International Journal of Hybrid Information Technology
Vol.7, No.2 (2014), pp.103-112
http://dx.doi.org/10.14257/ijhit.2014.7.2.11

Pre-Load Torque Responses for Flexibility in Single Link Manipulator

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Abstract

The Research article includes Model Torque Responses for flexibility of single link manipulators using Linearization Technique named as a LCQ. Manipulators are nothing but one type robotic arms commonly used in the industry .Here the controller design technique used for controlling manipulator was Linear Quadratic Controller Design. Generally the robotic arms are non-linear in nature. In order to control the non-linearity of manipulator and angular displacement, state space technique is used. The topology explains dynamic characteristics occurring in abnormal working condition torque responses are modified by using Linear Quadratic Controller Design Technique. The design method approach in state space control strategy. The dynamic torque responses of single link manipulator in abnormal condition and also using LCQ Technique are shown by M-File Controlling block of Simulink Library in Mat Lab Control tool box.

Keywords: *Single Link Manipulator, Linear Quadratic Controller Design, Linearization Technique, State Space Technique*

1. Introduction

The robot technology changes rapidly and it becomes most in advance one. The industry is moving from the current state of automation to robotic technology, to increase reliability and to produce uniform quality. S. Pal (1998) and D. Karandikar (2000) *et al.* suggests that Robots like manipulators are now commonly employed in every environment to avoid instrument and gross errors. Robots are being employed to construct and repair space technology and related equipments [1, 3].

A Manipulator: a machine that has functions similar to human upper limbs, and moves the objects spatially. Y. Aoustin (1994) *et al.* states generally, a manipulator means it is type of robot arm or robotic hand tool equipment. Every robot may possess some manipulators for flexible operations. Large weight manipulator introduces limitations in terms of speed, energy consumption, and mobility [2]. S. Pal (1998) and Jeffery H. Yakey (2001) *et al.* describes a suitable approach to overcoming these disadvantages is to design flexible manipulators in robotic applications [1, 5]. B. Subudhi (2000) and Ming-Tzu Ho (2005) *et al.* states Robotic manipulators are widely used for help in dangerous, authentic and highly intricate applications due to their robust performance. The present manipulators are designed and built in a manner to get maximum stiffness an attempt to minimize the end effectors to get good running performance and linear torque responses. The high stiffness is achieved by using good performed material and bulky design. Hence the existing manipulators are practically inefficient in terms of power consumption and their operating load conditions [7, 9]. Recent robotic technology initiates and design with respect to three parameters as follows

1. Power consumption should be less.

ISSN: 1738-9968 IJHIT

2. Statistical approach should apt for manipulator.
3. Torque performance should be smooth in order to maintain reliable and flexible operation.
4. Speed should be continuous with proper operating torque and pay –load conditions.

The operation of highly accurate and précised robotic manipulators are severally limited by their changed dynamic tip deflections which results a certain time period with specified complications. Book W. J. (2003) *et al.* describes the complication requirement with high speed and high accuracy has rendered the robotic assembly task, a challenging aspect in present research technology. Compared to conventional heavy and bulky robot manipulators, flexible link manipulators have added the advantage of lower cost lager extension of work volume, high operating torque, grater pay load to manipulator weigh ration, smaller actuators, lower energy consumption and better performance, movable too [11, 4]. Due to more importance and usefulness of robot manipulators, the investigation has started on control of flexible manipulator through controlling their tip vibrations and dynamic performance using some controllers like PID, MPID, pole placement, *etc.* Book W. J. (1979) *et al*. using the vibration signal, *i.e.*, from the motion of flexible link manipulators is one of the important methods used in controlling for tip vibration and model torque in system. The proposed LQC was used for eliminating non-linear tip vibrations and torque responses at end position into a linear one [10]. Dibakar Bandopadhya (2007) *et al.* states By carried out experimental orientation, the controlling of flexible link manipulators where position of end point was controlled by measuring position Using LQC Technique the finite number of iterations must be chosen for linearization in manipulator till we get linear torques at far end [8].

