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DYNAMICS MODELING AND ADAPTIVE CONTROL OF FLEXIBLE MANIPULATORS

J.Z. Sasiadek

Department of Mechanical & Aerospace
Engineering

Carleton University

Ottawa, Ontario, Canada

Abstract

This paper presents an application of Model Reference Adaptive Control (MRAC) to the position and force control of flexible manipulators and robots. In this paper a single-link flexible manipulator has been analyzed as an example [1].

1. Introduction

Control of flexible structures is of paramount importance in various applications in aerospace, mechanical and construction industry. The problem itself is not a new one and has been described extensively in literature related to control of distributed parameter systems. Robots with flexible links are interesting examples of mechanical systems with the flexible structure. Flexibility of links poses several difficult problems with position control. One of the most severe problems is vibration of the end-point caused by links structural flexibility. Design of an appropriate control system requires a good knowledge of dynamics. In general there are several methods for dynamics modeling. Two are of special interest: 1. an assumed modes method, 2. finite elements method. Both methods have been described in several books [2] and papers [3]. If, dynamics of a flexible manipulator or robot has been identified and

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determined, an appropriate control system can be designed. Robots have strongly nonlinear characteristics. This feature is even more visible for flexible manipulators. Thus, flexible robots require especially efficient control systems. There are numerous control systems based on feedback or feedforward principle. The link inertias change continuously with position, payload and time, therefore control system has to follow and adapt itself to assure a steady and smooth performance. The adaptive control seems to be well suited for that purpose. One of the most promising of such systems is Model Reference Adaptive Control (MRAC). The main advantage of adaptive control is that the system is payload insensitive and that its performance is steady over broad range of conditions.

2. Problem Formulation

The problem addressed in this paper was to develop a mathematical model of a flexible robot. The model has to be accurate and in some applications a real-time simulation may be required. Dynamics of the manipulator have been used in designing of its controller. Adaptive control schemes require special attention to make sure that stability of the system is maintained. The objective is to show that the adaptive control performs better than "conventional" systems and is suitable for flexible structure control.

3. Mathematical Model

The mathematical model described in this paragraph has been developed and described in detailed in [1]. The single link flexible manipulator has been modelled as a cantilever beam and following assumptions have been made [1]:

- the mass and elastic properties of the link are distributed uniformly along its longitudinal direction;
- Euler's beam theory is applicable, thus the transverse shear stresses and the moment of inertia with respect to elastic deformation are negligible;
- the elastic deformation of the link is small;
- the change in potential energy of gravity due to elastic deformation of the link is negligible.

Single-link flexible manipulator has been shown in fig.1 (all figures from [1]) and its dynamic performance has been shown in subsequent figures [1].

4. Adaptive Control

Figures 7 to 12 present various dynamic responses with control. The comparison between those responses and free responses has been shown. Simulation results show that the adaptive control system performance is satisfactory and is payload insensitive. It is clear that adaptive control can be used with success for flexible robots control.

5. Conclusions

- Modal expansion method is an accurate representation of flexible manipulator dynamics.
- Three flexible modes approximation can be considered as satisfactory.
- The discontinuities in the robot response caused by coupling between the rigid and flexible modes can be eliminated by an efficient control system.
- An adaptive control system reduces the positioning error of the end-effector and shortens the settling time.

Acknowledgement

This work is based on [1].

References

- [1] Sasiadek J.Z. and Srinivasan R., Dynamic Modeling and Adaptive Control of a Single-Link Flexible Manipulator, AIAA Journal of Guidance, Control and Dynamics, November 1989, Vol.12, No.6.
- [2] Meirovitch L., Elements of Vibration Analysis, McGraw-Hill, New York, 1986.
- [3] Cetinkut S. and Book W.J., Performance Limitations of Joint Variable-Feedback Controllers Due to Manipulator Structural Flexibility, IEEE Transaction on Robotics and Automation, April 1990, Vol.6, No.2.

