TEST PROGRAMME AND QUALIFICATION TRIALS OF SHEAR KEYS IN THE INNER INTERCOIL STRUCTURE (IIS)

Summary of project

Purpose

The purpose of this contract is to provide the qualification testing of prototype shear keys for the Toroidal Field Coils (TFCs). The work programme includes four main phases: detailed design of the test tooling, manufacture and commissioning of the tooling, execution of the test program and analysis of the test results with documentation.

Background

During ITER operation, poloidal shear forces will be generated between the TFCs. These forces will be resisted by the shear keys of the Inner Intercoil Structure (IIS). The IIS [1] consists of a set of cylindrical stainless steel keys installed between the stainless steel TFC cases (TFCC) in the curved sections above and below the straight section. After they are fabricated, the shear key modules will be fitted into matching semi-cylindrical keyways machined in the TF cases. Misalignments between keyways due to TFCC manufacture and assembly will be corrected by the use of oversized keyways in one TFCC mating face. Following TFC assembly, the keyways will be surveyed and custom sleeves will be installed in the oversized keyways to provide an accurate cylindrical geometry for the shear key installation. Each shear key module will consist of two main components: a tapered stud and a split tapered sleeve. The key module will be inserted in the cylindrical keyway and the tapered sleeve, expanded by pushing on the tapered stud to achieve an accurate fit in the keyway. The IIS is required to transmit very large compressive (toroidal) forces (~ 75 MN) and cyclic (poloidal) shear forces (~ 65 MN) at each IIS location The IIS key design and fabrication process needs to be qualified as part of the overall TFC manufacture and assembly programme to ensure the operational functionality of the final interfaces.
For the purpose of qualification, a single prototype key module [2] (~ 0.23 m long) will be mounted within a keyway formed between two dummy TFCC elements. The concept will be used to apply toroidal pre-loading and simulate PCR (Pre-Compression Ring) loading. A hydraulic ram will apply cyclic shear loading over a minimum of 30,000 cycles at a typical frequency of 0.1 Hz. The tooling will be mounted in a suitable custom test frame or testing machine, and testing will be performed at 77 K. The test facility will be equipped with the necessary instrumentation to monitor loading, the relative mechanical displacements of the dummy TFCC elements and the agreed stress levels in the keys. The facility will include a high-resistance meter to provide for the measurement of the electrical resistance of the key insulation at 300 K and 77 K. The contractor will develop inspection techniques to determine dimensional changes and assess wear at interfaces.

Scope of work

Task1: Detailed Design and Test Plan

The contractor shall prepare the detailed design of the test tooling and its interface to the testing machine based on this specification and the reference drawings provided by IO. This work package shall consist of four parts:

- Verification of the conceptual tooling proposals and of the interface to the testing facility/machine
- Detailed analysis of the IIS key module and tooling by an FEA to confirm the static and cyclic stress levels and displacements
- Preparation of the detailed mechanical design based on CAD models and drawings suitable for manufacture
- Preparation of the test plan, which shall include:
    - Proposals for testing sequences at 300 K and 77 K
    - Proposals for instrumentation monitoring and correlation with the FEA
    - A QA/QC plan including documentation and reporting
    - The overall schedule for the work

Task2: Manufacture and Commissioning of Tooling

The contractor shall be responsible for the manufacture of components in accordance with the approved drawings. The prototype IIS key module, which will be tested, will be supplied by IO. Proprietary items such as Superbolts and instrumentation components shall be procured by the contractor in accordance with the agreed specification.
The contractor shall perform a series of tests to commission the tooling. The commissioning shall be performed in 2 steps, the first at 300 K and the second at 77 K.

Task3: Execution of the Test Programme

The full test programme shall be developed and documented by the contractor in accordance with the agreed test plan. The test plan shall include the following steps for each test scenario:

- Toroidal preloading of the prototype key module using Superbolts to the specified preload for the scenario.
- Monitoring and recording of dimensional displacements, stresses and insulation resistances at 25, 50, 75 and 100% loading
- Mounting of the test module in the test frame/machine and cooldown to 77 K
- Execution of 100 shear load cycles at 50% of the specified shear loading
- Check of the insulation resistance at 77 K
- Execution of 100 shear load cycles at 100% of the specified shear loading
- Check of the insulation resistance at 77 K
- Execution of 30,000 shear load cycles at 100% of the specified shear loading
- Check of the insulation resistance every 5,000 cycles
- Warmup of the test module to 300 K
- Check of the insulation resistance at 300 K
- Dismantling of the test module with full visual (photographic), dimensional check of components
- Check and assessment of wear at the interfaces

Task4: Analysis of the TEST results and reporting

- The contractor shall prepare a detailed report and analysis of the test results. This shall include the following items:
  - A complete record of design drawings, analysis, material certification and manufacturing tolerances/inspection
  - Pre-assembly and commissioning records including toroidal Superbolt loading, test machine and instrumentation calibration
  - A full record of the test results, dimensional displacements, stress records and electrical insulation measurements
  - Comparison of experimental displacements and stress levels with the FEA results
  - Record of the final inspection and dimensional survey after completion of the tests
  - Record of wear at interfaces

Timetable

The tentative timetable is as follows:

Tender launch	October	2010
Tender submission	November	2010
Contract placement	December	2010
Deliverable: Task1	April	2011
Deliverable: Task2	July	2011
Deliverable: Task3	September	2011
Deliverable: Task4	October	2011

Experience

The contractor and its personnel shall have a well proven adequate experience in

- Performing mechanical and electrical tests on full-scale prototype assemblies (i.e., not only on standardized test samples) at cryogenic temperature;
- Handling instrumentation especially at low temperature (down to 77K) and vacuum environment. Proven experience in cabling, calibration, installation, operation and control software (data acquisition system) is required. The contractor shall show evidence of proven experience with resistive strain gages, linear displacement potentiometer measuring chains and electrical resistance measurements at low temperature;
- Performing 3D metrology and surface wear assessment by visual and microscopic examination. The contractor shall either have the necessary equipment in house or show evidence of proven experience with adequate laboratories in case this part of the work would be sub-contracted.

The contractor shall show evidence of owning a tensile test machine of sufficient load capacity to execute the required tests. The required minimum load capacity for the tensile test machine is 8MN and cyclic loading up to this level at 77 K over 30’000 cycles shall be possible.

Candidature

Participation is open to all legal persons participating either individually or in a grouping (consortium) which is established in an ITER Member State. A consortium may be a permanent, legally-established grouping or a grouping, which has been constituted informally for a specific tender procedure. All members of a consortium (i.e. the leader and all other members) are jointly and severally liable to the ITER Organization.
The consortium groupings shall be presented at the tender submission stage. The consortium cannot be modified later without the approval of the ITER Organization.