We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

BOOK CITATION INDEX
CLARIVATE ANALYTICS
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Dynamic Behavior of a Pneumatic Manipulator with Two Degrees of Freedom

Juan Manuel Ramos-Arreguin[1], Efren Gorrostieta-Hurtado[1], Jesus Carlos
Pedraza-Ortega[1], Rene de Jesus Romero-Troncoso[2],
Marco-Antonio Aceves[1] and Sandra Canchola[1]
[1]CIDIT-Facultad de Informática
[2] Facultad de Ingeniería
Universidad Autónoma de Querétaro, Querétaro, México

1. Introduction

The manipulator robots have many applications, such as industrial process, objects translation, process automation, medicine process, etc. Therefore, these kind of robots are studied in many ways.

However, most of the reported works use electrical or hydraulic actuators. These actuators have a linear behaviour and the control is easier than pneumatic actuators. The main disadvantages of electrical actuators are the low power-weight rate, the high current related with its load and its weight. The hydraulic actuators are not ecological, needs hydraulic oil which is feedback to the pump. On the other hand, the pneumatic actuators are lighter, faster, having a greater power-weight rate and air feedback is not needed. However, pneumatic actuators are not used into flexible manipulators developing, due to their highly non linear behaviour.

In the case of robot dynamic analysis, other researchers have presented the following works. An equations and algorithms are presented in an easy way to understand for all practical robots (Featherstone, 1987), (Featherstone & Orin, 2000), (Khalil & Dombre, 2002). Also, a dynamic simulation is developed to investigate the effects of different profiles into the contact force and the joint torques of a rigid-flexible manipulator (Ata & Johar, 2004). A study of dynamic equations is developed for a robot system holding a rigid object without friction (Gudiño-Lau & Arteaga, 2006). Furthermore, a dynamic modeling analysis is developed for parallel robots (Zhaocai & Yueqing, 2008). The link flexibility is considered for system performance and stability. Moreover, an innovative method for simulation is developed (Celentano, 2008) to allow students and researchers, to easily model planar and spatial robots with practical links. However, the reported works are developed using only electrical actuators, not pneumatic actuators. Therefore, this chapter presents how the pneumatic model is used with a two-link flexible robot and its dynamic analysis for the simplified system.

Previous researches by the authors include: a simplified thermo-mechanical model for pneumatic actuator has been obtained (Ramos et al., 2006). For animation purposes, the

Matlab - C++ - OpenGL Multilanguage platform, is used to solve the thermo-mechanical model (Gamiño et al., 2006), to get advantages of each language. Next, several algorithms are implemented to control the position (Ramos et al., 2006), including fuzzy control systems (Ramos-Arreguin et al., 2008). The flexible robot with pneumatic actuator is implemented, and practical results are compared with theoretical results (Ramos-Arreguin et al., 2008); where the PD control algorithm has been implemented into a FPGA device.

2. Pneumatic robot structure with one degree of freedom

A one degree of freedom (dof) pneumatic flexible robot is developed, for applications where a high risk for personal injury is present. This is shown in figure 1 (Ramos-Arreguin et al., 2008). This robot is light, cheap and ecological. Also, it uses a pneumatic actuator with high power-weight rate.
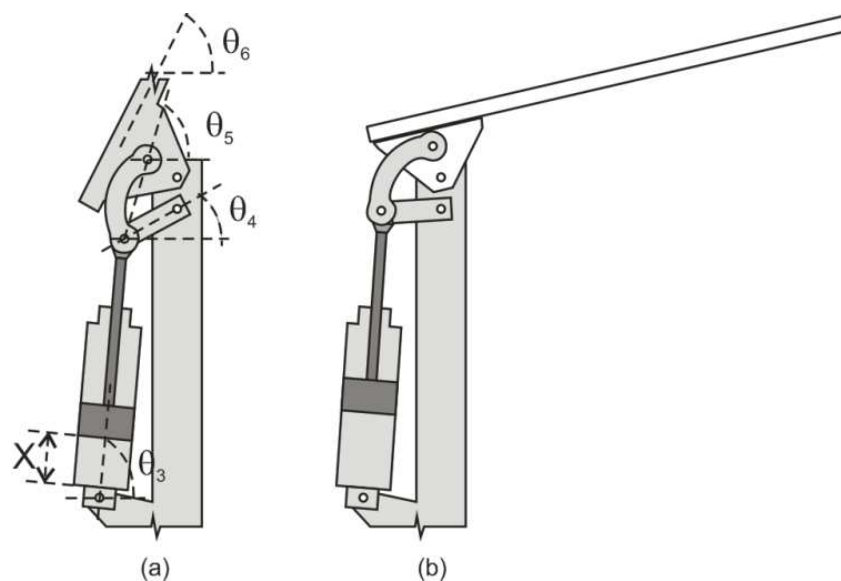

Fig. 1. One degree of freedom pneumatic robot. (a) Variables of the system. (b) General view.

In figure 1, the actuator used has damping at the boundaries of the cylinder. The control variable to take into account is θ_6, which defines the slope of the arm. The value of θ_3 defines the angle of the pneumatic force to be applied. A diagram of the actuator is shown in figure 2, including the parameters involved for the mathematical model.
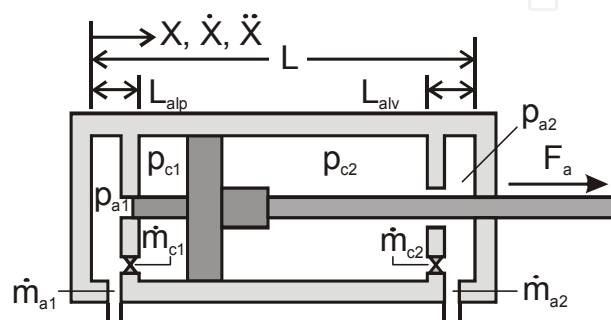

Fig. 2. Pneumatic actuator diagram, showing two damping zones.

