DTP2 – Verifying The Divertor Remote Handling Equipment For ITER

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Abstract. A major issue for the successful operation and long term availability of ITER reactor is the ITER reactor maintenance, which has to be done by remote controlled devices. Therefore, detailed design of the associated RH equipment and verification of its operation before ITER construction by way of prototypes and mock-ups, is considered an essential activity. The most important to meet the goal is the use of virtual techniques and virtual prototyping. However, the virtual prototyping shows just the behavior considered and modeled. Therefore, the real hardware is needed to expose the clearances, show the flexibility of structures, to point out the weak points of the proposed design.
The ITER divertor maintenance equipment will be tested in a test facility designated for that, DTP2. The test facility consists of the reactor mock-up, the reactor component transporters and various tools used for refurbishment. Essential element for the remote handling system is an operator control and command system with combination of graphical user interface, visualisation system and camera vision system. The work in DTP2 is just about to start. The divertor cassette transporter completing the DTP2 research platform will soon be delivered to Tampere. In this paper the DTP2 and its basic activities are explained and also some future activities are discussed.

1. Introduction

The ITER Tokamak machine aims to demonstrate the scientific and technical feasibility of fusion power. It is also the first fusion device producing thermal energy at the level of an electricity-producing power station. As a tokamak device, part of the plasma confining magnetic field is taken care by the plasma itself, so even minor disturbances can cause the plasma damage to the reactor walls and the divertor area. Also so called normal operation conditions produce high energy neutrons which are absorbed by components inside the reactor vessel leaving them beta and gamma activated to a level of several hundreds of Grays per hour. Therefore there is no human access into reactor and all the ITER in-vessel maintenance has to be made in a remote controlled manner. [4]

2. ITER divertor maintenance

The lower part of the reactor chamber is called divertor. The divertor is the region of the highest neutron flux density in the reactor. Due to erosion of the plasma-facing surfaces and the possible need for improving the basic divertor design, its periodic replacement and refurbishment in the hot cell is foreseen at least 3 times during ITER's 20 year operational lifetime. The ITER machine divertor componets are integrated into cassettes to minimize the number of activated components to be handled during the ITER maintenance. This simplifies the divertor replacement operations and allows divertor cassettes to be refurbished in hot cell.
There are 54 divertor cassettes to fully cover the toroidal divertor. Each of the cassettes weights approx. 9 tons and each of the cassettes is mounted on the toroidal rails in the reactor vessel. The cassettes are removed from the vessel and transported out from the vessel by

remote handling devices called “cassette movers”. A mover carrying the cassette in and out the reactor along the radial rails in the maintenance tunnel is CMM (Cassette Multifunctional Mover). To carry a cassette the CMM is equipped with an end-effector. There are many types of end-effectors suitable for different types of handling tasks. For carrying cassettes there are Central Cassette End-Effector (CCEE), Second Cassette End-Effector (SCEE) and Standard Cassette End Effector (StCEE). The SCEE is used specifically to remove the cassettes immediately to the left of the vessel access port. [4], [2]

