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The use of virtual prototyping and simulation in ITER maintenance device development

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Abstract

Virtual prototyping technology has become a very valued tool in the early phases of product design. The use of virtual technologies is of special interest in the development of the ITER maintenance devices, mainly due to the large costs, sizes and complexity of physical prototypes. This paper shows how virtual prototypes are built and implemented in simulation tools, which are then used to develop the design of the maintenance equipment. Two applications are presented. The first case concerns the controllability of the water-hydraulics servo-actuators of the cassette mover. In the second application, a bilateral teleoperation architecture is designed to remotely control a robot manipulator. The resulting designs are going to be transferred, in a later phase, to a full-scale prototype facility (Divertor Test Platform 2).

Keywords: Virtual prototyping; Water-hydraulics; Manipulator; Teleoperation; ITER

1. Introduction

The ITER divertor maintenance [1] consists basically in the removal and installation of 54 divertor cassettes, which are mounted on toroidal rails along the lower part of the vacuum vessel. Each cassette weighs approximately 10 tonnes and has an external size of $3.5\,\mathrm{m} \times 2\,\mathrm{m} \times 0.8\,\mathrm{m}$ ($L \times H \times W$).

The presence of beta and gamma activated components within the vessel, together with hazardous dust, requires the use of special remotely operated equipment to handle the maintenance of the divertor. These maintenance operations are very demanding due to the weight of the components and due to constricted space around the components. The operations require high position accuracy, high forces and compact size of the

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actuators. The use of oil hydraulics is not allowed in fusion reactor because of the risk of reactor contamination with leaking oil and also because of the danger of oil becoming active by the radiation. Water-hydraulics is thus the only feasible solution for these conditions.

The use of virtual prototyping in the ITER maintenance is vital in the design and training of the maintenance procedures. The complexity, size and costs of the maintenance system justify the use of virtual models. Moreover, the time frame of the development process can be shortened by using the advantages and possibilities of the virtual technologies.

The Institute of Hydraulics and Automation (IHA) of Tampere University of Technology (TUT) has participated in the European FUSION program since 1994 within the ITER reactor maintenance activities. IHA took part in the mechanical design of the CMM (cassette multi-functional mover), providing its expertise in virtual and simulation technology. The CMM design was assisted with the use of software such as MSC.ADAMS, ANSYS, Envision, and Matlab/Simulink. During the current second phase, which is the focus of this paper, virtual techniques are used in the development of control architectures for the Remote Handling (RH) equipment. The obtained achievements are going to be implemented and tested in a physical mock-up facility named Divertor Test Platform 2 (DTP2). This platform is going to reproduce the lower part of the vacuum vessel and the remote handling ports. It will include also mock-ups of divertor cassettes and cassette movers. The main goal of the DTP2 is to verify and prove the RH equipment and its operation. The coordinator of the European fusion programme EFDA (European Fusion Development Agreement) decided to locate the DTP2 development and test laboratory for the maintenance of ITER reactor in Tampere. The DTP2 laboratory is hosted by the partnership between TUT and VTT, and it will be built during 2006–2007.

Safety studies have been systematically implemented in order to determine the safety requirements and the safety and security systems needed for the implementation and operation of the DTP2 test facility. The safety study, carried out by VTT, has consisted of three parts: preliminary hazard analysis, hazard and operability analysis, and safety and security system specification. From these studies, the essential safety risks and potentially hazardous situations related to the RH equipment were identified. Safety functions were categorised according to a "defence in depth" strategy. The functional requirements specifications of the CMM/SCEE control software have been taken into account the recommendations, findings and guidelines of the DTP2 safety studies, as well as the software dependability guidelines obtained in these safety studies.

This paper shows the use of virtual prototyping in the design and development of two different applications. The first case deals with the control system, and its user interface, to guide the cassette mover during the installation and removal of second cassette. In the second application, a teleoperation architecture with force feedback is implemented to govern a robotic manipulator, mounted on the top of the CMM.

2. Development of a control system for the cassette mover

Cassette multi-functional mover (CMM) is a remotely controlled device (see Fig. 1) which is used to remove and install divertor cassettes from and to the ITER divertor. The CMM travels radially through the racks of the RH port by means of two sets of rack and pinion systems powered by servomotors. An articulated two-link mechanism is attached to the main body of the CMM. This mechanism is driven by water-hydraulic servo-actuators and it provides lifting and tilting movements to the CMM end-effector. Due to the complex geometry of the RH port duct and the small clearances between this and the cassette, the lifting and tilting positions must be continually adjusted in order to transport the divertor cassette.

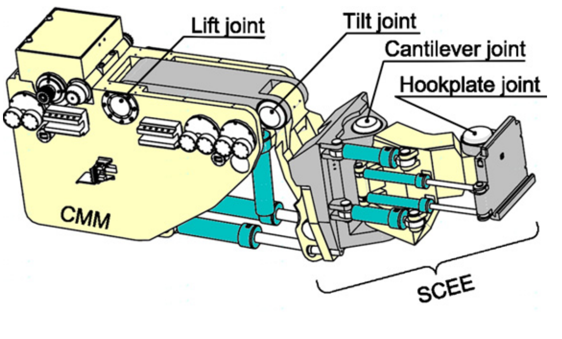

Fig. 1. CMM and SCEE.