Table 1 shows a description of each variable of pneumatic actuator in figure 2.

Variable	Description	Variable	Description
X	Rod position relative to the cylinder	$\dot{X}$	Rod speed relative to the cylinder
$\ddot{X}$	Rod acceleration relative to the cylinder	F_a	Actuator force
P_{a1}	Piston damping pressure	P_{c1}	Piston chamber pressure
P_{a2}	Rod damping pressure	P_{c2}	Rod chamber pressure
$\dot{m}_{a1}$	Mass flow from compressed air tank to the piston pad	$\dot{m}_{c1}$	Mass flow between the pad and chamber 1
$\dot{m}_{a2}$	Mass flow between the atmosphere and the piston pad	$\dot{m}_{c2}$	Mass flow between the pad and chamber 2

Table 1. Variables descriptions for pneumatic actuator.

The thermo-mechanical model (Kiyama & Vargas, 2005) use the variables defined in table 1. This original model takes considerable time to compute it. Therefore, a simplified model has been performed. Section 3 presents the simplified thermo-mechanical model.

3. Pneumatic actuator modelling

The rod displacement is controlled with a 5/2 electrovalve, as presented in (Ramos-Arreguin et al., 2008). The simplified thermo-mechanical model for pneumatic actuator of figure 2, is shown in equation (1) (Ramos et al. 2006). This model includes the parameters values and the space states are expressed as polynomial functions.

For the interval $0 \le X \le L$:

$$\dot{X} = \frac{d}{dt}X \tag{1a}$$

$$D\dot{X} = \frac{d^2}{dt^2}X \tag{1b}$$

For the interval $0 \le X \le Lalp$:

$$\dot{P}_{a1} = \left(-4.2316X + 8.0741\right)\left(\dot{m}_{a1} - \dot{m}_{c1} - 9.176 \times 10^{-10}P_{a1}DX\right) \times 10^{16} \tag{1c}$$

$$\dot{P}_{c1} = 38.8 \times 10^6\, X^{-1}\left(\dot{m}_{c1} - 3.608 \times 10^{-8}P_{c1}DX\right) \times 10^6 \tag{1d}$$

For the interval $Lalp < X \le L$

$$\dot{P}_{a1} = \left(-2.0952X^3 + 0.6233X^2 - 0.0777X + 0.0060\right)\left(\dot{m}_{a1} - 3.7 \times 10^{-8}P_{a1}DX\right) \times 10^{22} \tag{1e}$$

$$\dot{P}_{c1} = \left(-2.0952X^3 + 0.6233X^2 - 0.0777X + 0.0060\right)\left(\dot{m}_{c1} - 3.7 \times 10^{-8}P_{c1}DX\right) \times 10^{22} \tag{1f}$$

For the interval $0 \le X < L\text{-}Lalv$

$$\dot{P}_{c2} = \left(1.1549X^3 + 0.0900X^2 + 0.0152X + 0.0025\right)\left(\dot{m}_{c2} + 3.469 \times 10^{-8}P_{c2}DX\right) \times 10^{22} \tag{1g}$$

$$\dot{P}_{a2} = \left(1.1549X^3 + 0.0900X^2 + 0.0152X + 0.0025\right)\left(\dot{m}_{a2} + 3.469 \times 10^{-8}P_{a2}DX\right) \times 10^{22} \tag{1h}$$

For the interval $L\text{-}Lalv \le X \le L$

$$\dot{P}_{c2} = \left(1.3895X^2 - 0.2189X + 0.0088\right)\left(\dot{m}_{c2} + 3.352\times10^{-8}X_4X_6\right)\times10^{26} \tag{1i}$$

$$P_{a2} = \left(8.3664X + 9.2571\right)\left[9.983\times10^3\left(\dot{m}_{a2} - \dot{m}_{c2}\right) + 1.168\times10^{-5}X_5X_6\right]\times10^8 \tag{1j}$$

The mass flow is given by

$$\dot{m} = \sqrt{\frac{2}{k-1}\left(\frac{p_t}{p_0}\right)^{\frac{1+k}{2k}}\left[\left(\frac{p_t}{p_0}\right)^{\frac{1-k}{k}} - 1\right]^{\frac{1}{2}}}\sqrt{\frac{k}{RT_o}}\,p_o A_t \tag{2}$$

This mathematical model let us to compute the rod force over the mechanism, and is useful for simulation process. The actuator force (F_a) is expressed as:

$$F_a = P_{c1}A_{c1} - P_{c2}A_{c2} + P_{a1}A_{a1} - P_{a2}A_{a2} - P_{atm}A_v \tag{3}$$

Section 4 presents the methodology used for simulation purposes.

