles;
- Frequency of cycling was 0.3 Hz;
- Temperature of the helium inlet sample was T=77 K.

Practical needed strain ε = 0.9х10^{-3} is achieved in the jacket of the conductor. Thus the main aim of the dummy joint sample sample creation is achieved.

Conclusion
• A symmetrical model of a full-scale dummy joint sample for fatigue tests has been designed and verified by ANSYS software;
• The full-scale helium inlet sample for fatigue tests has withstand 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.

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

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

Tails for load transfer from testing machine

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

Contact surface

During fatigue tests of a dummy joint sample the strain of the conductor jacket should be in the range of 4х10^{-4} to 9х10^{-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.

Helium inlet fatigue tests at 77 K

Full-scale helium inlet and dummy joint samples for fatigue tests at T=77 K

Welded part of helium inlet and jacket of superconductor cable

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 NITI 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.

 실제로는 다음과 같은 주요 내용을 포함합니다:

-氦气入口和电气接头是双层饼的ITER PF-1线圈的关键元件。氦气入口是用于将液氦注入PF1导线通道的一部分。设计并制造了全尺寸氦气入口和机械加载装置，以进行77K下的疲劳试验，检查氦气入口的泄漏密封性。火焰测试前进行了热循环（296K-77K-296K）。

-设计的主要特点是两个假肢组合对称，以补偿弯矩。氦气入口样本在2013年成功通过了疲劳测试。

-在2013年，根据JSC TsNIITMASH（莫斯科）的试验，获得了以下结果：
  - 所施加的负载范围为Fmin = 49.8 kN, Fmax = 547.56 kN；
  - 氦气入口的应变范围为εmin = 1.4х10^{-4} to εmax = 15.4х10^{-4}；
  - 样品经受了30,000次循环；
  - 循环频率为0.3 Hz；
  - 样品的温度为T=77 K。

-在喷气机的转向下，所需的应变ε = 0.9х10^{-3}在导线的套管中实现。因此，假肢样本的设计目标已实现。

-结论
  -设计了全尺寸假肢样本的对称模型，用于疲劳试验，验证了ANSYS软件；
  -全尺寸氦气入口样本在疲劳试验中的所有阶段均承受了所有测试，并完全符合技术规格的要求，证明了氦气入口设计的可操作性；
  -全尺寸假肢样本的疲劳试验将在2014年进行。