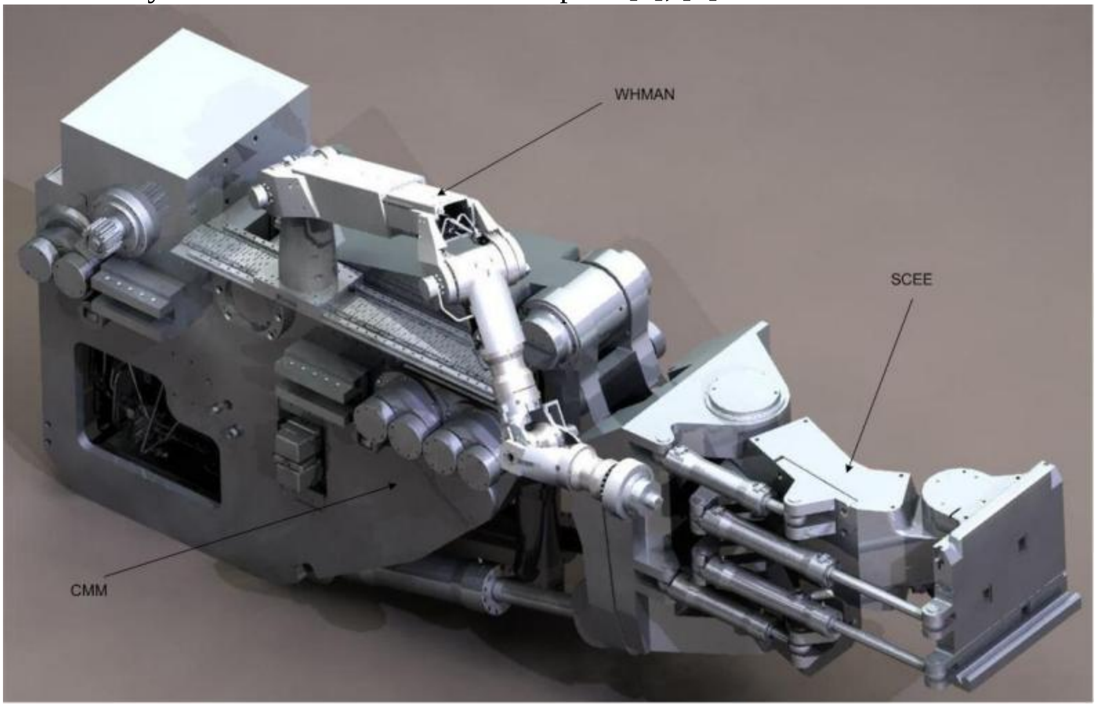

Figure 1. The Cassette Multifunctional Mover (CMM) with an end effector SCEE.

3. DTP2 test facility

One of the most important issues for the successful operation and long term availability of ITER reactor is the ITER reactor maintenance, which has to be done by remote controlled devices. Therefore, detailed design of the associated RH equipment and verification of its operation before ITER construction by way of virtual and hardware prototypes and mock-ups, is considered very important. An essential tool to for developing maintenance devices is the use of virtual techniques and virtual prototyping. In early phase the complicated operation environment is presented as 3D-CAD model. By adding kinematic features and motion, the maintenance tasks, movers, robots and tools can be designed and presented in the same environment. Further, by adding also the dynamic behavior, the maintenance devices can be tested through the complete modeled tasks.

However, the virtual prototyping shows just the behavior considered and modelled by the designer. Therefore, the real hardware is needed to expose the clearances, show the flexibility of structures, to point out the weak points of the proposed design, like the combination of clearances, flexibility and the control accuracy.

Therefore, after developing the outline engineering design for the CMM and its SCEE, the European Participant Team for ITER intends to construct hardware prototypes. These prototype devices will subsequently be used for the detailed development of ITER divertor remote handling procedures within a purpose built test facility which replicates the lower part of the ITER vessel, the divertor region. An experimental programme will be carried out in the test facility to demonstrate and test the remote maintainability of the ITER divertor. The "Divertor Test Platform" (DTP2) facility will present 27° sector of the ITER Vacuum Vessel. The facility is constructed in the laboratory hall of VTT Technical Research Centre of Finland in Tampere. The DTP2 laboratory is a joint venture activity between F4E, Euratom Tekes, Tampere University of Technology (TUT) and VTT. The facility is constructed in Tampere, Finland and operated by the Finnish Fusion Association, TEKES. [1]