4. Simulation methodology

The simulation methodology is based in a multilanguage interface, developed with Matlab – C++ – OpenGL (Gamiño et al. 2006), (Ramos et al. 2009). Figure 3 shows a block diagram of the simulation process.
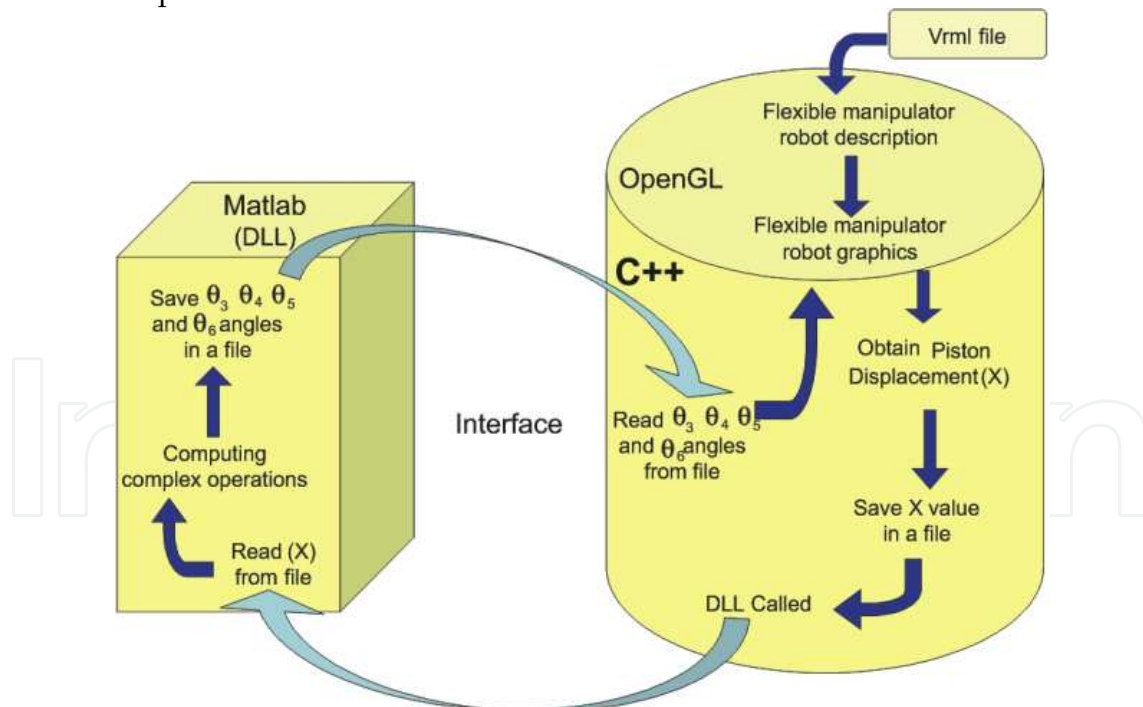

Fig. 3. Block diagram for Multilanguage interface development.

Figure 4 shows the result of this methodology. Matlab is used to compute the thermo-mechanical model; C++ is used for data interchange and to execute the matlab process, and OpenGL libraries are used for graphical view.
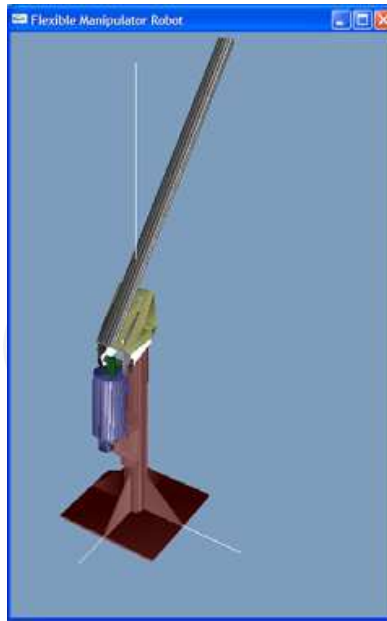
Fig. 4. Simulation of one degree of freedom flexible arm with pneumatic actuator.

Using this methodology, the control simulation with shorter computing time has been achieved. Some control algorithms used are PID, Discrete PID and Fuzzy (Ramos et al. 2006). The simulation results are used to implement a digital control, using FPGA technology (Ramos et al. 2008).

5. Pneumatic Flexible Robot with two degrees of freedom

5.1 Dynamic equations
The previous works developed are based in one degree of freedom for a flexible manipulator robot. To take this project further, a second degree of freedom system is considered.

The new contribution presented in this chapter, is a dynamic analysis of pneumatic flexible robot with two degrees of freedom. This analysis considers the pneumatic force for each of the joints. This first approach considers only a simplified structure, as shown in figure 5.
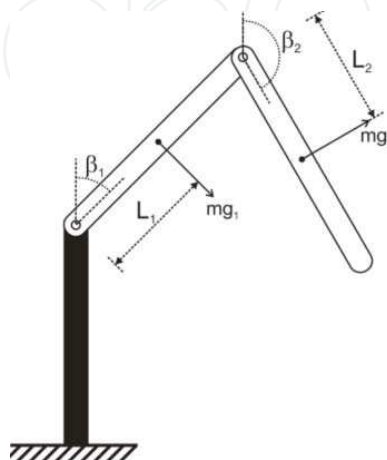

Fig. 5. Structure proposed for a manipulator robot with two degrees of freedom.

For the propose system on figure 5, the generalized variables are β_1 y β_2. The speed equation for the gravity center of each link is

$$V_1{}^2 = L_1{}^2 \dot{\beta}_1{}^2 \tag{4}$$

$$V_2{}^2 = 4L_1{}^2\dot{\beta}_1{}^2 + L_2{}^2\dot{\beta}_2{}^2 + 4L_1L_2\cos(\beta_1 - \beta_2)\,\dot{\beta}_1\dot{\beta}_2 \tag{5}$$

The kinematic energy of the system is given by

$$V_1{}^2 = L_1{}^2 \dot{\beta}_1{}^2 \tag{6}$$

$$K = \left(\frac{1}{2}m_1L_1{}^2 + 2m_2L_1{}^2 + \frac{1}{2}J_1\right)\dot{\beta}_1{}^2 + \frac{1}{2}\left(m_2L_2{}^2 + J_2\right)\dot{\beta}_2{}^2 + \tag{7}$$
$$2m_2L_1L_2\cos(\beta_2 - \beta_1)\,\dot{\beta}_1\dot{\beta}_2$$

The potential energy is

$$U = gL_1\left(\frac{1}{2}m_1 + m_2\right)\cos\beta_1 + \frac{1}{2}m_2gL_2\cos\beta_2 \tag{8}$$

