International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Modeling and Simulation of Two Link Flexible Manipulator Using Bond Graph Technique

Amardeep Singh[1], Aman Kumar Maini[2]

[1]Assistant Professor, SBBSIET Hoshiarpur (Pb), India

[2]Assistant Professor, DAVIET, Jalandhar, India

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

1. 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 takes 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.

2. Model Description

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

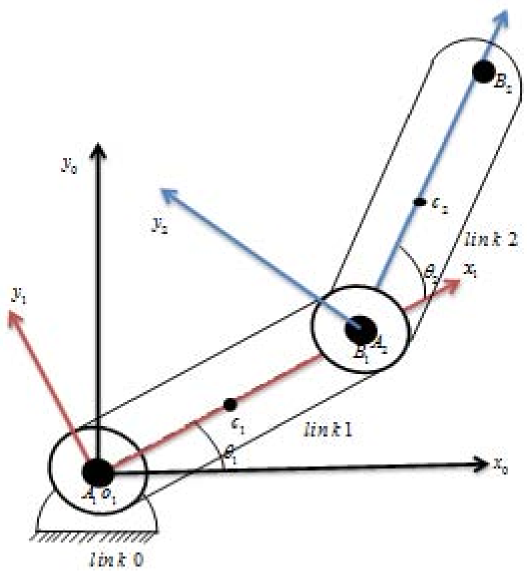

Figure 1: Two Link Flexible Manipulator

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 , 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. For simulation, angular velocity of 25rad/s and torque of 2N-m has been applied at link 1 and link 2 respectively. The both links made to rotate about point A_1 and B_1 that is about z axis. The movement of both link in X and Y direction will be restricted by applying sf equal to zero.

3. Simulation and Result

Matlab has been used for simulation .Table 1 shows the parameter and Table 2 shows the stiffness and damping value used for simulation. The time span for simulation is takes as 5 sec.

Table 1: Link parameters for Simulation

Link 1			
	^1l_x=1m	^1l_y=.01m	^1l_z=.01m
Link 2			
	^2l_x=.75m	^2l_y=.01m	^2l_z=.01m

Table 2: Different value of stiffness and damping

Location	**Stiffness (k)**	**Damping (R)**
Translation coupling between		
Link 1 and Link 2(at joints)	K_5=10^7 N/m	R_4=10^3 N-s/m
Link 2 and Link 3(at joints)	K_{48}=10^7 N/m	R_{49}=10^3 N-s/m
Rotational coupling		
Link 1 and Link 2(at joints) Z axis component	1) K_{52}=10^9 N/m K_{52}=10^6 N/m K_{52} =10^4 N/m K_{52} = 0 N/m	1)R_{51}= 10 N-s/m 2)R_{51}= 10^2 N-s/m 3)R_{51}= 10^3 N-s/m
X axis component	2) K_{11}=10^9 N/m K_{11}=10^6 N/m K_{11} =10^4 N/m K_{11}= 0 N/m	1)R_{10}= 10 N-s/m 2)R_{10}= 10^2 N-s/m 3)R_{10}= 10^3 N-s/m
Y axis component	3) K_{15}=10^9 N/m K_{15}=10^6 N/m K_{15} =10^4 N/m K_{15}= 0 N/m	1)R_{16}= 10 N-s/m 2)R_{16}= 10^2 N-s/m 3)R_{16}= 10^3 N-s/m