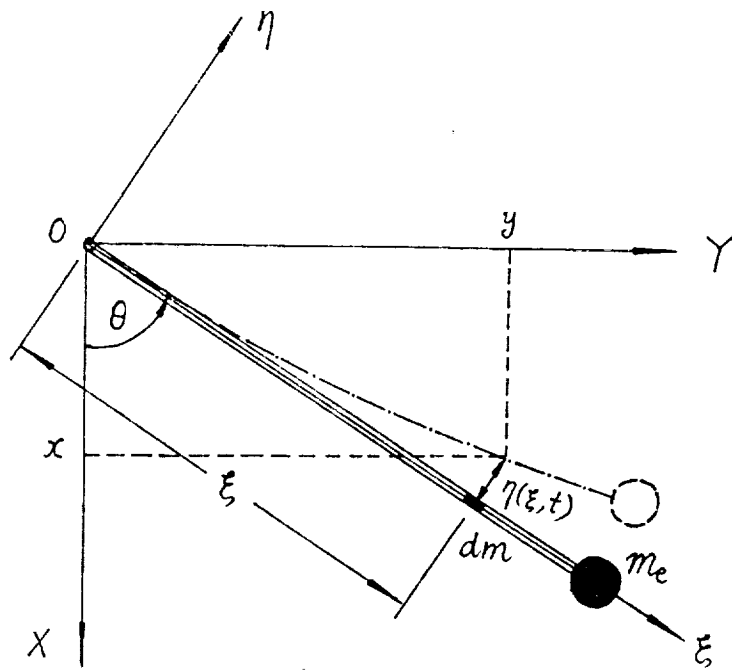
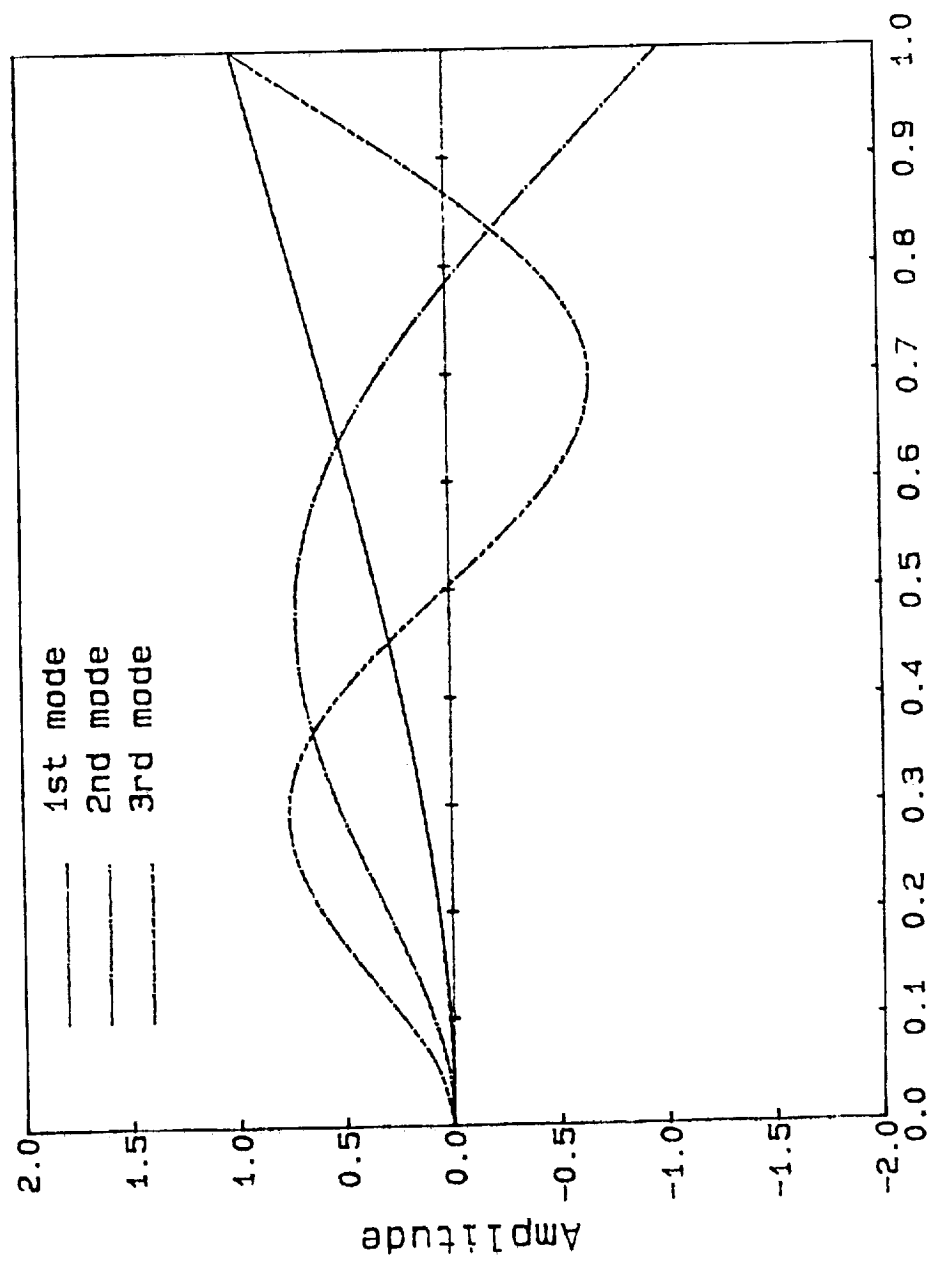