2. Flexible Manipulators

Flexible manipulators possess a lot of advantages over their traditional rigid link counter parts, like less weight, less power input, higher speed response and less energy consumption etc. But flexible manipulators require accuracy in end position of the manipulator and they need to control the tip deflections of the manipulator. Since a flexible link has an infinite number of modes of vibration, it is impossible to control all these modes similarly, therefore the iterative part to be chosen for feedback control to get good angular position and rectified or damped vibration of the manipulator.

2.1 Dynamic Modeling

The Dynamic modeling of the manipulator is done by taking the link parameters form the model object.

Length (L) = 0.5m

Width (B) =25mm.

Thickness (T) = 2mm.

Mass density /unit volume (ρ_b) =7800kg/m ^{3}

Youngs modulus (E)=210*(10^9)N/m ^{2} .

Tip mass load (m $_0$)=100gm/200gm.

By using the values of beam parameters the mass matrix (M) and the stiffness matrix (K) are found. The values of elements of matrix M and K are found by using the M-file program

The co-ordinates of the point p1 on the beam at a distance of x from the origin

$p_x^{\ 1}$=xCosθ-wCosθ. (1)

$p_y^{\ 1}$=xSinθ+wCosθ. (2)

Position vector of a point P^1 is given by

$$P^1 = \begin{bmatrix} p_x^{\ 1} \\ p_y^{\ 1} \end{bmatrix} = \begin{bmatrix} x\cos\theta - w\cos\theta \\ x\sin\theta + w\cos\theta \end{bmatrix} \quad (3)$$

Velocity vector of point P^1 is represented by

$$\dot{P}^1 = \begin{bmatrix} -x\sin\theta\dot{\theta} - w\cos\theta\dot{\theta} - \sin\theta\dot{w} \\ x\cos\theta\dot{\theta} - w\sin\theta\dot{\theta} + \cos\theta\dot{w} \end{bmatrix} \quad (4)$$

2.2 Kinetic energy of the flexible link

Dynamic modeling of the manipulator is done by taking the link parameters as shown.

Length (L) = 0.5m,

Width (B) =25mm,

Thickness (T) = 2mm.

Tip load (m_0) =100gm/200gm.

Mass density per unit volume (ρ_b) =7800kg/m^3,

Youngs modulus (E) =210*(10^9) N/m^2.

Finally the mass matrix (M) and stiffness matrices are found for first two modes as shown below.

$$M=\begin{bmatrix} 0.0163 & 0.0551 & 0.0092 \\ 0.0551 & 0.1950 & 0.0000 \\ 0.0092 & 0.0000 & 0.1950 \end{bmatrix} \text{and } K1=\begin{bmatrix} 0 & 0 & 0 \\ 0 & 346.0621 & -0.2070 \\ 0 & -0.2070 & 13593 \end{bmatrix}$$

The proposed state space variables and described state space model is given by

x (1) = Theta x(4) = Theta_dot

x (2) = q1 x (5) = q1_dot

x (3) = q2 x (6) = q2_dot

The proposed technique was designed in M-File for LQC and the gain matrix elements are feedback with state variables.

3. Linear Quadratic Controller (LQC) Design

Generally, the dynamical aspects of robots are in non-linear in nature. This technique helps to convert the non-linear State space parameters in to linear mode output parameters. For the application of this linmod we have to made a SIMULINK subsystem by giving one input port and two output ports as shown below and also by giving the name m_for linmod .After that we are calling this in M-file. For that we are using the linmod command in command file.

3.1 Linearization of State Space Model

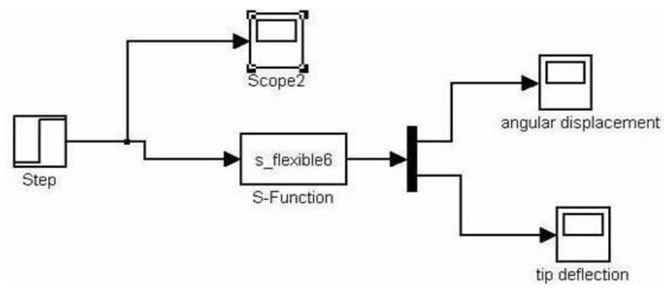


Figure 1. Open Loop Response of State Space Model

SIMULINK provides the linmod and linmod functions to extract linear models in the form of states space matrices A, B, C and D. The following diagram shows the Model for M-File for Single link manipulator in simulink.

