

# The Mechatronic Design of six axes Industrial Robot

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## ABSTRACT

In this work, the Matlab based control system for six degrees of freedom for an industrial robot is designed. The mechatronic system is modelled, so as to simulate the controller which is actually deployed for an industrial application like spray painting robot. The six axes industrial robot is undertaken as case study for which a virtual prototype using ADAMS is adopted. The output of the Matlab based controller acts as input to this virtual industrial manipulator and position feedback signal is taken as input to thus designed controller. The control system is so designed in MATLAB/Simulink that the actual position follows the desired set points. The angular position and angular velocity are fed back to the system to yield the better accuracy. The system also enables to test various PID setting so that a comparative study of virtual performance could be compared. The given point in space is initially calculated in terms of joint coordinates from home position and then actual position is sensed through feedback and decision is taken about the joint movement and direction. The series of points in space is also possible to taken up as path in space and implemented through is co-simulation platform. The virtual co-simulation results on the model of the industrial robot confirms the performance of the control system in terms of the cycle time and the positional accuracy.

**Keywords—** Co-simulation, Controller, Industrial manipulator, MATLAB/Simulink, Mechatronic, Simulation

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## I. INTRODUCTION

Recent advancements in mechatronics have allowed to use computer offline simulation for the development of industrial robot. This offline simulation starts with the virtual mechanical model of the industrial robot along with the sensors and actuators. The control system is designed based on the robot dynamics for specific industrial applications like spray painting. Due to Multiple Degrees of Freedom (MDF), the model based controller and the identification algorithm are time consuming process. Therefore, the PID controllers with different settings are widely used for control design and to rectify the errors. It also offers the distinct advantage of simple design and wide usage. The actual robots are inaccessible, due to their high

price and changes in the setup is required for each specific application. With the new advents in the design of mechatronics system by the manufacturers there is need for exact and precise virtual simulation models. Hence the virtual simulation plays significant role in the design of six axes industrial robot on co-simulation platform.

In this paper, the MATLAB based control system for six degrees of freedom for an industrial robot is designed. The controller is simulated for the industrial application like spray painting. The virtual prototype case study is taken on six axes industrial robot using ADAMS (Automatic Dynamic Analysis of Mechanical Systems). The signal generated by the MATLAB based control system acts as an input to for the virtual industrial robot and the feedback

received from the system is compared with thus designed controller so that the errors are rectified. The control system is designed to track down the errors if any by rectifying the difference of the desired and the obtained angular position. The series of points in space can be taken as the path and implemented on the co-simulation platform.

## II. LITERATURE REVIEW

The simulation modelling of the system based on the mechatronic approach [1] [2] is presented for the development of mechatronic system. The simulation modelling of mechatronic system is intensively used to study behaviour and maturity of the product [1]. The MTB model and its behaviour is simulated on the virtual prototype environment for the 3 DOF industrial manipulator. The co-simulation technique for the development and optimization of the parameters is presented [2]. The interface between ADAMS and MATLAB software based on the crank slider mechanism is presented. The comparison of the PD and PID controller is carried out, PID is found to be delivering the adequate response [3]. The dynamic and simulation modelling six axis industrial robot using precise simulator is presented. The co-simulation technique is advocated for the prototyping of industrial robot [4]. A class of PD robust control along with feed forward plus PD type controller is stated based on the perturbation theory for parameter identification. The desired position of the industrial manipulator is tracked on 2 DOF direct drive motor [5]. The output feedback controller is presented with two approaches. First advocates the use of nominal robot dynamics while another uses the model independent PD type output feedback. It has been found that the bounds can be made arbitrarily small by using gains [6]. The inverse dynamics control based gains are used for robust control law. The Lyapunov function based solution is used for the stability analysis on decentralised PID controllers [7]. A linear PD controller designed by Qu and Dorsey suggested the parameterization of the gains to follow the time varying desired position. As the gain becomes high, the system becomes more stable [8]. The high gain observer is proposed with perturbation theory for the estimation of velocity using closed loop PD control [9]. Adaptive PD learning algorithm based on linear and non-linear approach advocates the best tracking performance [10].