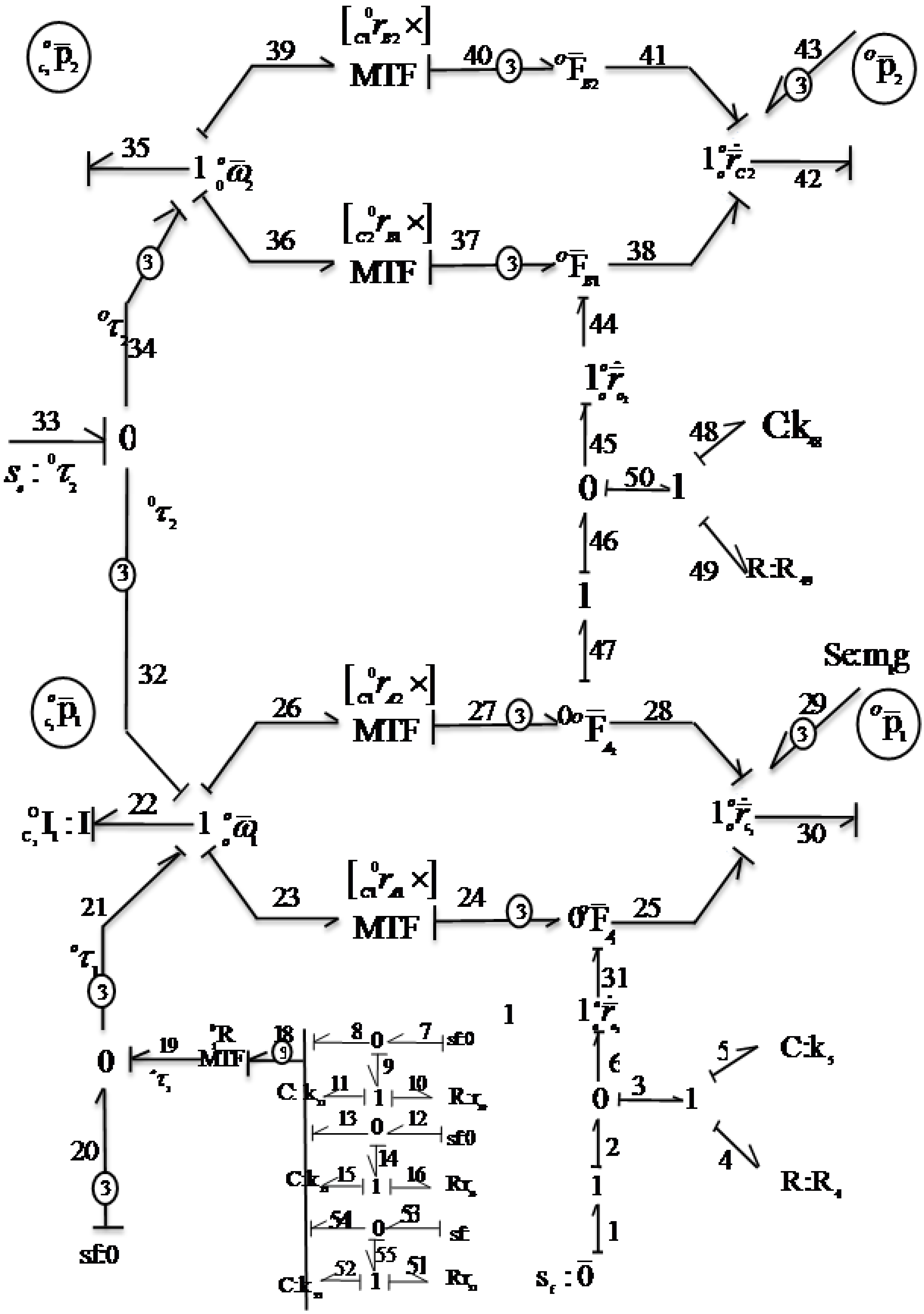

Figure 2: Bond graph of two link flexible Manipulator

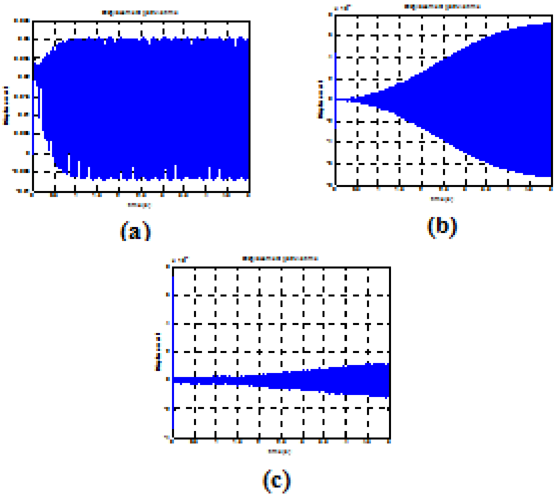

Figure 3: Displacement-time graph for joint of 2 link manipulator with R =100Ns/m damping at various stiffness (a) k=0, (b) K=10^6 N/m (c) k =10^9N/m

