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Design and development of the Articulated Robotic Inspection Arm (ARIA) for fusion machine

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Remote Handling (RH) systems for maintenance and inspection of in-vessel components have been addressed in great detail for fusion machines around the world. Maintaining high availability of fusion machine and minimizing the maintenance time require robust and dependable RH systems. Such RH systems, being electro-mechanical in nature, requires research and development in various areas such as structural design, kinematic and dynamic modelling, efficient real-time control, and Virtual Reality (VR) based monitoring. Adding to the aforesaid requirements, is criticality of investment protection of the sophisticated in-vessel components and their size and weight scales. The Articulated Robotic Inspection Arm (ARIA) has been indigenously developed at IPR, India as a proof-of-concept for in-vessel maintenance.
The paper presents, in detail, the design and development of the ARIA and associated VR based monitoring and control system. ARIA is a 6-Degrees of Freedom manipulator with a cantilevered payload capacity of ~25kg at 2meters distance. ARIA is controlled using a VR based user interface that immerses the ARIA model into the working environment. The effective 1:1 scale mapping of the VR model with the manipulator hardware makes provision for task planning and executing of the control commands from a remote location. The theoretical calculations with structural analysis of components like links, shafts, couplers, lugs and bearings are elaborately discussed. Results for payload sensitivity analysis during dynamic behavior are also presented. The system is optimized and developed to incorporate efficient commercially available servo actuators, bearings and gear-boxes, to maintain a high degree of accuracy and repeatability. Experimental validation and test results on a mock-up facility show that the system can be controlled with an end-effector positional accuracy within 2mm. The design and integration methodology, presented here, lays foundation to develop efficient RH systems with greater reach and payload capacity for future fusion machines.

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