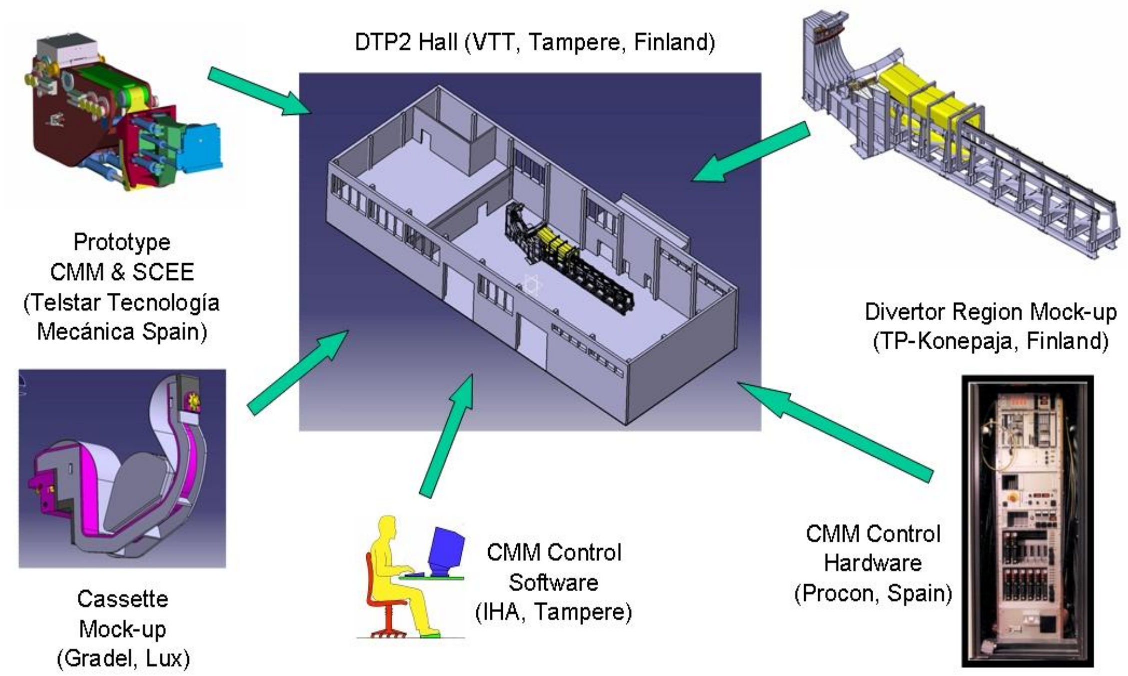

Figure 2.Components for DTP2 are procured form European companies.

Four separate procurement contracts were executed within European Industry for the supply of the major DTP2 sub-systems (See FIG. 2.) namely, a mock-up of the ITER divertor region (Divertor Region Mock-up, DRM), a mock-up cassette, a prototype cassette mover (CTM+SCEE, See FIG.1. & FIG. 3.) and the mover control hardware. The main element of the DTP2 is the DRM, a large fabricated structure which replicates the geometry of the lower part of the ITER vessel in the region of one radial port. The DRM provides the necessary radial and toroidal rails to support the divertor cassette, and the rails for remote handling equipment which carries out the divertor maintenance (See FIG. 4.).