The figure 3 shows the displacement –time graph for various stiffness at joint .which the graph shows the role of flexibility at damping value 100Ns/. When the value of k=0(a) then the displacement of the link varies from 0.03m to -0.005m . In case of k= 10^6 N/m (b) the displacement value lies between 7x10^{-3}m to-7x10^{-3}m but when value of k=10^9 N/m (c) then displacement at joints is close to zero.It means minimum flexibility is provided at joint.

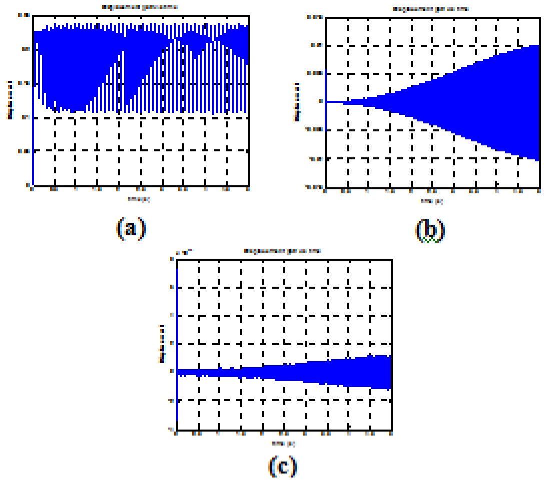

Figure 4: Displacement-time graph for joint of 2 link manipulator with R =10Ns/m damping at various stiffness (a) k=0, (b) K=10^6 N/m(c) k =10^9N/m

The figure 4 shows the displacement at the joints of a two link manipulator for constant damping value R =10 and different stiffness value (K) . when there is no stiffness k=0 (a) then the displacement at joints is varies from 0.15m to 0.225m. In case of stiffness value k=10^6N/m(b)the joint displacement is negligible for one second then displacement is increased as the time increased and lies between -.01m to .01m. The joints show minimum displacement when the stiffness k=10^9 N/m(c).

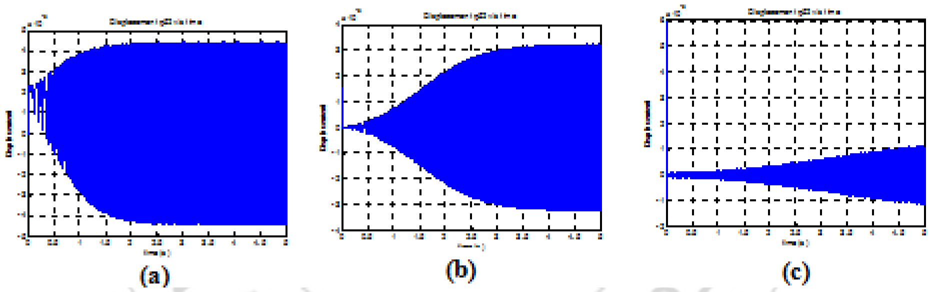

Figure 5: Displacement-time graph for joint of 2 link manipulator with R =1000 Ns/m damping at various stiffness (a) k=0, (b) K=10^6 N/m(c) k =10^9N/m

The figure 5 displacement- time graph for damping value R=1000.The displacement is varies from 4x10^{-3}m to -4x10^{-3}m to stiffness value k=0.The displacement for the joint is negligible at the start after 0.5 sec it starts increasing and lies between 3x10^{-3}m to- 3x10^{-3}m for k=10^6N/m(b). The displacement is minimum when the k=10^9N/m (c)

