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DYNAMIC SINGULAR MODELING, ROBUST SLIDING MODE FUZZY CONTROL AND DOUBLE ELASTIC VIBRATION ACTIVE SUPPRESSION OF FREE-FLOATING FLEXIBLE-JOINT AND FLEXIBLE-LINK SPACE ROBOT WITH BOUNDED TORQUES

Abstract

Nowadays the flexible space robot has received considerable attention. The flexibility of the space robot exists in both of the links and the joints. The flexible link has the advantages of lighter mass, lesser inertia, lower energy consumption, larger working place, and higher work efficiency. But it may deform and vibrate. The flexible joint can reduce the damage when the space robot collides with other objects. But it will generate system error and vibration. With the requirements of light weight, high speed and high precision for the space technology, the flexibility of the space robot system can not be ignored. Especially for the free-floating space robot system, the dynamic analysis and the control algorithm design become difficult due to the system's nonlinearity and strong coupling.Meanwhile, in the practical application, the drive's output torques are limited because of the change of the drive's size, weight, the battery voltage and so on. In this case, the control quality of the system will be affected. So the bounded torques should be taken into account when designing the control method of free-floating space robot system.Based on the above discussions, considering the external disturbances, uncertain parameters and bounded torques, the problem of the dynamic modeling, motion control and double elastic vibration active suppression for free-floating flexible-joint and flexible-link space robot is developed. The system's dynamic equations are established according to linear momentum conservation, angular momentum conservation, assumed mode method and Lagrange equation. And according to singular perturbation theory, the system's dynamic equations is decomposed into a slow subsystem(represents the system's rigid motion), a fast subsystem 1 (represents the system's flexible motion caused by the flexible joints) and a fast subsystem 2(represents the system's flexible motion caused by the flexible link). Then, for the slow subsystem, a robust sliding mode fuzzy control method based on hyperbolic tangent functions is proposed to compensate the uncertain parameters, external disturbances and system errors, and to achieve the asymptotic tracking of the system's desired trajectory. For the fast subsystem 1, a velocity difference feedback control method is designed to suppress the elastic vibration caused by the flexible joints. For the fast subsystem 2, a linear quadric regulator is used to suppress the elastic vibration caused by the flexible link. So the system's control method is an integration of the above three control method. The simulation results validate the efficiency of the proposed hybrid controller.