Finally, the Lagrangian equation, $L=K-U$, is given by:

$$L = \left(\frac{1}{2}m_1L_1{}^2 + 2m_2L_1{}^2 + \frac{1}{2}J_1\right)\dot{\beta}_1{}^2 + \frac{1}{2}\left(m_2L_2{}^2 + J_2\right)\dot{\beta}_2{}^2 - gL_1\left(\frac{1}{2}m_1 + m_2\right)\cos\beta_1$$
$$-\frac{1}{2}m_2gL_2\cos\beta_2 + 2m_2L_1L_2\cos(\beta_2 - \beta_1)\,\dot{\beta}_1\dot{\beta}_2 \tag{9}$$

The equations of movement, are derived as follows:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial\dot{\beta}_1}\right) - \frac{\partial L}{\partial\beta_1} = 0 \quad \text{and} \quad \frac{d}{dt}\left(\frac{\partial L}{\partial\dot{\beta}_2}\right) - \frac{\partial L}{\partial\beta_2} = 0 \tag{10}$$

$$2\left(\frac{1}{2}m_1L_1{}^2 + 2m_2L_1{}^2 + \frac{1}{2}J_1\right)\ddot{\beta}_1 + 2m_2L_1L_2\cos(\beta_2 - \beta_1)\ddot{\beta}_2 - 2m_2L_1L_2\sin(\beta_2 -$$
$$\beta_1)\dot{\beta}_2{}^2 - gL_1\left(\frac{1}{2}m_1 + m_2\right)\operatorname{sen}\beta_1 = 0 \tag{11}$$

$$\left(m_2L_2{}^2 + J_2\right)\ddot{\beta}_2 + 2m_2L_1L_2\cos(\beta_2 - \beta_1)\ddot{\beta}_1 + 2m_2L_1L_2\sin(\beta_2 - \beta_1)\dot{\beta}_1{}^2$$
$$-\frac{1}{2}m_2gL_2\operatorname{sen}\beta_2 = 0 \tag{12}$$

To convert the equations (11) and (12) into space states, the equation (13) are used.

$$
\begin{aligned}
X_1 &= \dot{\beta}_1; & \dot{X}_1 &= \ddot{\beta}_1 \\
X_2 &= \beta_1; & \dot{X}_2 &= \dot{\beta}_1 = X_1 \\
X_3 &= \dot{\beta}_2; & \dot{X}_3 &= \ddot{\beta}_2 \\
X_4 &= \beta_2; & \dot{X}_4 &= \dot{\beta}_2 = X_3
\end{aligned}
\tag{13}
$$

The space state for dynamic equations are:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C_3 \cos(X_4 - X_2) & 0 & 2C_1 \\ 0 & 0 & 1 & 0 \\ 0 & 2C_2 & 0 & C_3 \cos(X_4 - X_2) \end{bmatrix} \begin{bmatrix} \dot{X}_4 \\ \dot{X}_3 \\ \dot{X}_2 \\ \dot{X}_1 \end{bmatrix} = \begin{bmatrix} X_3 \\ C_4 \operatorname{sen} X_2 + C_3 \sin(X_4 - X_2) X_4{}^2 \\ X_1 \\ C_5 \operatorname{sen} X_4 - C_3 \operatorname{sen}(X_4 - X_2) X_1{}^2 \end{bmatrix} \quad (14)$$

Where:

$$\begin{aligned} C_1 &= \tfrac{1}{2} m_1 L_1{}^2 + 2 m_2 L_1{}^2 + \tfrac{1}{2} J_1 \\ C_2 &= \tfrac{1}{2}\left(m_2 L_2{}^2 + J_2\right) \\ C_3 &= 2 m_2 L_1 L_2 \\ C_4 &= g L_1 \left(\tfrac{1}{2} m_1 + m_2\right) \\ C_5 &= \tfrac{1}{2} m_2 g L_2 \end{aligned} \quad (15)$$

Considering the friction force, on each of joint, the equation (16) is given by:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C_3 \cos(X_4 - X_2) & 0 & 2C_1 \\ 0 & 0 & 1 & 0 \\ 0 & 2C_2 & 0 & C_3 \cos(X_4 - X_2) \end{bmatrix} \begin{bmatrix} \dot{X}_4 \\ \dot{X}_3 \\ \dot{X}_2 \\ \dot{X}_1 \end{bmatrix} = \begin{bmatrix} X_3 \\ C_4 \operatorname{sen} X_2 + C_3 \sin(X_4 - X_2) X_4{}^2 - K_2 X_2 \\ X_1 \\ C_5 \operatorname{sen} X_4 - C_3 \operatorname{sen}(X_4 - X_2) X_1{}^2 - K_1 X_1 \end{bmatrix} \quad (16)$$

Where K is the constant friction of each joint.

5.2 Test of state space

In order to test equation (16), a Matlab program is used, considering the information given on table 2.

Parameter	Description	Value
m_1	Link 1 weight	1.1 Kg
m_2	Link 2 weight	1.5 Kg
L_1	Length of link 1	0.5 m
L_2	Length of link 2	0.5 m
J_1	Inertia of link 1	0.015193 Kgm²
J_2	Inertia of link 2	0.03192 Kgm²
K	Friction constant	0.25
g	Gravity force	9.81 m/s²

Table 2. Values used for evaluation of equation (16).