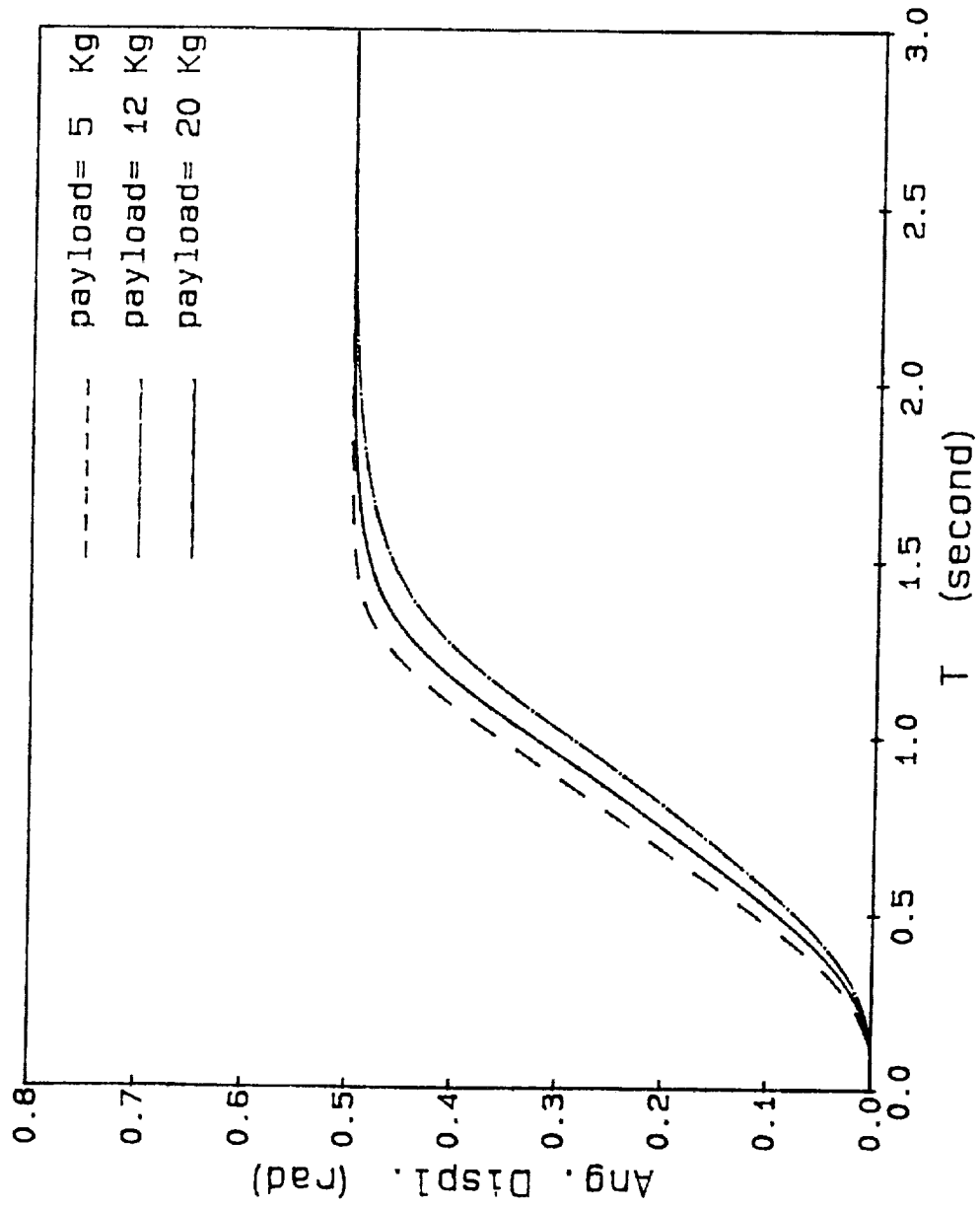