4. Dynamics of links

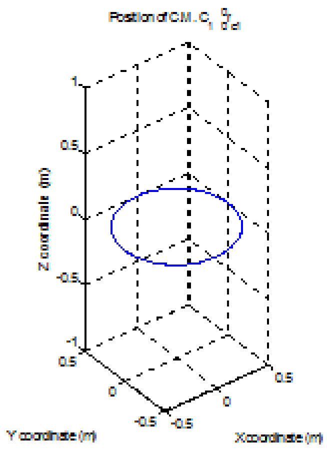

Figure 6: Position of center of mass Link1

The Link 1 rotates at origin O_1 about z axis . So the path traced by center mass C_1 of the link is circle as shown in figure 6

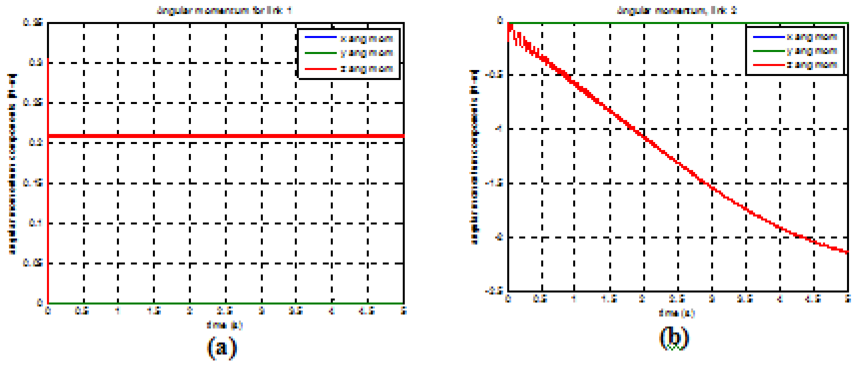

Figure 7: Variation of angular momentum of link 1(a) and link 2(b)

The figure 7 (a) shows only the z component of angular momentum varies because other two moments have been constrained. The angular momentum increases sharply in the initial period of time due to high angular velocity and then remain constant . The angular momentum of link 2 is decrease with time as shown in figure 7 (b).

5. Conclusion

In this paper, Bond graph technique has been used to model the two link flexible manipulator. Matlab is used for simulation Various plots has been analyzed for the dynamics of links by considering different value of stiffness and damping at each joints.

References

[1] Ower J.C and Vegte Van De.(1987) , "Classical control design for a flexible manipulator: modeling and control system design", IEEE Journal of Rob

[2] DeLuca A. and Siciliano B (1990), "Explicit dynamic modeling of a planar two-link flexible manipulator", Journal of the IEEE International Conference on Decision and Control, Vol 2 , pp. 528-530.

[3] Sharan A.M , Jain J. and Kalra P.(1992), "Efficient methods for solving dynamic problems of flexible manipulators", ASME Journal of Dynamic Systems, Measurement, and Control, Vol 114, pp. 78-88

[4] Yu. S.and Elbestawi M .A.(1993), "Modelling and Dynamic Analysis of Two link Manipulator with Both Joint and Flexibility", Journal of Sound and Vibration,Vol 5, PP.839-854

[5] Morris A.S., Madani A(1995), "Static and dynamic modeling of a two-flexible-link robot manipulator", Robotica, Vol 3 , pp. 289-300.

[6] Rosado V.O.G. and Yuhara E.A.O.(1999), "Dynamic modeling and simulation of a flexible robotic manipulator" , Robotica vol 17 . pp. 523–528.

[7] Farid .M. and. Lukasiewicz .S .A.(2000) "Dynamic modeling of spatial manipulator with flexible links and joints . Computers & Structures ,Vol.75, issue4,419-437

[8] Tokhi. M.O Mohamed Z. and Shaheed. M.H .(2001) "Dynamic characterization of a flexible manipulator system.Robotica19(5), 578-580

[9] Craig . J.J (2005) Inroduction to robotics and control , 3rd ed , Pearson Education.

[10] Ahmad M. A. ,Mohamed. Z . and Hambali1. N.(2008), " Dynamic modeling of Two Link Flexible Manipulator System Incorporating Pay Load" Journal of the IEEE International conference on industrial Electronics and Application, pp.96-101

[11] K Moolam Rajesh , Braghin Francesco and Vicentini Federico (2013), "Dynamic modeling and Simulation of spatial Manipulator with flexible links and joints" International conference of vibration problem. pp9-13