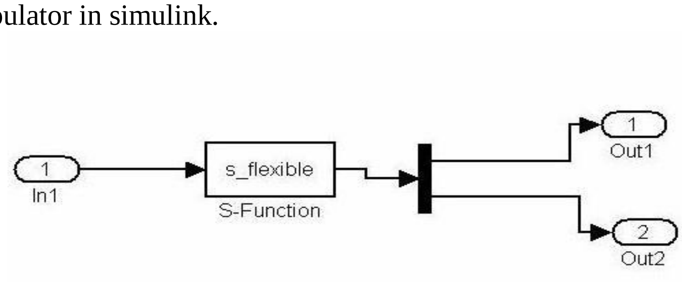


Figure 2. Model of m_for Linmod in Simulink

3.2 M-file program for linearization

Clc

[A, B, C, D]=linmod ('m_for linmod', [0 0 0 0])

Here the above four zeros are known as initial state vectors. By executing this M-file program we will get the liberalized A, B, C, D matrices in command window.

3.3. Concept of Controllability and Observability

The composite matrix

$$Q_c = [B: AB: A^2B: A^3B: A^4B: A^5B] \quad (5)$$

By running the command Q_c= ctrb (A, B) we will get the Q_c matrix as follows.

$$Q_{C=}1.0e+014^{*}\begin{bmatrix} 0 & 0 & 0 & -0.00 & 0 & 2.3064 \\ 0 & -0.0 & 0 & 0.00 & 0 & -0.6559 \\ 0 & -0.0 & 0 & 0.00 & 0 & -0.1471 \\ 0.00 & 0 & -0.0 & 0 & 2.3064 & 0 \\ -0.0 & 0 & 0 & 0 & -0.6559 & 0 \\ -0.00 & 0 & 0 & 0 & -0.1471 & 0 \end{bmatrix} \quad (6)$$

The rank of matrix Q_c is 6 by executing the command rank (Q_c) in command window. This indicates the system is controllable.

The Composite matrix

$$Q_0 = [\,C^T : A^T C^T : (A^T)^2 C^T : (A^T)^3 C^T : (A^T)^4 C^T : (A^T)^5 C^T\,] \quad (7)$$

By executing Q0 = obsv (A, C) in command window we will get Q_0 and the rank (Q_0) is given as 6, this means the system is observable.

3.3 M-file for State Space Model

Function [sys, x0, str, ts] = s_flexible6 (t, x, v, flag)

X (1) = Theta

X (2) = q1

X (3) = q2

X (4) = Theta_dot

X (5) = q1_dot

X (6) = q2_dot

Inputs: t - time in secs

x - Manipulator state

v - Control variable

flag - an integer value that indicates the task to be performed by the S-function:

flag = 0 - initialize the state vector

flag = 1 - calculate the state derivatives

flag = 3 - calculate outputs

Outputs: sys - a generic return argument whose values depend

On the flag value.

X0 - the initial state values. X0 is ignored, except

When flag = 0.

str - argument reserved for future use.

ts - a two column matrix containing the sample times

and offsets of the blocks. For continuous time

Systems ts = [0 0].

X (1) = Theta

X (2) = q1

X (3) = q2

X (4) = Theta_dot

X (5) = q1_dot

X (6) = q2_dot

Switch flag.

Case 0

Initialization

Call function: simsizes to create the sizes structure.

Sizes = simsizes;

Load the sizes structure with the initialization information.

sizes.NumContStates = 6;

sizes.NumDiscStates = 0;

sizes.NumOutputs = 7;

sizes.NumInputs = 1;

sizes.DirFeedthrough = 1;

sizes.NumSampleTimes = 1;

Load the sys vector with the sizes information.