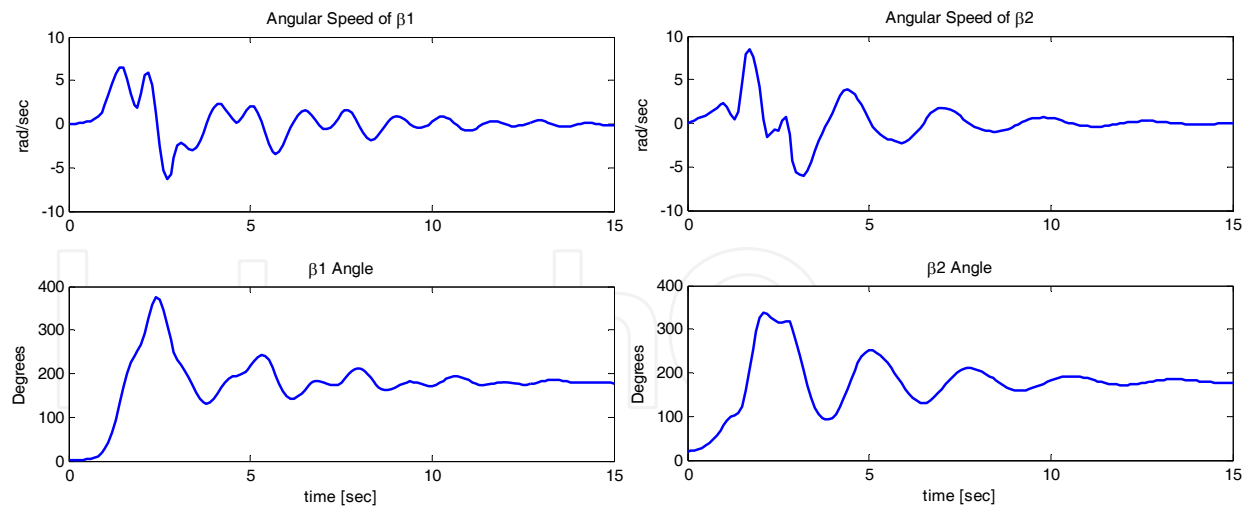Figure 6 shows the results of test of equation (16), without external force applied.

Fig. 6. Proposal structure behavior with pneumatic force equal to zero.

Figure 6 shows a steady behavior. The conditions initials are: $\beta_1 = 1°$, $\beta_2 = 20°$, $\dot{\beta}_1 = 0$ and $\dot{\beta}_2 = 0$. The movement is limited from 0° to 180° for both β_1 and β_2. Since a force is not applied to the arms, from the initial conditions, the arms fall and their final position are 180°.

5.3 Dynamic behavior with pneumatic actuator

The figure 7 shows how the force of the pneumatic actuator is applied to the flexible manipulator robot, combining both pneumatic and actuator dynamic models. The torque for each joint link is generated by the pneumatic actuator, according with equation (17).

$$\tau_1 = Fa_1\, d_1; \qquad \tau_2 = Fa_2\, d_2 \tag{17}$$

Equation (18) shows the state equations with torque considerations.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C_3\cos(X_4 - X_2) & 0 & 2C_1 \\ 0 & 0 & 1 & 0 \\ 0 & 2C_2 & 0 & C_3\cos(X_4 - X_2) \end{bmatrix} \begin{bmatrix} \dot{X}_4 \\ \dot{X}_3 \\ \dot{X}_2 \\ \dot{X}_1 \end{bmatrix} = \begin{bmatrix} X_3 \\ C_4\operatorname{sen}X_2 + C_3\sin(X_4 - X_2)X_4^2 - K_2X_2 + \tau_2 \\ X_1 \\ C_5\operatorname{sen}X_4 - C_3\operatorname{sen}(X_4 - X_2)X_1^2 - K_1X_1 + \tau_1 \end{bmatrix} \tag{18}$$

Figure 8, shows the sinoidal forces applied to links 1 and 2. Figure 9 shows the dynamic structure response. Given the initials conditions, the behaviour of both arms show a complete turn before stabilizing. The force applied to link 1, doubles the force on link 2. Figure 9 shows the pneumatic force on each joint.
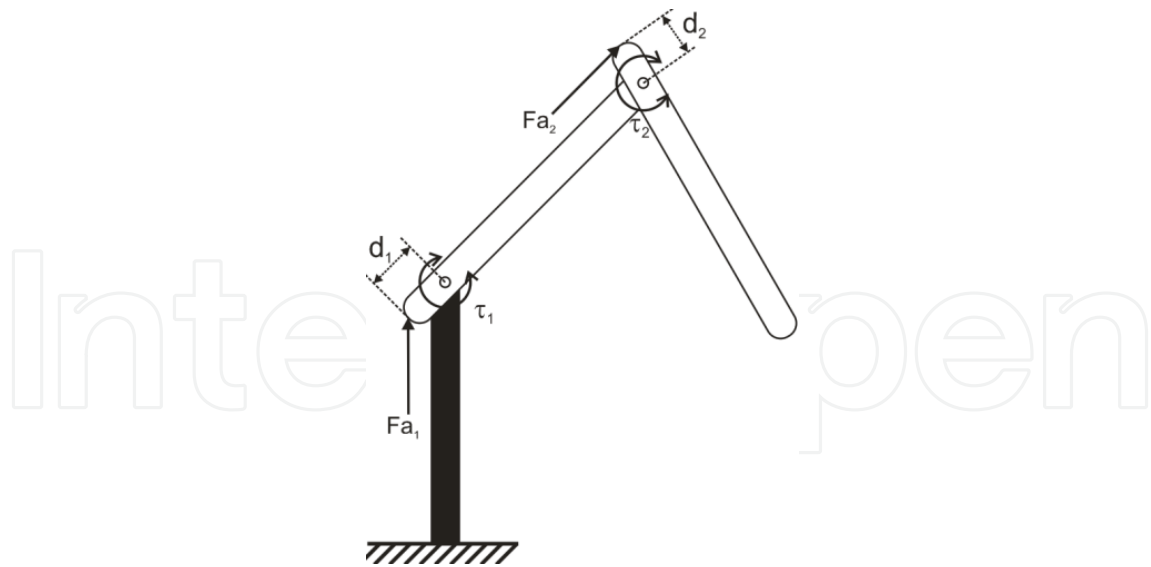
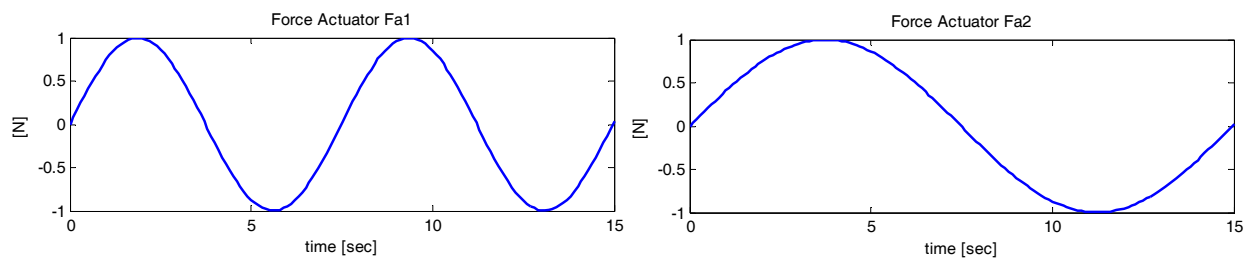Fig. 7. Diagram of pneumatic force applied into each joint of flexible robot manipulator.