Fig. 1 Single-Link Flexible Manipulator [1]

[Fig. 2] MODAL SHAPE OF MANIPULATOR []

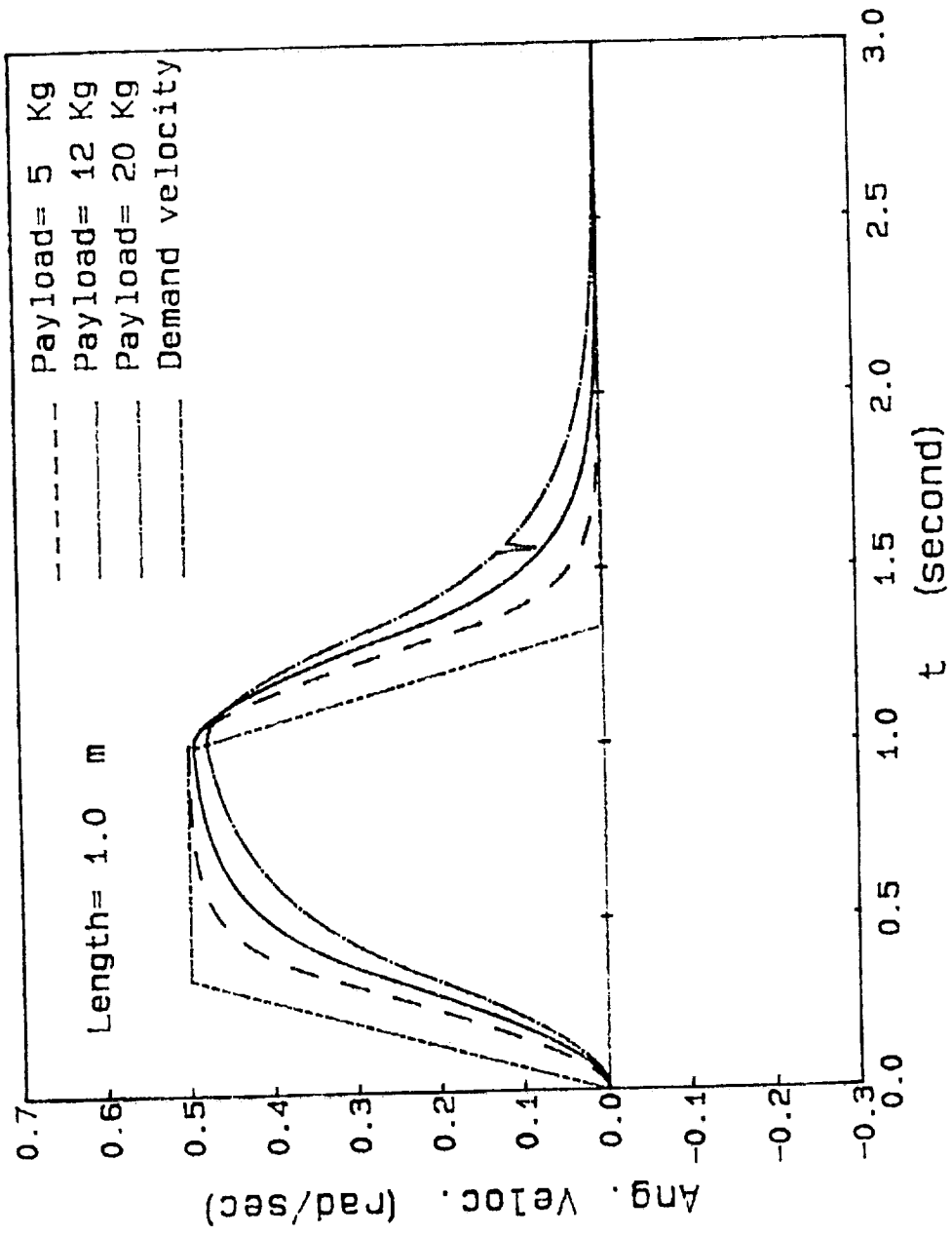


[Fig. 3 J] TRANSIENT RESPONSE OF MANIPULATOR [I]

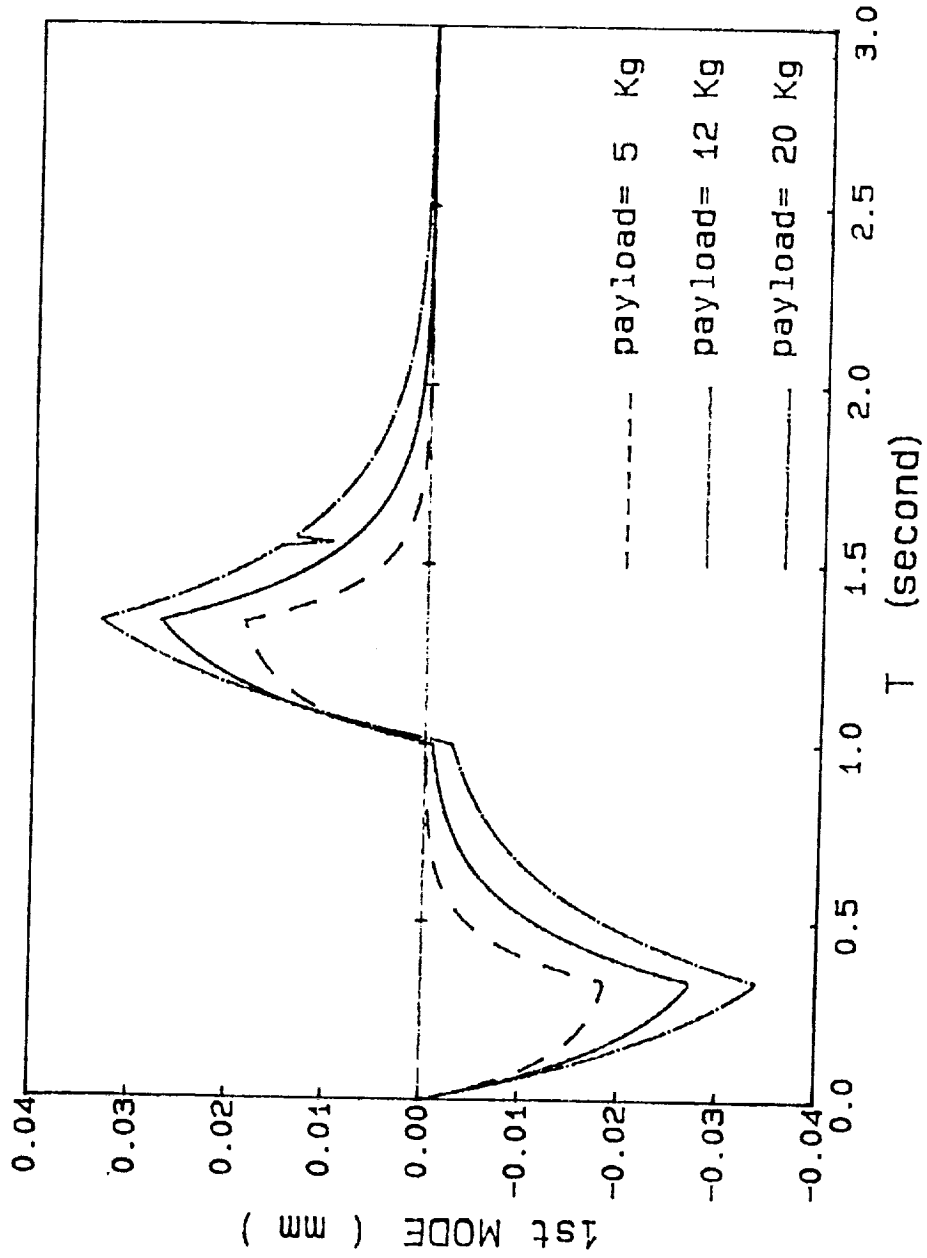


TRANSIENT RESPONSE OF MANIPULATOR [1]