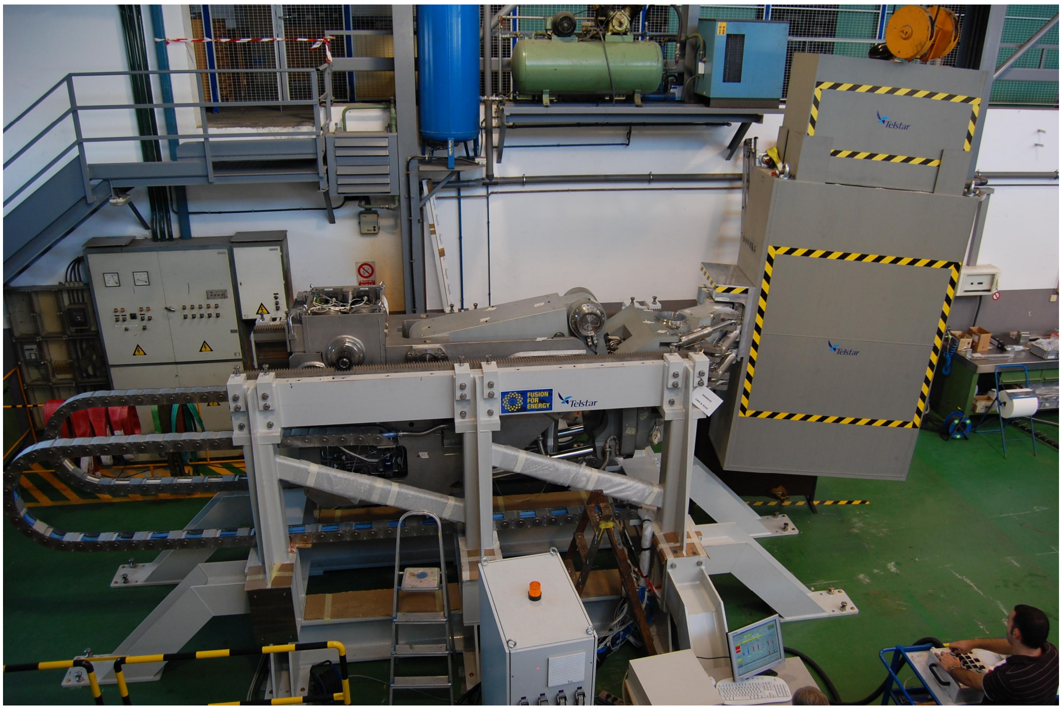

Figure 3. CMM under load test in factory.

The control system hardware is delivered without the software, so in parallel to the mechanical development, the software development is being carried out by staff of the DTP2 host organisation. All these DTP2 sub-systems were brought together in Tampere during 2006 and 2007. The first part of the divertor region mock-up was installed during 2007 and is fully prepared for the arrival of the cassette mover (expected Autumn 2008). After obtaining the mover, the DTP2 will be fully operational for performing RH trials. The planning and design of another mover carrying cassette toroidally is on the way. Also the planning for the full 63 degree divertor mock-up started in 2008. [3]

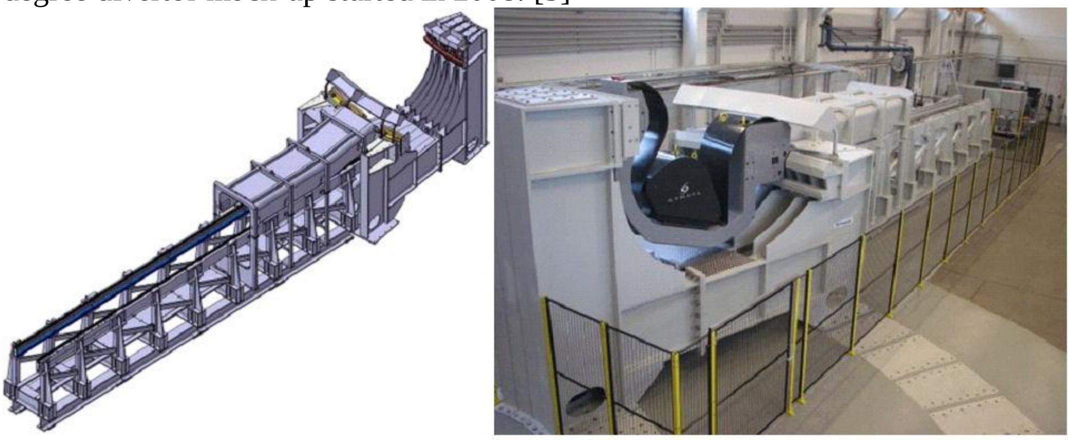

Figure 4. Divertor Region Mock-up is a heavy steel structure which can be extended further to cover also other maintenance tests.

4. CMM test program

The scope of the first phase of the test programme is to verify the operation of the planned divertor cassette removal process, and to develop it further where seen necessary. The removal is done with CMM carrying the seconf cassette end-effector (SCEE), assisted by a manipulator arm. The manipulator arm is used to handle tools for releasing the cassette locking to the vessel rails.

