THE DYNAMIC AND ROBUST CONTROL OF SPACE ROBOT DURING CAPTURE OPERATION

Qiuhuang Dong*, Li Chen*
* *School of Mechanical Engineering and Automation, Fuzhou University, Fuzhou, 350108, China*

Summary In this paper, base on the multi-body dynamic theory, the dynamic equations of a free floating space robot are derived during capturing a free motion target. The dynamic equations of the space robot are derived with the Lagrange formulation, and the dynamic equations of the free motion target are derived with the Newton-Euler formulation. The combination equations are obtained base on the above equations of space robot and target during capture operation. The final combination equation can be decomposed in a linear form about the uncertain parameters, base on the above decomposition, a robust control are design for the space robot which will calm down the space robot and overcome the effect of uncertain parameters

INTRODUCTION

As the development of the space technology, more and more equipments are applying in the outer space. The servicing works for these equipments are becoming heavier than before. The space robot is becoming a good assistant for the astronaut [1]. The free floating space robot is a kind of special robot; the base of the robot is free under the micro gravity condition when the robot works in the outer space. This is different with the robot which works in the earth, so there are strong dynamic coupling between the links and the base of the space robot. The main assignment of the space robot is capture operation. The impact between the robot and the target can not avoid when the robot capture the target. The impact force will affect the state of the robot, and the uncertain parameters of the target will affect the control [4][5][6].

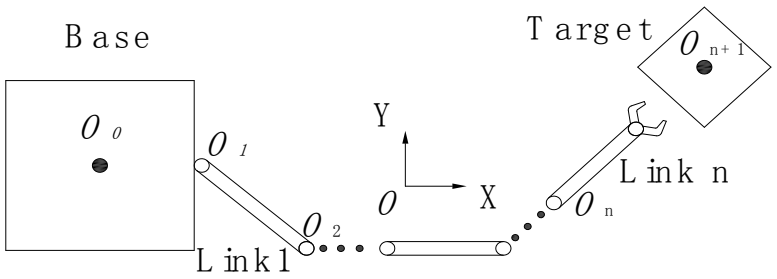

Fig.1. The model of the space robot and the target during capture operation

DYNAMIC MODEL

The model of the space robot during target capture operation shown in Fig1. The free motion base and the links comprise the space robot, and the target is free motion. The dynamical equations of the space robot are derived with Lagrange formulation:

$$\boldsymbol{D}\ddot{\boldsymbol{q}} + \boldsymbol{H}\dot{\boldsymbol{q}} = \boldsymbol{\tau} + \boldsymbol{J}_m^T \boldsymbol{F}_e \tag{1}$$

The dynamical equations of the target are derived with Netwon-Euler formulation:

$$\mathbf{D}_t\ddot{\boldsymbol{\varphi}} + \mathbf{C}_t = \mathbf{J}_t^T \mathbf{F}_e' \tag{2}$$

Base on the Newton law, the impact forces have the relation:

$$\boldsymbol{F}_e' = -\boldsymbol{F}_e \tag{3}$$

Upon the combination of Eq.(1),Eq.(2) and Eq.(3) the following is obtained:

$$\mathbf{D}_c\ddot{\mathbf{q}} + \mathbf{C}_c = \boldsymbol{\tau} \tag{4}$$

The Eq.(4) is the combination equations of space robot and the target. The left part of Eq.(4) can be rewritten in a new form:

$$\mathbf{W}\boldsymbol{\Phi} = \boldsymbol{\tau} \tag{5}$$

The $\mathbf{W}$ is a matrix which do not contain the uncertain parameters, and the $\boldsymbol{\Phi}$ is a vector which contain the uncertain parameters. The left side of the new equations has a linear relation with the uncertain parameters, so the robust dynamic control can be used for the space robot during capture operation. The robust control will calm down the space robot during the capture operation, and it will overcome the difficulty of the parameters uncertain.

References

[1] Noriyasu Inaba, Mitsushige Oda: Autonomous Satellite Capture by a Space Robot[C]. Proceedings of the 2000 IEEE International Conference on Robotics & Automation , San Francisco, CA April 2000.

[2] Steven Dubowsky , Evangelos Papadopoulos: The Kinematics, Dynamics, and Control of Free-Flying and Free-Floating Space Robotic Systems [J]. IEEE Transactions on robotics and automation, 1993.10,9(5):531-543.

[3] Yoji Umetani,Kazuya Yoshida: Resolved Motion Rate Control of Space Manipulators with Generalized Jacobian Matrix [J]. IEEE Transactions on robotics and automation, 1989.6,6(3):303-314.

[4] Liang-Boon Wee, Michael W. Walker: On the Dynamics of Contact between Space Robots and Configuration Control for Impact Minimization[J]. IEEE Transactions on robotics and automation,1993.10,9(5):581-591.

[5] Panfeng Huang，Yangsheng Xu，Bin Liang: Contact and impact dynamics of space manipulator and free-flying target[J]. Intelligent Robots and Systems,2005:1181-1186.

[6] Kazuya Yoshida, Dimitar Dimitrov, Hiroki Nakanishi: On the Capture of Tumbling Satellite by a Space Robot[C]. Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems. October 9 - 15, 2006, Beijing, China,4127-4132.