[Fig. 4]



[Fig. 5] TRANSIENT RESPONSE OF MANIPULATOR [1]



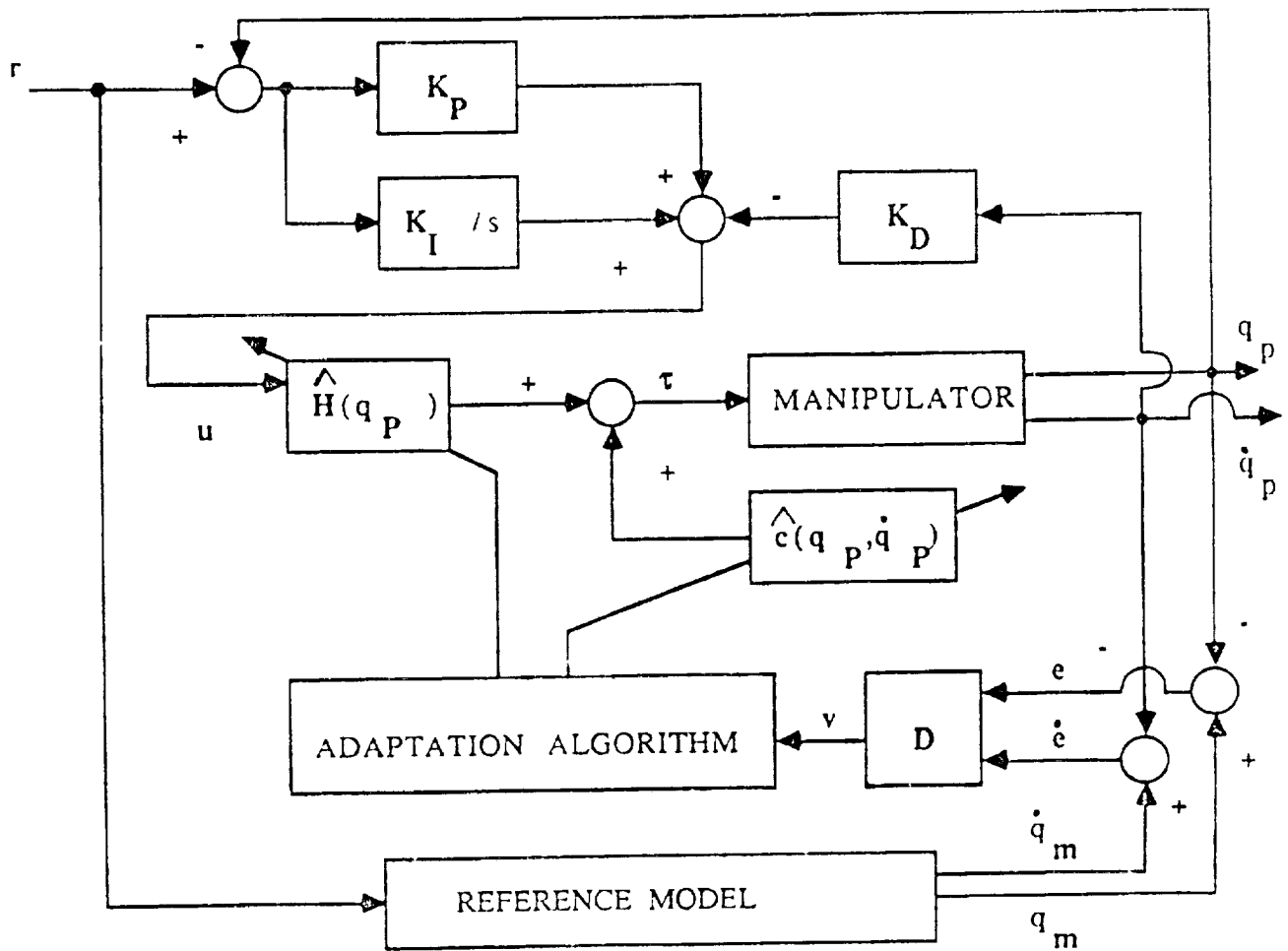


Fig. 6 Block Diagram of MRAC [1, Arare-Hulbon]