Sys = sim sizes (sizes);

Initialize the state vector

X0 = [0 0 0 0 0 0]';

str is an empty matrix.

str = [ ]

ts = [0 0];

4. Control Block for Single Link Manipulator Using Linear Quadratic Controller (LQR)

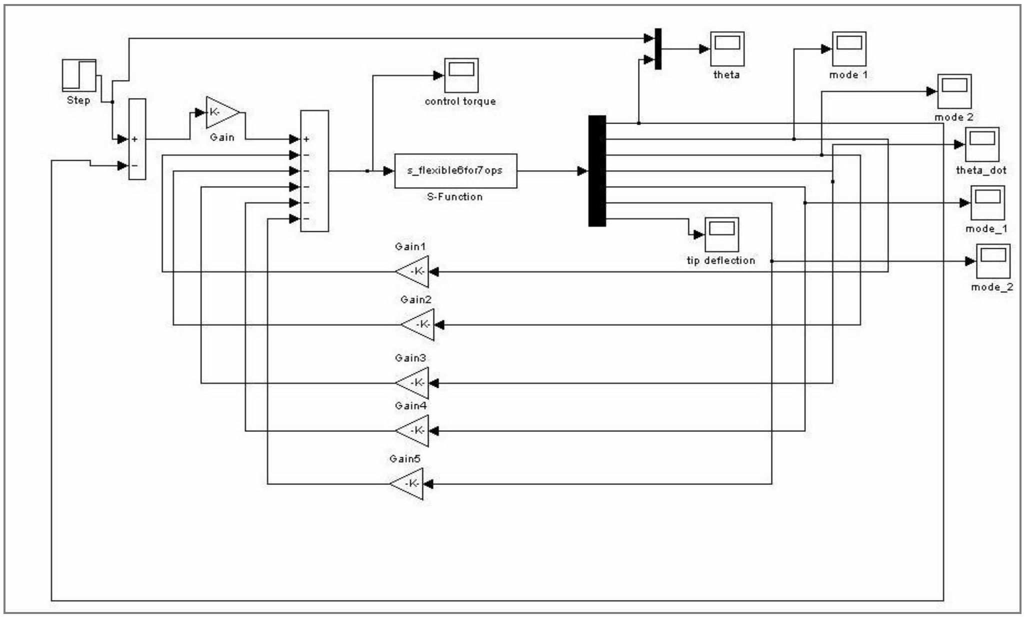
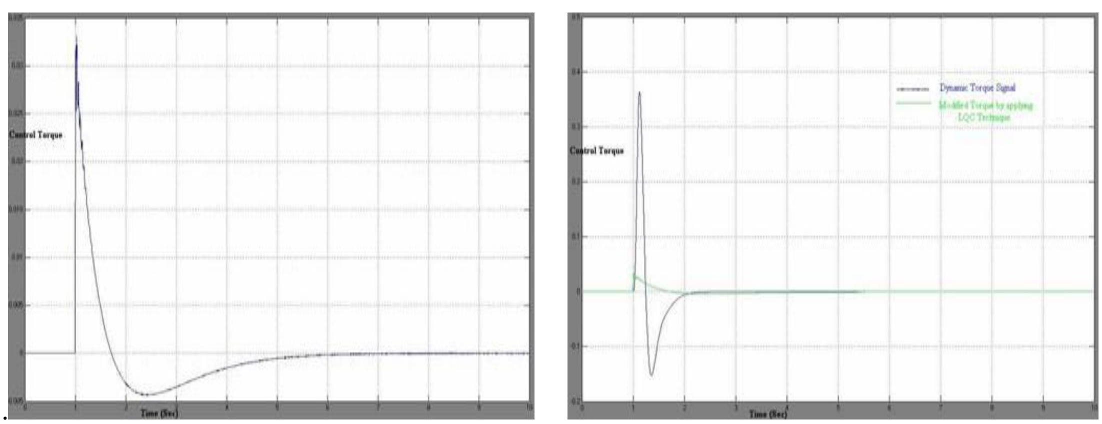


Figure 3. LQR controller design for Single Link Manipulator in Simulink

5. Results and Discursions

The following shows results for the performance of Single link manipulator dynamic characteristics and Modified Torque response by using LCQ Technique. Here, the manipulator in abnormal condition which shows non-linear and dynamic characteristics. But through applying the proposed technique, performance of manipulator torque responses becomes linear and proto type in nature.