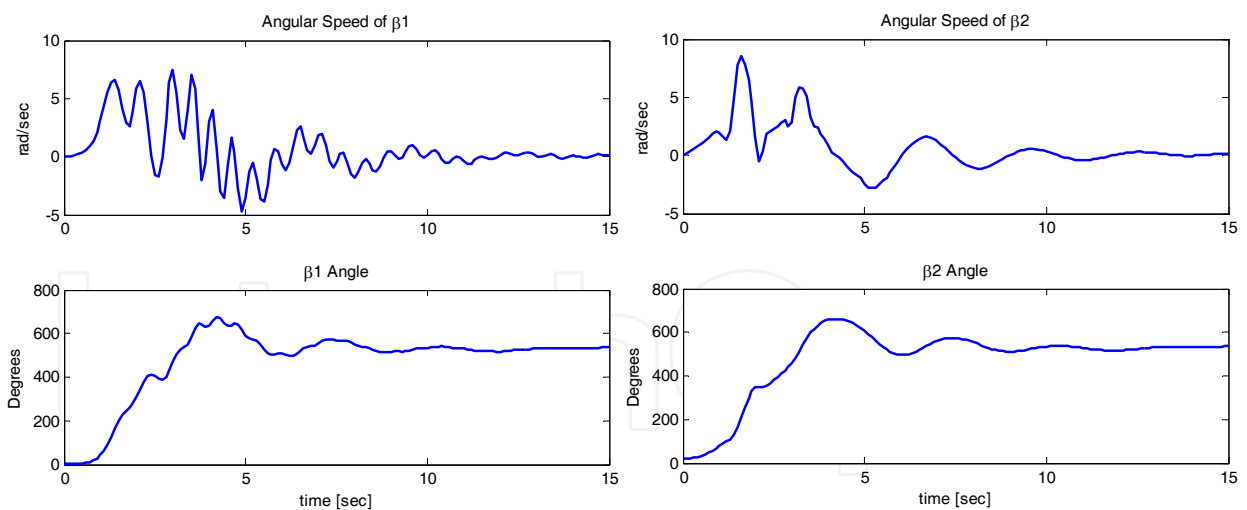Fig. 8. Sinoidal pneumatic force applied into both link robots.

Fig. 9. Behaviour of the structure with pneumatic force applied into both link robots.

Figure 10 shows a block diagram where the simplified thermo-mechanical model and the equation (16) are evaluated to learn about the dynamic behavior of the structure. The valves apertures are the input of the thermo-mechanical model, and thermo-mechanical output is the pneumatic actuator force (Fa). The force Fa is the input for the state spaces and the output is β, which is the arm angle of the links 1 and 2. The diagram on figure 10 shows the proposed simplified model for each link.
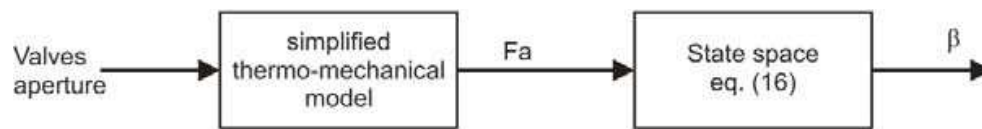
Fig. 10. Block diagram for simplified thermo-mechanical model and space states integration.

The result of the integration of the simplified thermo-mechanical model and state space are shown in figure 11.
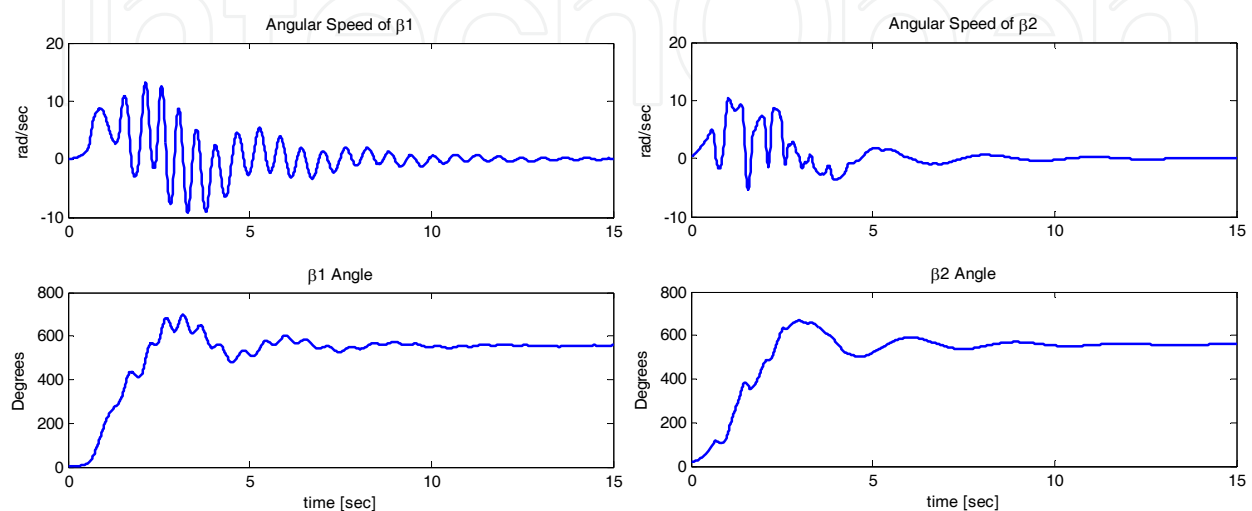