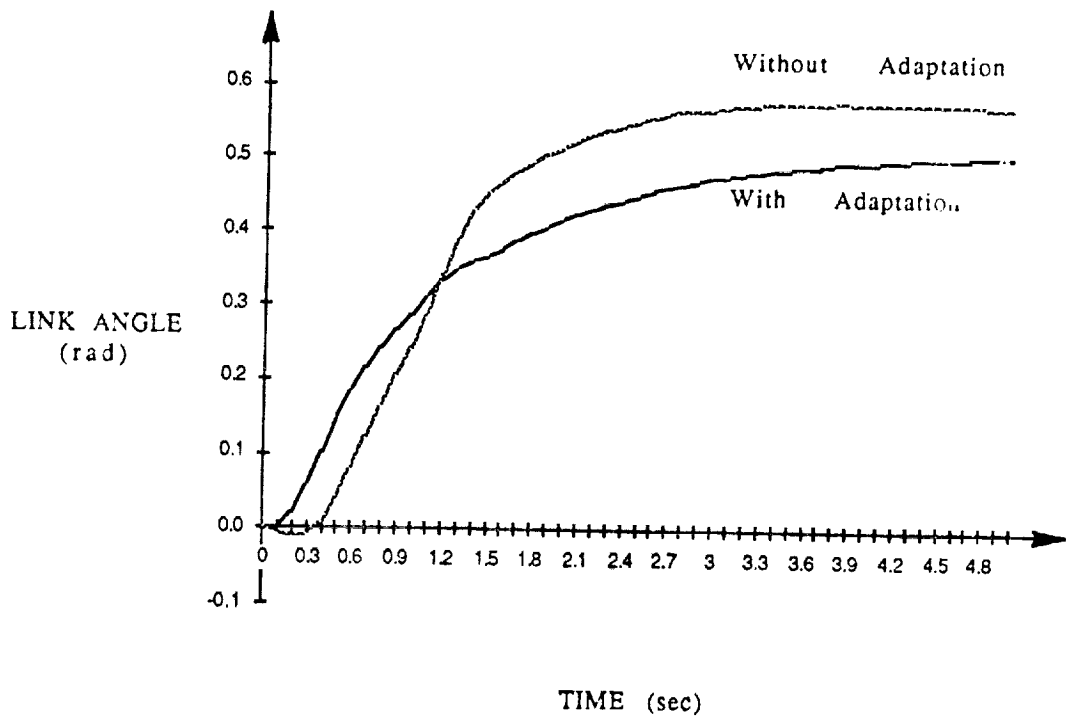


Fig. 7 Step Response of Joint Angle [1]

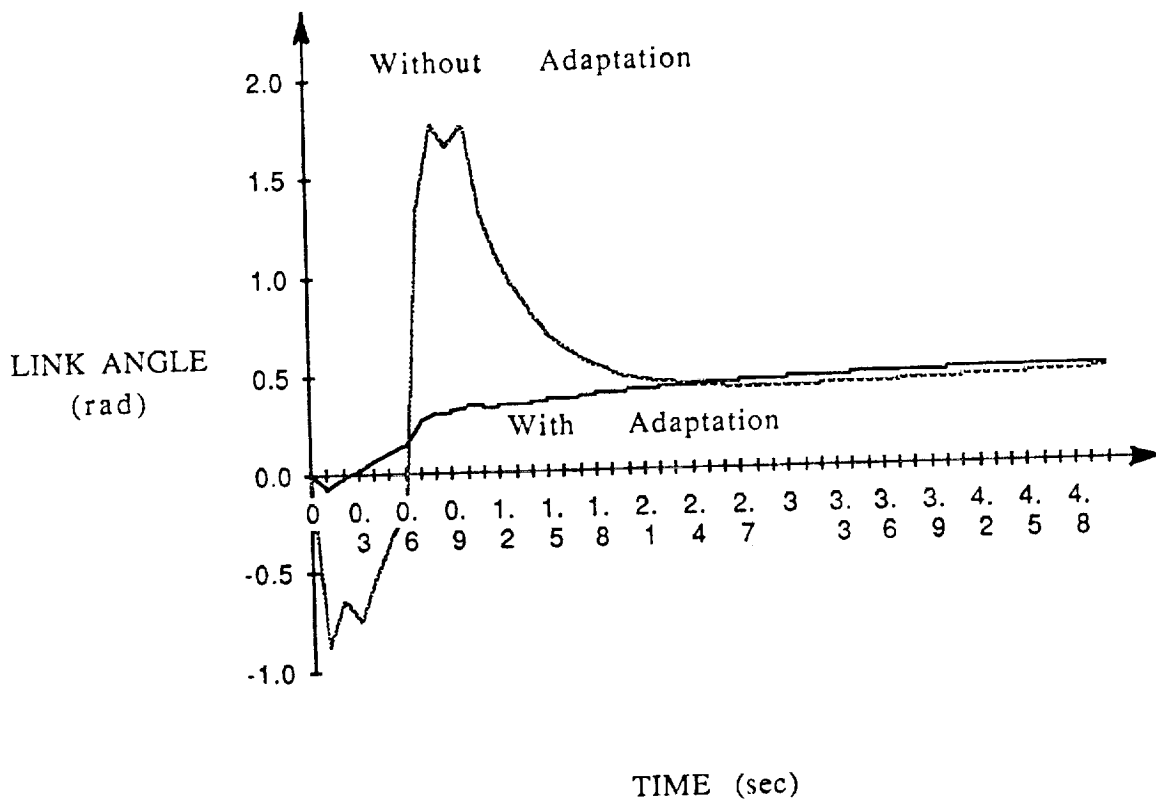


Fig. 8 Impulse Response of Joint Angle [1]

