# ADVANTAGE OF REDUNDANCY IN THE CONTROLLABILITY OF REMOTE HANDLING MANIPULATOR

A. Muhammad[1], J. Mattila[1], M. Vilenius[1], M. Siuko[2], L. Semeraro[3]

[1] *Department of Intelligent Hydraulics and Automation, Tampere University of Technology*
[2] *VTT, Technical Research Centre of Finland*
[3] *F4E, Fusion for Energy*

*Corresponding author: muhammad.ali@tut.fi*

To carry out a variety of Remote Handling (RH) operations inside the ITER divertor a Water Hydraulic Manipulator (WHMAN) and its control system has been designed and developed at Tampere University of Technology (TUT) [1]. The WHMAN is designed to be installed on top of CMM and currently the preparations for this installation are underway. The functionality of WHMAN along with other divertor maintenance manipulators, i.e. Cassette Multifunctional Mover (CMM) and Cassette Toroidal Mover (CTM) will be validated at the Divertor Test Platform (DTP2), which is a full scale mock-up facility located at Tampere, Finland. The purpose of the DTP2 is to study the divertor RH concepts. While CMM and CTM are designed to carry heavy components such as cassettes through the service ducts relying on positioning accuracy and repeatability, WHMAN is designed to execute a mix of RH operations using position trajectories and master-slave telemanipulation. These operations includes cutting, bending and welding of pipes, locking and unlocking of cassettes during installation and removal, etc. The WHMAN is composed of seven joints: six rotational and one translational. Since the manipulator is installed on CMM via linear slide, this provides the eighth robotic joint for WHMAN (Figure 1). This arrangement of joints provides the manipulator a compact mechanical structure while fulfilling the demands of dexterity and reachable workspace inside the divertor. Since a manipulator requires only six joints to acquire the desired position and orientation in operational-space, the two additional joints of WHMAN provide the redundant degrees of mobility. The advantages of redundancy on the kinematic manipulability of the manipulators have been studied previously. Kinematic constraints such as mechanical limits, singularities and obstacles in the workspace can be avoided by using redundant Degrees Of Freedom (DOFs). However, the effect of redundancy on the dynamic manipulability has not been considered, which provides the motivation for this work. This paper presents how the redundancy of WHMAN can be an advantage to optimize the execution of RH tasks with long reach ability requirements in the constricted space of ITER RH tunnel. The paper also discusses an efficient and effective way to practically utilize the redundant DOFs. The results show that the additional DOFs improve the dynamic behavior of the manipulator and in turn its position and force control characteristics.

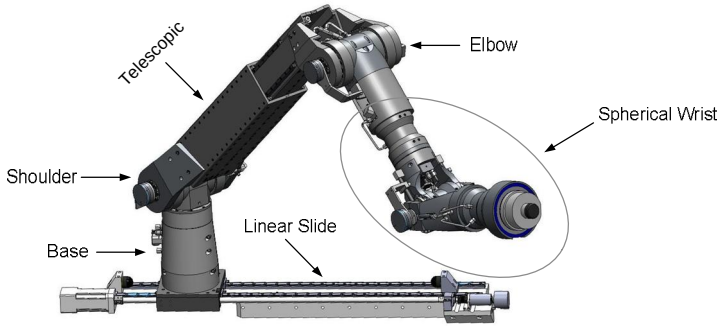


*Figure 1: 3D model of WHMAN showing the arrangement of joints*

[1] A. Muhammad et al., "Water hydraulic teleoperation system for ITER." *Proceedings of the 10th Scandinavian International Conference on Fluid Power.* Tampere : s.n., 2007, Vol. 3, pp. 263-276.