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Modeling of Two Link Flexible Manipulator using Bond Graph Technique

Amardeep singh
Mechanical Engineering Department,
SBBSIET
Jalandhar, India.
er.amar24@gmail.com

Amrinder Singh Minhas
Mechanical Engineering Department,
SBBSU
Jalandhar, India.
amrinderminhas@gmail.com

Pawanjot Singh
Mechanical Engineering Department,
SBBSIET
Jalandhar, India.
pawanjotsingh@gmail.com

***Abstract*- A mechanism involves a number of interconnected rigid bodies. To design and control a system, modeling of mechanism plays an important role .There are many methods used for modeling like Newton –Euler, Lagrange's Euler and Hamiltonian method. These methods become very laborious and cumbersome for complex multibody systems. The above mention techniques however, do not expose the cause and effect relationship. In this paper, bond graph approach is used for modeling two link manipulator by considering the flexibility at the joints. Bond graph technique shows the pictorial representation of the dynamics of the system. Moreover it may also be used for modeling multi energy domain systems**

Keywords - Bond Graph , Modeling, Two Link Flexible Manipulator

I. INTRODUCTION

A robotic manipulator consists of several rigid bodies that are connected together by various types of joints. A typical robotic manipulator consists of various joints and links . Modeling of two link manipulator has been done by various researchers using different methods like Lagrange (1987), Newton's Euler method(1990) and Assume mode method (1993) but the flexibility at the joints has rarely been considered(2013). These methods never show the physical aspects of the system and also mathematical too inclined for the complex system. Bond graph technique overcomes all these problems. Bond graph is a graphical modeling technique. In bond graph approach any system whether it is mechanical, electrical and hydraulic system may be modeled. Therefore , it means that bond graph is a multi energy domain system. Elements in a system interact with each other by exchanging energy or power. Bond graph clearly depicts how the exchange of energy in terms of effort and flow variables take place. Moreover, it gives the first order state space equation. In addition, modification in the model developed using bond graph method can be easily done as compare to the other method. In this paper, Bond graph technique is used to model the two link flexible manipulator. To provide the flexibility at the joints, stiffness and damping of various magnitudes is being considered. The reason behind considering the stiffness and damping at the joints is to protect the joints from wear and tear which occurs due to impact forces at joints.. Owner and Vegte (1987) modeled the planar motion of a manipulator having two flexible links and two rotor joints with the help of Lagrangian approach. De Luca and Siciliane (1990) obtained the equation for two-link flexible manipulator by Lagrangian based Finite dimension method and Assume Mode Method. S YU and M Aelbestawi in 1993 developed the model of two link manipulator using Lagarngian and Assume mode method approach. Morris and Madani(1995) derived the equation of two link flexible Manipulator. V.O. Gamarra- Rosado and Yuhara (1999) presented the model of two link flexible manipulator having two revolute joints and flexible links. The dynamic equations for the manipulator is derived using Newton- Euler formulation and finite element method. M A. Ahmad et al (2008) used Euler Lagrangian approach and Assume mode method to derive the equation for flexible manipulator. Simulation was done for dynamic model using Matlab. P Kalra, A.M Sharan (1992) used Finite element method to develop the equation of motion of two link manipulator. M . Farid and S .A. Lukasiewicz (2000) used Lagrangian approach and finite element method to develop the dynamic model of flexible manipulator. The experimental validation was carried out on a single flexible manipulator and compared with numerical finite element model in both frequency and time domain. The result from FEM model is very close to the experimental validation. M.O. Tokhi et. al (2001) showed the dynamic modeling of flexible links and joints . The elastic deformation on each link is assumed due to bending and torsion. Rajesh et. al (2013) discussed two link flexible spatial manipulators modeled considering both link and joint flexibility. The deformation occur on each link and joint is due to bending, torsion and pure torsion respectively. The equation of motion for the manipulator is obtained using principal of virtual work and FEM. The numerical simulation of different cases considering rigid links and rigid joints, flexible links and flexible joints, flexible links and flexible joints is performed. The simulation result show significant effect of flexibility on the overall manipulator motion.

II. MODEL DESCRPTION

In this paper, Two link flexible manipulator has been modeled using Bond graph technique. The whole mechanism consists of three rigid links and connected by turning joints. Springs and dampers are provided at each joint for considering the flexibility. Denavit – Hartenberg convention is used to fix the reference frames on each link (Craig 2005). The link 0 is called a fixed frame and also called inertial frame . The link 1 and 2 connected together and have relative motion with each other, and also with inertial frame. Inertial frame does not have any movement that is translational and rotational. In figure 1 O_1, A_1 are origin of link 0 and link 1 respectively and A_2 is the end point of link$_2$, on the other hand B_1 is the origin of link 2 ,

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end point of link 2 is B_2. θ_1 is the angle made between the X axis and arm 1 whereas angle between the X_1 and X_2 is θ_2. Center of masses of the respective links are C_1 , and C_2. The bond graph of the mechanism is shown in the figure 2 . In the bond graph the thick and thin lines shows the vector and scalar bonds respectively. The left side of the bond graph shows rotational dynamics and translational dynamics is represented on the right side of the bond graph. Translational dynamics of link 2 is restricted by applying sf equal to zero. For the flexibility, Stiffness k_{11}, K_{15}, k_{52} and damping r_{11} , r_{16} , r_{52} are provided at the joints of link 0 and link 1 The stiffness K_{48} and damping r_{49} at the joint of link 1 and link 2.