Fig. 11. Behavior of the robot, with both simplified thermo-mechanical and state space model.

With constant force applied on link 1 and 2, an initial oscillation on both links is observed, before reaching a steady state. That behavior can be observed in figure 11. To control the position of the angles β_1 and β_2, is necessary to control the pneumatic force, and the aperture of the air flow through the pneumatic cylinder. Figure 12 shows the pneumatic forces Fa_1 and Fa_2, generated by thermo-mechanical model.
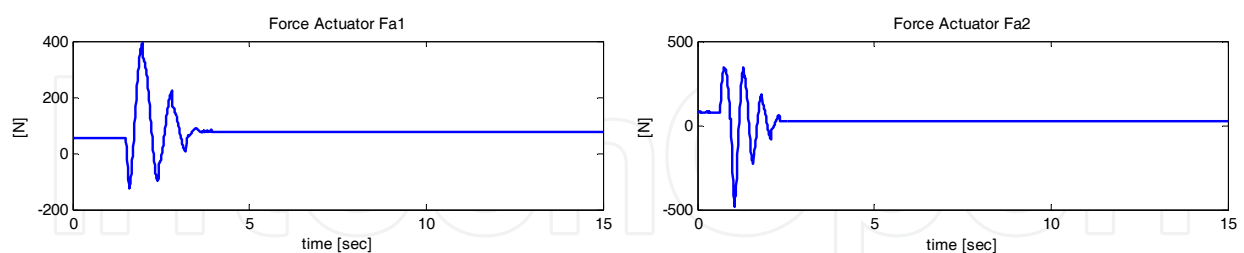

Fig. 12. Pneumatic forces generated using the simplified thermo-mechanical model.

With this work, a base of knowledge is generated about a pneumatic flexible manipulator robot with two degrees of freedom.

6. Future work

For future work, the simulation methodology for mechatronic applications (Ramos et al. 2009) will be applied to get a visual simulation of the behavior of flexible manipulator robot

with two degrees of freedom, with pneumatic actuator. Figure 13 shows a proposed flexible structure of the two-link robot, with pneumatic actuator on each arm. Therefore, including the effect of both four bar mechanism effects on the analysis is required. Also, a finite element analysis of both flexible links would be applied.
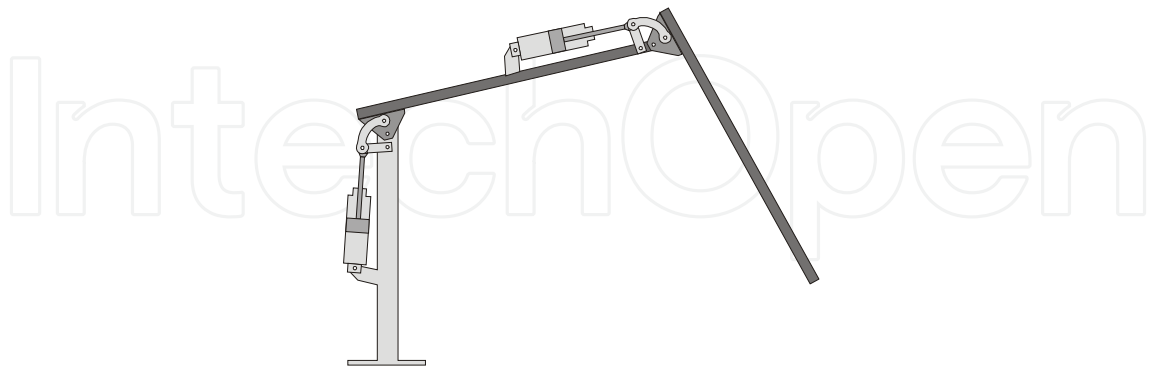
Fig. 13. Proposed structure of two degrees of freedom for flexible manipulator robot, with two pneumatic actuators.

7. Conclusions

The majority of the work previously developed use electrical actuators. The pneumatic actuators are not considered due to the highly non linear behavior. Previous work only considered one link and dynamic behavior of the pneumatic actuator. Also, graphical simulations have been developed under the same considerations. The innovation of this work is addition of the second degree of freedom for the flexible manipulator robot, together with dynamic analysis to study the robot behavior. In simulation of dynamic models, an oscillation can be observed; however, the oscillations decrease until the structure achieves the stability. The mechanical limitations are not considered into dynamic simulation. With this dynamic analysis, we can conclude that the proposed structure of two degrees of freedom for flexible robot with pneumatic actuators is feasible and can be controlled.

