A METHOD FOR ENABLING REAL-TIME STRUCTURAL DEFORMATION IN REMOTE HANDLING CONTROL SYSTEM BY UTILIZING OFFLINE SIMULATION RESULTS AND 3D MODEL MORPHING

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A full scale physical test facility, DTP2 (Divertor Test Platform 2), has been established in Finland for demonstrating and refining the Remote Handling (RH) equipment designs for ITER. The first RH equipment at DTP2 is the Cassette Multifunctional Mover (CMM) equipped with the Second Cassette End Effector (SCEE). The purpose of the facility is to prove that CMM/SCEE prototype can be used successfully for the second divertor cassette operations.

During the ongoing F4E grant "DTP2 test facility operation and upgrade preparation" it has already been proved that CMM/SCEE can be used for 2nd Cassette operations, when the operator has visual contact to the device and surrounding environment. The developed searching and picking process for the 2nd Cassette and a good repeatability of CMM/SCEE guarantee that 2nd Cassette operations can also be repeated remotely without a need to improve the absolute accuracy. However, the absolute accuracy is crucially important in the RH applications, where the visual information of the controlled device in the surrounding environment is limited. In this case, static 3D models are used to support the RH operations and recovery from abnormal situations.

Due its design, CMM/SCEE robot has relatively large mechanical flexibilities when the robot carries the nine-ton-weighting 2nd Cassette on the 3.6-meter-long lever. This leads into a poor absolute accuracy and into the situation where the 3D model is not reflecting the actual deformed state of the CMM/SCEE robot. To improve the accuracy, the effect of the load on the CMM/SCEE has been measured and taken into account in the load compensation functions, which were applied to the control system software. This resulted in a considerable improvement of the CMM/SCEE absolute accuracy. But when the 2nd Cassette is moved along a toroidal trajectory, CMM/SCEE also has large flexibilities in the direction, which can not be compensated by any of the joints of CMM/SCEE.

The paper presents how the load compensation functions have been implemented in the control system software to improve the absolute accuracy and visualization accuracy. It also proposes a method for accounting structural deformations in real-time through 3D model morphing that utilizes the FEM analysis results for linear deformations under the Hooke's law. This approach overcomes the limitations of the traditional joint-based flexibility by applying the fully flexible mesh morphing between the robot's unloaded neutral states and the loaded deformed states. The proposed method enables the use of existing flexibility measurements and offline simulation results, such as FEM analysis. The method is general and applicable to various problems in virtual engineering and robotic RH. In DTP2, the first application of this method is for providing accurate visualization of the CMM/SCEE robot deformations for the RH operators.