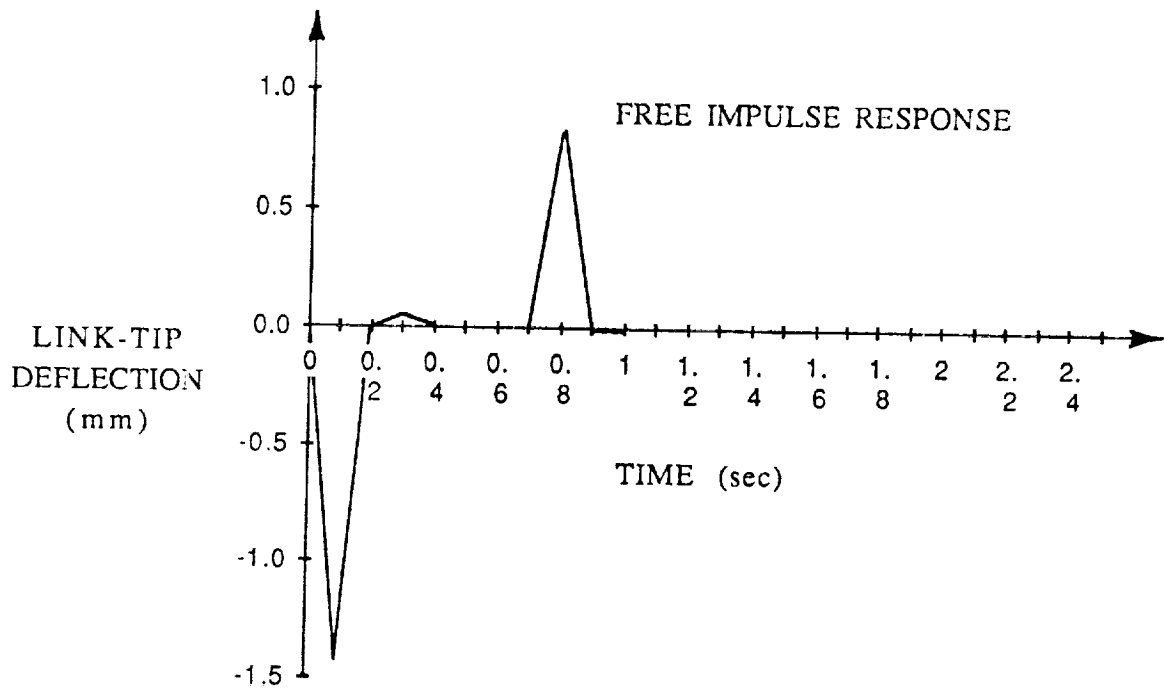


Fig. 9 Free Impulse Response of the Flexible Manipulator [1]

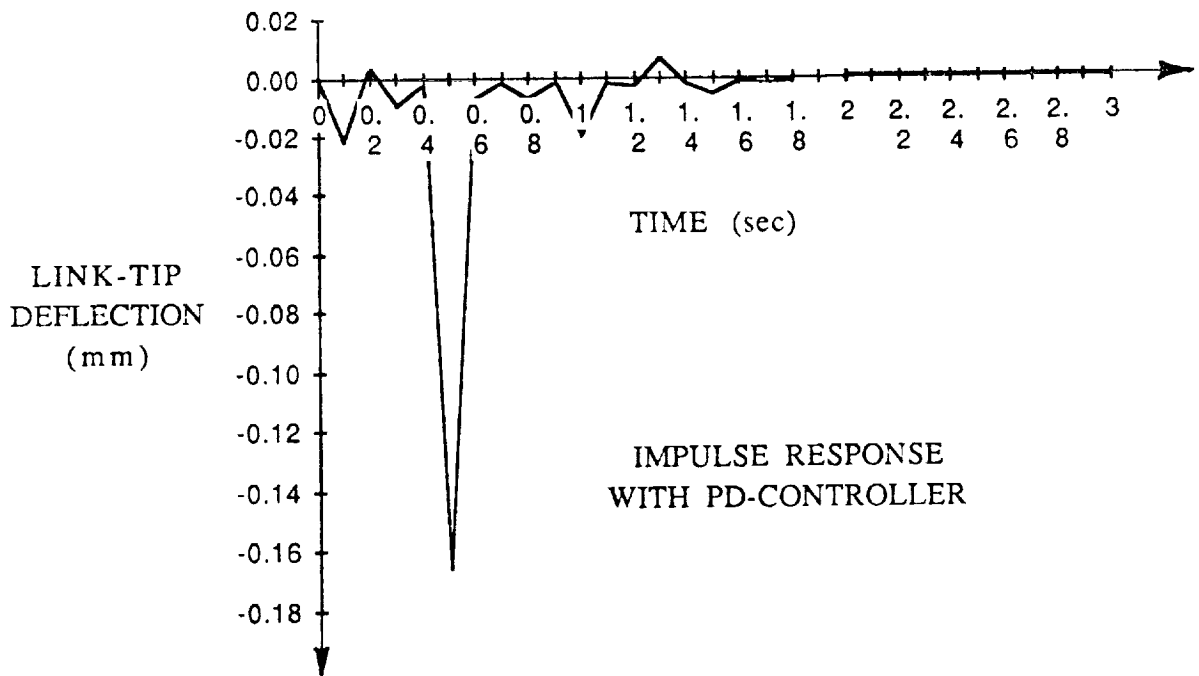


Fig. 10 Impulse Response with PD Controller [1]