8. References

Ata, A. A. & Johar, H. (2004). Dynamic simulation of task constrained of a rigid-flexible manipulator, pp. 61 - 66, *International Journal of Advanced Robotic Systems, Volume 1 Number 2*, ISSN 1729-8806

Celentano, L. An Innovative Method for Robots Modeling and Simulation. *New Approaches in Automation and Robotics*, Book edited by: Harald Aschemann, ISBN 978-3-902613-26-4, pp. 392, I-Tech Education and Publishing, Vienna, Austria.

Featherstone, R. & Orin, D.E. (2000). Robot Dynamics: Equations and Algorithms. *Proceedings of the 2000 IEEE International Conference on Robotics and Automation*, pp. 826-834

Featherstone, R. (1987). *Robot Dynamics Algorithms*, Kluwer Academic Publishers, Boston/Dordrecht/ Lancaster.

Gamiño, M.; Pedraza, J. C.; Ramos, J. M. & Gorrostieta, E. (2006). Matlab-C++ Interface for a Flexible Arm Manipulator Simulation using Multi-Language Techniques. *5th Mexican International Conference on Artificial Intelligence, MICAI 2006*. Tlaxcala, México.

Gudiño-Lau, J. & Arteaga, M. A. (2006). Dynamic Model, Control and Simulation of Cooperative Robots: A Case Study. *Mobile Robots, Moving Intelligence*, Edited by Jonas Buchli, pp. 241-270, ISBN: 3-86611-284-X, Germany.

Khalil, W. and Dombre, E. (2002). *Modelling, Identification and Control of Robots*, Hermes Penton Science, London, UK

Kiyama, F. F. & Vargas, J. E. (2005). Dynamic Model Analysis of a Pneumatically Operated Flexible Arm. *WSEAS Transactions on Systems, vol. 4*, pp. 49-54.

Ramos-Arreguin, J. M.; Pedraza-Ortega, J. C.; Gamiño-Galindo, M; Gorrostieta-Hurtado, E.; Romero-Troncoso, R. J.; Aceves-Fernandez, M. A. & Hernandez-Valerio J. S. (2009). Simulation Methodology for Mechatronic Applications using Multilanguage Techniques. *14th IFAC International Conference on Methods and Models in Automation and Robotics*. August, Miedzyzdroje, Poland.

Ramos-Arreguin, J. M.; Pedraza-Ortega, J. C.; Gorrostieta-Hurtado, E.; Romero-Troncoso, R. J.; Vargas-Soto, J. E. & Hernandez-Hernandez, F. (2008). Pneumatic Fuzzy Controller Simulation vs Practical Results for Flexible Manipulator. *Automation and Robotics*. Edited by Juan Manuel Ramos-Arreguín, Ed. I-Tech Education and Publishing, pp. 191-200, ISBN 978-3-902613-41-7, Austria

Ramos-Arreguin, J. M.; Gorrostieta-Hurtado, E.; Vargas, J. E.; Pedraza-Ortega, J. C.; Romero-Troncoso, R. J. & Ramírez B. (2006). Pneumatic cylinder control for a flexible manipulator robot. *12th IFAC International Conference on Methods and Models in Automation and Robotics*. August, Miedzyzdroje, Poland.

Ramos, J. M.; Vargas, J. E.; Gorrostieta, E. & Pedraza, J. C. (2006). New Polynomial Model of Pneumatic Cylinder Model. *Revista Internacional Información Tecnológica*, vol. 17, no. 3, Edited by José O. Valderrama, ISSN 0716-8756, La Serena, Chile.

Zhaocai, D. & Yueqing, Y. (2008). Dynamic Modeling and Inverse Dynamic Analysis of Flexible Parallel Robots. *International Journal of Advanced Robotic Systems*, *Vol. 5, No. 1*, pp. 115-122, ISSN 1729-8806.
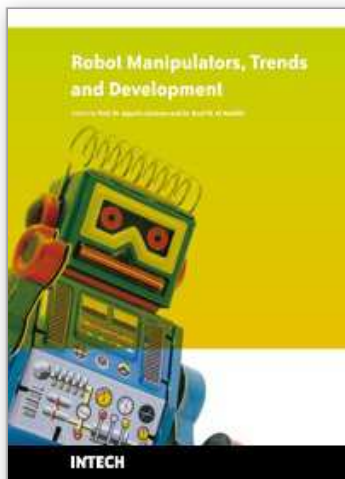
Robot Manipulators Trends and Development

Edited by Agustin Jimenez and Basil M Al Hadithi

This book presents the most recent research advances in robot manipulators. It offers a complete survey to the kinematic and dynamic modelling, simulation, computer vision, software engineering, optimization and design of control algorithms applied for robotic systems. It is devoted for a large scale of applications, such as manufacturing, manipulation, medicine and automation. Several control methods are included such as optimal, adaptive, robust, force, fuzzy and neural network control strategies. The trajectory planning is discussed in details for point-to-point and path motions control. The results in obtained in this book are expected to be of great interest for researchers, engineers, scientists and students, in engineering studies and industrial sectors related to robot modelling, design, control, and application. The book also details theoretical, mathematical and practical requirements for mathematicians and control engineers. It surveys recent techniques in modelling, computer simulation and implementation of advanced and intelligent controllers.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Juan Manuel Ramos-Arreguin, Efren Gorrostieta-Hurtado, Jesus Carlos Pedraza-Ortega, Rene de Jesus Romero-Troncoso, Marco-Antonio Aceves and Sandra Canchola (2010). Dynamic Behavior of a Pneumatic Manipulator with Two Degrees of Freedom, Robot Manipulators Trends and Development, Agustin Jimenez and Basil M Al Hadithi (Ed.), ISBN: 978-953-307-073-5, InTech, Available from:
http://www.intechopen.com/books/robot-manipulators-trends-and-development/dynamic-behavior-of-a-pneumatic-manipulator-with-two-degrees-of-freedom

INTECH
open science | open minds