4.1. Test environment

In the real operational environment there is no human aspect to consider, but on DTP2, while testing and developing the RH equipment, human safety has to be taken into account. Within the DTP2 facility, there are two platforms where the movers can be tested. The first one is the CMM test stand allowing space for testing and tuning all the mover joints, without and with the cassette. The second one is the Divertor Region Mock-Up (DRM) representing the vacuum vessel sector and radial rails. On DRM the CMM can perform only movements allowed by the limited space between the rails. When the CMM movements are studied carefully, research persons are under continuous risk of being injured by moving devices. Therefore both test platforms are surrounded by a safety fence. When any of the doors of the fence are opened, all equipment motion is stopped. Operation can only be continued by having a “dead man’s handle” device (in this case wireless), which must be pressed continuously by the operator in the active area. There are also several emergency stop switches around the platform disabling all the motion of the devices in the case they are actuated.

4.2. The operator control system of the DTP2

The operator control system of DTP2 remote maintenance equipment combines several techniques. There is a camera system providing operator actual camera views where it is possible. The use of cameras is limited due to their reach to critical points, so the most used aid is a computer model of the operation environment. By complementing camera information with a calibrated computer model, the operator can get views required to drive the maintenance manipulators into wanted positions. While moving the device, the position information of the movers and manipulators are sent to the virtual model which is updated practically in real-time (See FIG. 5.).

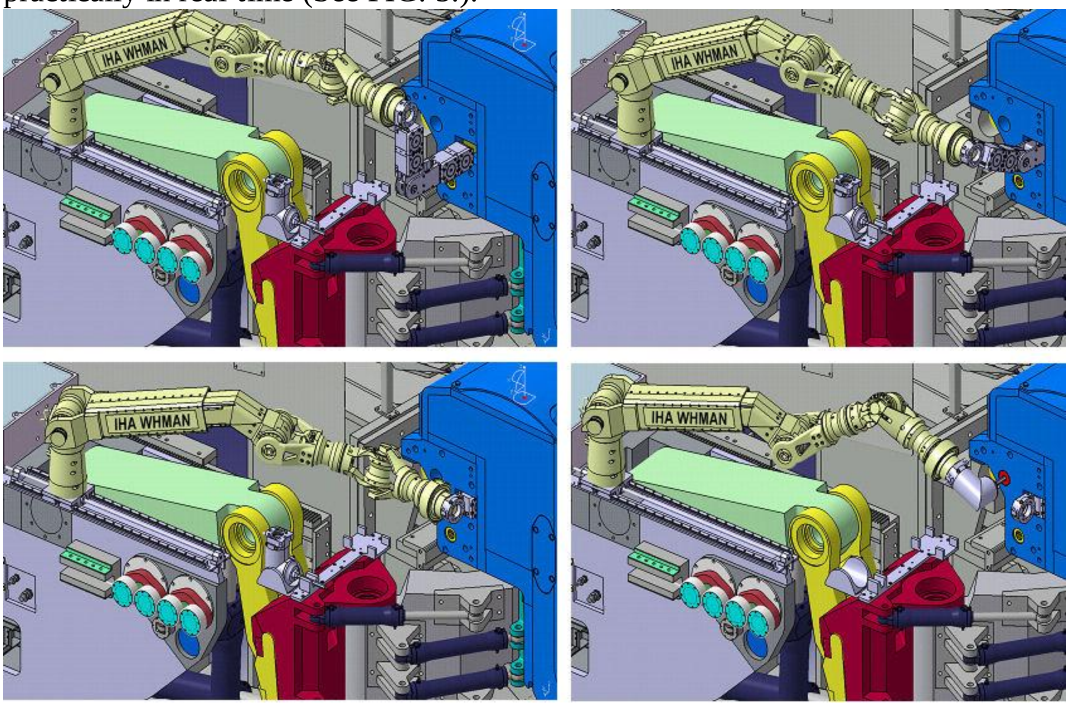

Figure 5. Control of complicated tasks can greatly be eased by using virtual model .

The command of the devices can be done by joy stick, numerically from the key pad, by pointer device from the graphical user interface or by combination of these methods. The use of the computer model provides many possibilities for ensuring that the operator keeps the equipment in the allowed area or path and for preventing unwanted collisions. For manipulator tasks requiring force feedback, like inserting tools for the cassette locking operations, a force feedback input device is used.

