

ITER articulated inspection arm (AIA): R&d progress on vacuum and temperature technology for remote handling

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Abstract

This paper is part of the remote handling (RH) activities for the future fusion reactor ITER. The aim of the R&D program performed under the European Fusion Development Agreement (EFDA) work program is to demonstrate the feasibility of close inspection tasks such as viewing or leak testing of the Divertor cassettes and the Vacuum Vessel (VV) first wall of ITER.

It is assumed that a long reach, limited payload carrier penetrates the ITER chamber through the openings evenly distributed around the machine such as In-Vessel Viewing System (IVVS) access or through upper port plugs.

To perform an intervention a short time after plasma shut down, the operation of the robot should be realised under ITER conditioning i.e. under high vacuum and temperature conditions (120 °C).

The feasibility analysis drove the design of the so-called articulated inspection arm (AIA) which is a 8.2 m long robot made of five modules with a 11 actuated joints kinematics. A single module prototype was designed in detail and manufactured to be tested under ITER realistic conditions at CEA-Cadarache test facility.

As well as demonstrating the potential for the application of an AIA type device in ITER, this program is also dedicated to explore the necessary robotic technologies required to ITER's IVVS deployment system.

This paper presents the whole AIA robot concept, the first results of the test campaign on the prototype vacuum and temperature demonstrator module.

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1. Introduction

During the design phase of ITER, technical requirements became identified in terms of inspection tasks

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Fig. 1. AIA concept in ITER design.

and maintenance of the facility. One of the needs identified concerns close inspection and helium leak detection inside the Vacuum Vessel (VV) (see Fig. 1).

The main scope of this R&D program is to demonstrate the feasibility of an in-vessel remote handling inspection using a long reach, limited payload carrier (10 kg) that penetrates the ITER chamber through the openings evenly distributed around the machine. The possible ports taken into account are the In-Vessel Viewing System (IVVS) access and upper port access. This device is dedicated to close inspection processes of the plasma facing components (PFCs).

The work performed under the EFDA-CSU Workprogramme includes the design, manufacture and testing of an articulated device demonstrator called articulated inspection arm (AIA).

The first phase of the project concerned the analysis to define a realistic conceptual design of the equipment that fit the requirements of inspection operation inside the Vacuum Vessel.

A scale one mock up was manufactured, focusing on the electro mechanical test in air and at room temperature of a single module. The test campaign of a 2 degrees of freedom module was finally successfully

performed and gave confidence of structural resistance of the system which was the first essential design driver to verify.

In parallel, a feasibility study of operation under vacuum and temperature was performed to select the possible applicable technologies. At this step it has been identified the need for developments of specific new technologies in particular for bearings, actuators and electronics.

This development required proof of principle test phase. Therefore, a scale one full module with 2 degrees of freedom was manufactured and tested under vacuum and temperature conditions at Tore Supra facilities.

This paper presents in a first part the AIA robot, with its conceptual design, the kinematics of the robot and the relevant technologies. Then, the presentation focuses on the results of the test campaign performed on the CEA-Cadarache test facility.

2. Articulated inspection arm (AIA) conceptual design

A challenging design issue is being addressed to improve significantly the operational range of inspection tools. A long reach multi link carrier, like the AIA, is characterized by its large workspace and reduced mass. Unfortunately, increasing the number of joints with reduction of mass increases significantly structural compliance. When considering the ITER requirements for AIA, the limited access, the large operational range, the ultra high vacuum and pollution avoidance and the temperature ambience at 120 °C, a great improvement in the technology is required.

Due to the kinematics (a lot of actuated joints), with respect to the small outer diameter of the carrier (160 mm diameter), integration of actuators, sensors, electronics and wires is a major issue. Strong reduction of size and weight is required to successfully achieve the design. ITER in Vessel operational conditions have as well a strong impact on the design. The control of the system should also be able to provide easy driving. Full remote control under blind conditions requires on line collision avoidance and monitoring.

The AIA is a 8-m long multi link carrier with five identical modules of diameter of 160 mm and with two electrical joints. Each module includes pitch ($\pm 45^\circ$ in the vertical plane) and yaw ($\pm 90^\circ$ in the horizontal

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