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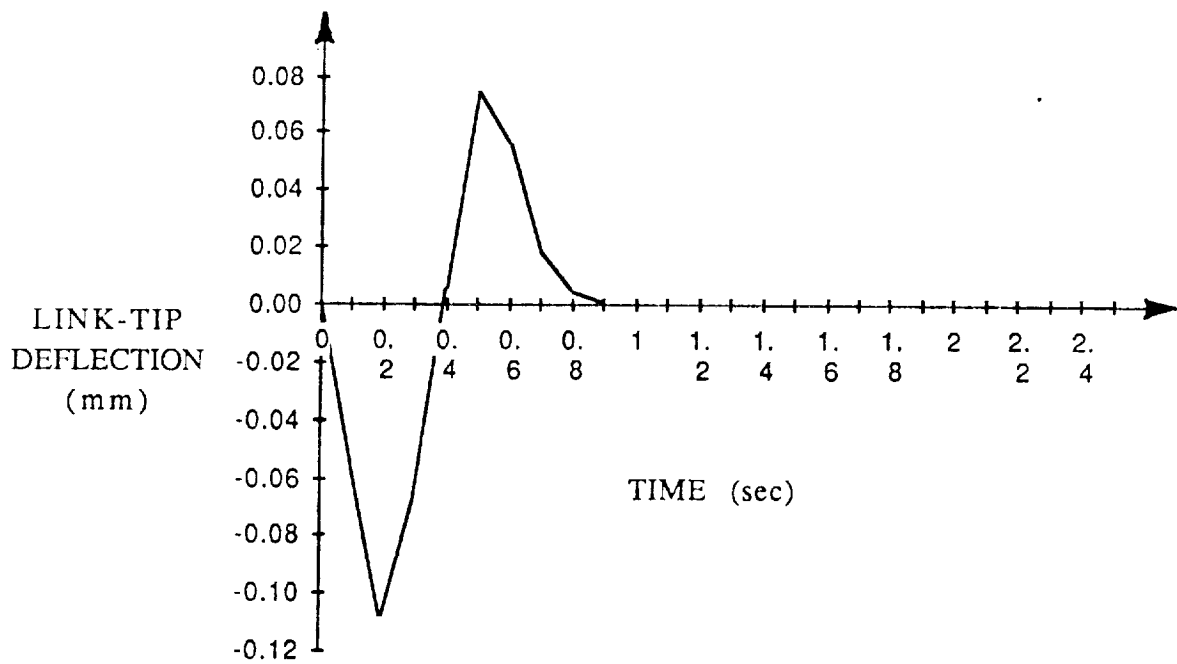


Fig. 11 Flexible Manipulator Response with MRAC [1]

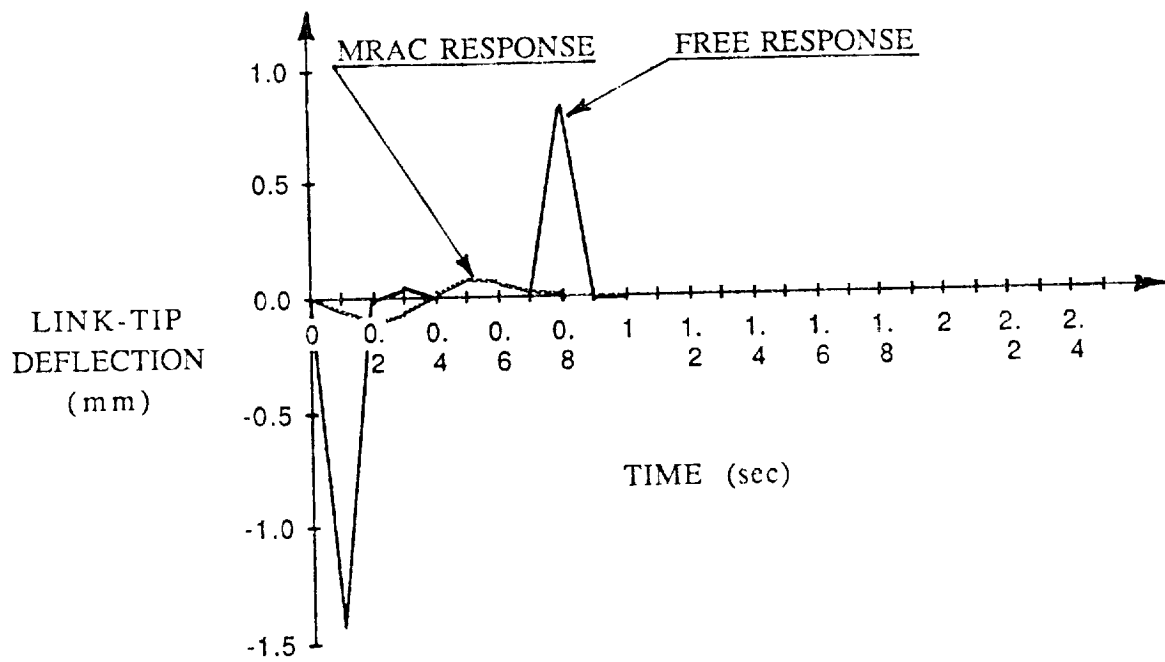


Fig. 12 Comparison between Free and MRAC Responses [1]