4.3. The DTP2 control room

The control room lay out is based on two operators and one supervisor. The operators have a number of computer screens on their desk. Additionally, there are two data projectors pointing onto the wall infront of the operators (See FIG. 6.). The supervisor can select the views shown on the wall to be able to follow the work and to point out issues to discuss with the operating team. The work and information flow of the team, the appearance of the information shown, the log files stored, and the ways to store the maintenance procedure for later use are important topics to be studied during the further DTP2 development work.

Figure 6. Operators in DTP2 control room use camera view and virtual model to control the divertor maintenance devices.

4.4. Extension of the DTP2

During 2009 the tests with the CMM+SCEE will be carried out. The continuing divertor maintenance test programme with an additional in-vessel mover, the CTM (Cassette Toroidal Mover), requires the DRM to be extended toroidally. After this extension DRM will cover a

63 degree sector of the vessel divertor area and will allow also in-vessel movers to operate in the reactor mock-up. The CTM will carry the cassettes toroidally from the reactor to the vicinity of the radial mover (CMM). The CTM will be designed and manufactured in 2009 and 2010. After that it will be installed into DTP2 and integrated to the operation control system for testing and further analysis. On the CTM there will be a manipulator arm to assist the cassette releasing operations in the same way as is done by the CMM manipulator for the Second cassette.

4.5. Practising the cassette replacement process

THE DTP2 environment provides an ideal facility to train and prepare the real reactor maintenance related routines. Besides the technical issues, there are also other type of processes to explore and practise during the DTP2 experiments.

- QA procedures of procurements, ensuring data exchange between subcontractor and F4E/ITER to meet ITER PLM-system.
- QA procedures for the divertor maintenance tasks, how to prepare the maintenance period, how to organize operator guidance through the maintenance procedure, how to handle unexpected events, storing information and experience for future operation.
- The level of CMM and manipulator arm automation vs. manual operations.

During all the divertor maintenance and the cassette replacement trials in DTP2, the operations will be recorded and analysed in a way that allows them to be analysed to provide information for the real ITER maintenance processes.

5. Conclusions

The DTP2 test program includes mechanical, electrical end software engineering to get the maintenance equipment working. However, simplicity of the maintenance tasks, operation instructions and operator user interface are necessary as well. Also the processes to obtain reliable maintenance equipment, processes to obtain controlled maintenance procedures and processes providing records of decisions made and data used will be developed. [5]

During the DTP2 operation, all the elements of ITER remote handling activities should be studied and developed. As a result, most of the issues will already have a solution when real maintenance work on ITER starts.

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7. References

[1] Siuko, M., Vilenius, M., Mattila, J., Muhammad, A., Linna, O., Sainio, A., Mäkelä, A., Poutanen, J., Verho, S., Mäkinen, H., Luomaranta, M. & Saarinen, H. 2006. Provision of test models and software for the CMM system. Fusion Yearbook, Association Euratom-Tekes, Annual Report 2005, VTT Publications 606 Espoo. VTT. pp. 58-60

[2] Siuko, M., Vilenius, M., Mattila, J., Verho, S., Mäkinen, H., Saarinen, H.& Keto, K. 2006. CMM design finalization. Fusion Yearbook, Association Euratom-Tekes, Annual Report 2005, VTT Publications 606 Espoo. VTT. pp. 60-61.

[3] Mattila, J., Poutanen, J., Saarinen, H., Kekäläinen, T., Siuko, M., Palmer, J., Irving, M., Timperi, A., 2007, “The design and development of Iter divertor RH equipment @ DTP2 facility”, Proceedings of the Tenth Scandinavian International Conference on Fluid Power, Tampere, Finland

[4] J. Palmer, M. Irving, J. Järvenpää, H. Mäkinen, H. Saarinen, M. Siuko, A. Timperi, S. Verho, The design and development of divertor remote handling equipment for ITER, Fusion Engineering and Design, Volume 82, Issues 15-24, October 2007, Pages 1977-1982

[5] M. Siuko, J.Järvenpää, J. Mattila, J.Palmer, C.Damiani, The Status of DTP2 (Divertor Test Platform 2) Project, 25th Symposium on Fusion Technology, Rostock Germany, 2008, accepted to be published.