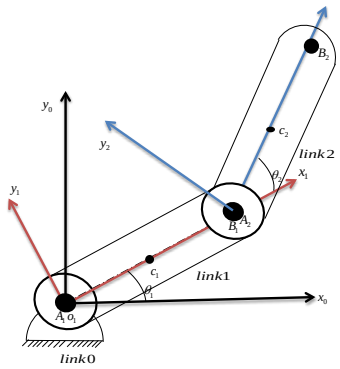

Figure 1: Two Link Flexible Manipulator.

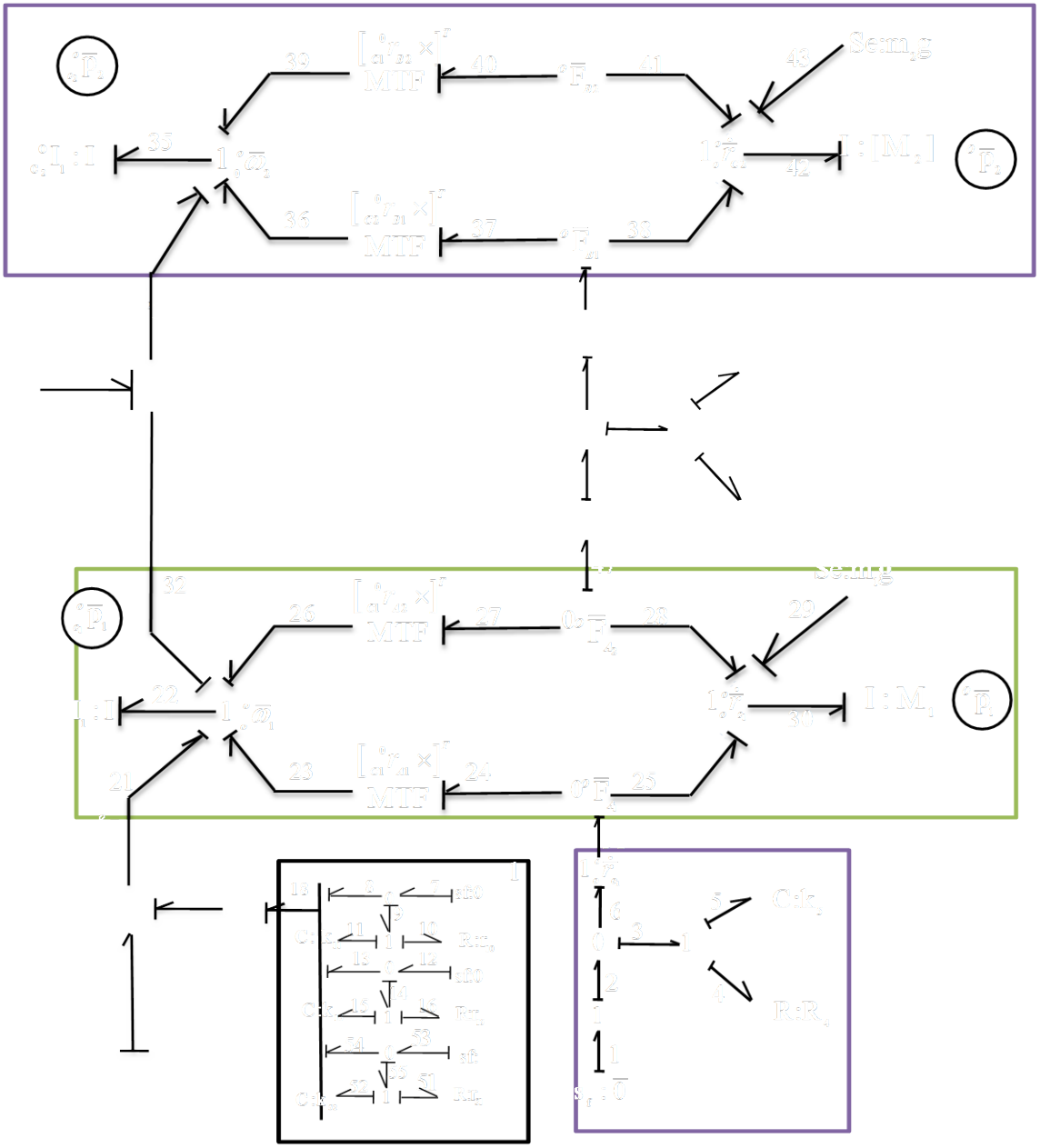

Figure 2: Bond graph of two link flexible Manipulator

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III. CONCLUSION

In this paper, Modeling of two link flexible manipulator has been done using bond graph technique. .The main characteristics of the bond graph is that the bond graph module of each link can be modeled and assembled to get a complete bond graph . For the control of the end effector and accuracy , the flexibility plays a major role . In bond graph, the angular velocity has been split from vector to scalar component and actuating source is applied about z axis so that the link may oscillate or rotate about z axis . Further simulation of this system will be done using MATLAB to analyzed the dynamics of links by considering different value of stiffness and damping at each joints.

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