(a) **(b)**

Figure 4. Model Torque Responses of Single Link Manipulator (a) Dynamic Response in no-linear condition (b) Response obtained through LQC Technique

i. Figure 4(a) shows dynamic response of single link manipulator in non-linear condition .Here on x-axis, torque and y-axis, time in sec are represented. In utmost cases, the performance of single link manipulator in abnormal conditions was non-linear. So, torque obtained by manipulator is also low. The response is under damped and the performance was very poor.

ii. From Figure 4(b), obtained response through LQC Technique. The performance shown by the single link manipulator is much better. Here the non-linear dynamic characteristics are compensated and modified in number of iterations using state space approach. This approach helps to convert non-linear characteristics into linear using LQC Technique.

6. Conclusions

In this paper, the model of Linear Quadratic Controller Design Technique was controlled by using state space approach and simulated. Initially, the performance of single link manipulator in dynamic non-linear torque condition was shown. By applying Linear Quadratic Controller Design Technique, the non-linear torque charters tics are replaced by linear one. The entire topology explains flexibility improvement of manipulator using proposed technique. This technique helps to keep the manipulator in proper condition as well as efficient. The advance topology for this technique is, by increasing number of iteration of state space approach in less number of time intervals achieves good performance in working of single link manipulators. Hence the overall topology was investigated, designed and simulated. The simulation is executed with help of control block of MATLB/SIMULINK.

References

[1] T. Ravichandran, D. Wang and G. Heppler, “Simultaneous plant-controller design optimization of a two-link planar manipulator”, Journal of Mechatronics, vol. 16, **(2006)**, pp. 233-242.

[2] R. Fotouhi-C, W. Szyszkowski and P. N. Nikiforuk, “Trajectory planning speed control for a two-link rigid manipulator”, Journal of mechanical design, vol. 124, **(2002)**, pp. 585-589.

[3] R. Fotouhi-C, P. Nikiforuk and W. Szyszkowski, “Combined trajectory planning and parameter identification of a two link rigid manipulator”, Proceedings of ASME Design Engineering Technical conferences, Atlanta, Georgia, **(1998)**.

[4] R. Fotouhi-C, W. Szyszkowski, P. N. Nikiforuk and M. M. Gupta, “Parameter identification and trajectory following of a two link rigid manipulator”, Journal of Systems and Control Engineering, proceedings part I, **(2000)**, pp. 213.

[5] J. W. S. Chong, S. K. Ong, A. Y. C. Nee and K. Youcef-Youmi, “Robot programming using augmented reality: An interactive method for planning collision free paths”, Journal of Robotics and Computer – Integrated manufacturing, **(2004)**.

[6] A. Lopes and F. Almeida, “A force impedance controlled industrial robot using an active robotic auxiliary device”, Journal of Robotics and Computer – Integrated manufacturing, vol. 24, **(2008)**, pp. 299-309.

[7] K. Abdel-Malek and J. Yang, “Sweeping of an object held by a robotic end-effector”, Journal of Robotics and Computer – Integrated manufacturing, vol. 21, **(2005)**, pp. 159-173.

[8] D. Oetomo and M. H. Ang Jr, “Singularity robust algorithm in serial manipulators”, Journal of Robotics and Computer – Integrated manufacturing, **(2007)**.

[9] A. Gasparetto and V. Zanotto, “A technique for time-jerk optimal planning of robot trajectories”, Journal of Robotics and Computer – Integrated manufacturing, vol. 24, **(2008)**, pp. 415-426.

[10] K. A. Atia and M. P. Cartmell, “A general dynamic model for a large scale 2-DOF Planar parallel manipulator”, Robotica, vol. 17, no. 6, **(1999)**, pp. 675-684.

[11] Z. Shiller and H. H. Lu**,** “Computation of path constrained time optimal control motions with dynamic singularities”, Transaction of ASME Journal of Dynamic Systems, Measurement and Control, vol. 114, no. 2, **(1998)**, pp. 34-40

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