## III. MODEL OF AN INDUSTRIAL ROBOT

The virtual model of the six axes industrial robot is presented. The model consists of six motors connected at each axes. It contains base, shoulder, arm, elbow, wrist and tool flange are driven by DC motors along with the joints, gravity, applied torques and forces. The co-simulation technique for the development of the mechatronic system for the six axes industrial robot is presented. The virtual model of an industrial robot Staubli© TX40 along with the movements at each axes is shown in Fig. 1 as,

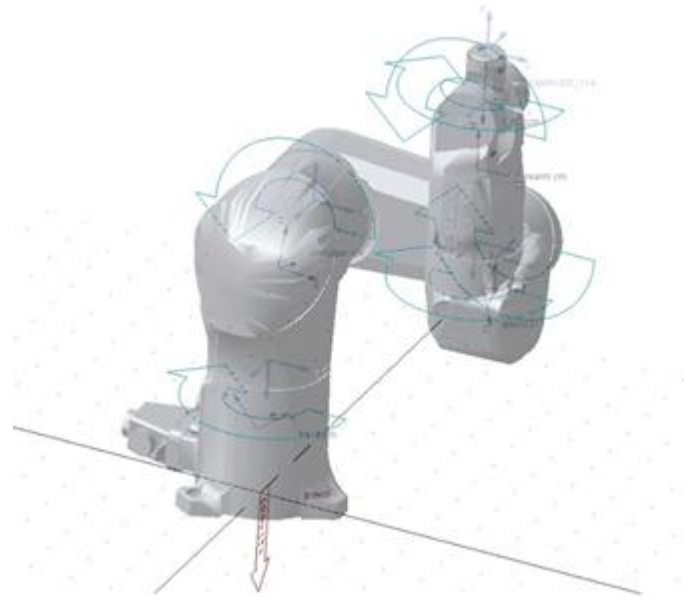


Fig. 1 Mechatronic System – Industrial robot Staubli© TX40 with 6 DOF.

The ADAMS model is driven by the DC motors modelled in the MATLAB/Simulink.

## IV. ROBOT DYNAMICS AND CONTROL

The robot dynamics for highly non-linear  $n$  link robot based on the Euler-Lagrange equation of motion is characterised by,

$$M(q)\ddot{q} + C(q, \dot{q})\dot{q} + G(q) + F_v\dot{q} = \tau \quad (1)$$

Where,  $q \in \mathbb{R}$  is the  $n \times 1$  vector of joint displacements,  $\dot{q} \in \mathbb{R}$  is the  $n \times 1$  vector of joint velocities,  $M(q) \in \mathbb{R}$  is the  $n \times n$  is symmetric positive inertia matrix,  $C(q, \dot{q})\dot{q} \in \mathbb{R}$  is the  $n \times 1$  vector of Centripetal and Coriolis torques,  $G(q) \in \mathbb{R}$  is the  $n \times 1$  vector of gravitational torques,  $F_v \in \mathbb{R}$  is the  $n \times n$  diagonal positive definite matrix containing viscous friction coefficients of each joint,  $\tau \in \mathbb{R}$  is the  $n \times 1$  is the applied input vector.

The robot dynamics are computed and the control system based on the robot dynamics is presented with the aim to sense the actual position. However if the difference arises with the desired signal, the error signal is generated to rectify the position errors. The error signal is the difference of the desired and obtained joint position. Thus an independent control system is designed for each axes which is then combined to form the control system for six axes industrial robot.

### A. ADAMS/Control system

The MATLAB based control system is designed for the control action. Prior to that, the ADAMS has plugin as ADAMS/Control, through which the control plant is exported into the MATLAB for the co-simulation. The exported plant is called into the MATLAB using the Command Window. The state variables exchanges the data between plugin and the Simulink as shown in Fig. 2. There is provision for linear and non-linear analysis while exporting the model into MATLAB.

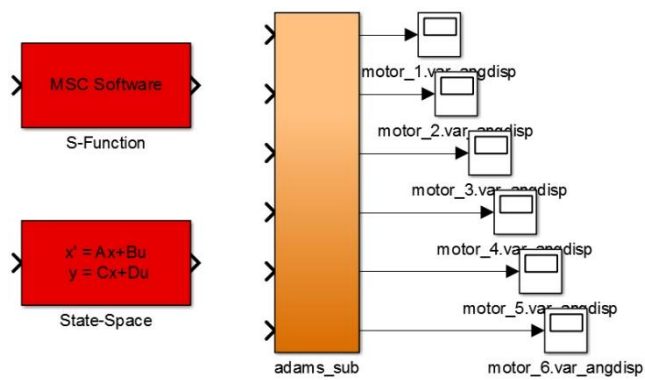


Fig. 2 The 'adams\_sub' system showing the data exchange between MATLAB and ADAMS.

### B. Control in MATLAB/Simulink

The m-file created in the MATLAB, connects adams\_sub system in the Simulink environment with the solver. The architecture of the 'adams\_sub' block is shown in Fig.3.

