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Design and development of snake arm maintainer for fusion reactor

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ABSTRACT

Fusion energy is the ultimate energy strategy for humanity and countries around the world are focusing on theoretical and experimental research on the fusion reactor. Remote maintenance of the fusion reactor is a technical challenge that must be addressed before it can operate commercially. The extreme environment of the vacuum chamber with its high temperatures and radiation limits the technical solution, which means that all operations must be done remotely. This study develops a remote handling system with a Snake Arm Maintainer (SAM) as the end effector, which aims to meet the maintenance needs of various narrow working spaces of the fusion reactor. The structure adopts the layered cable drive principle, whereby a single drive layer drives multiple joints. By changing the number of joints in the single driver layer of the snake arm, the arm can be adapted to various complex environments. The forward and inverse kinematic model are established based on the structural characteristics of the SAM. The trajectory planning and trajectory tracking of the SAM are completed based on the main curve method and the adaptive trajectory control algorithm, respectively. The static cable-driven forces of SAM are calculated based on force balance and torque balance. For the dynamic characteristics of the strong coupling of each joint cable, the cable traction dynamics are forcibly decoupled by means of force analysis and the joint torque equivalent transformation. Then, the equivalent dynamic model is obtained based on traditional series robot dynamic modelling methods (Lagrangian method, etc.). Finally, we established a SAM prototype and measured the position accuracy and cable force of the robot with laser trackers and multiple sensors. Experimental results validate the correctness of the structural design and control methods of the SAM.

Keywords: Snake Arm Maintainer, Cable-driven, Motion control, Special environment application.