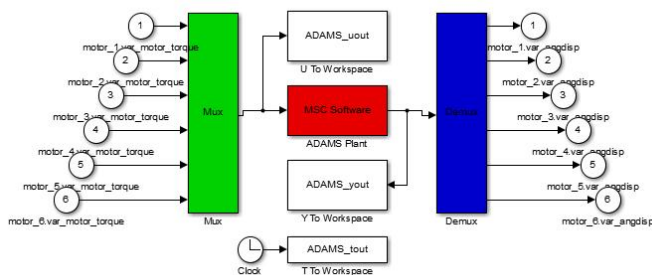


Fig. 3 The architecture of 'adams\_sub' block .

The simple control system with PID regulator is designed for the control of six axes industrial robot. The control system consists of the DC motor model preceded by the PID regulators which is given to the adams\_sub block for the interfacing. The angular position generated is feed backed to the controller to rectify the error signals. The control system design is shown in Fig. 4.

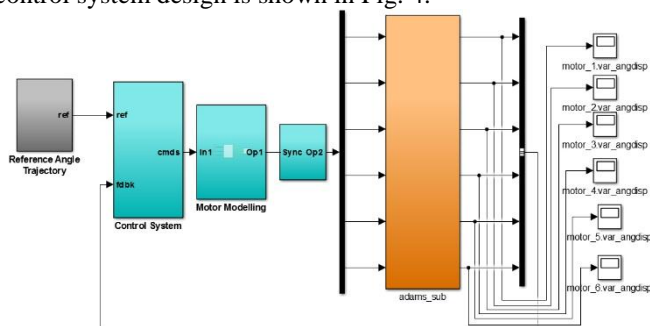


Fig. 4 The co-simulation model – control system design.

### V. CO-SIMULATION RESULTS

The investigation for the effectiveness of the stated approach has been carried out for the six axes industrial robot. The set of points in the space are created and the angular position can be displayed on the scope of MATLAB Simulink. The angular position at each axes of the robot is shown in Fig. 5-10. The PID controller acts as rectifier and the error signal is generated and shown in Fig. 11.

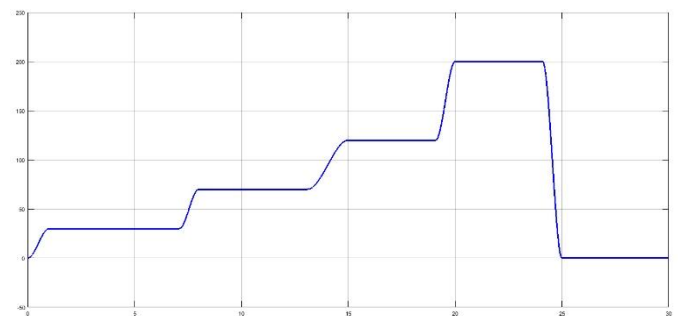


Fig. 5 Angular position of the axes 1 (between Base and Shoulder) of six axes industrial robot.

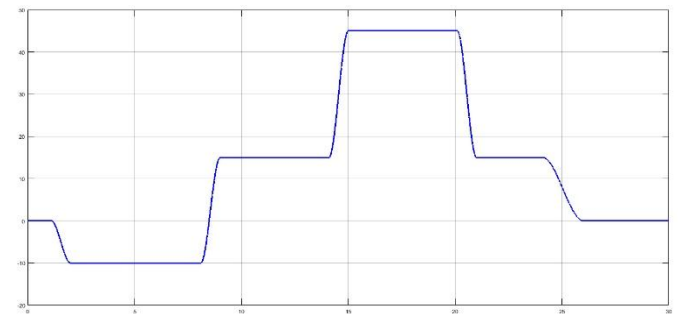


Fig. 6 Angular position of the axes 2 (between Shoulder and Arm) of six axes industrial robot.



Fig. 7 Angular position of the axes 3 (between Arm and Elbow) of six axes industrial robot.

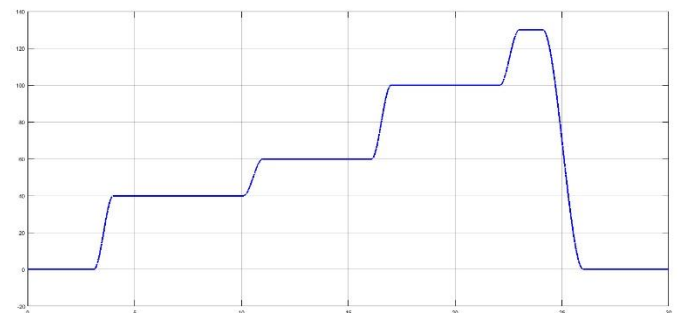


Fig. 8 Angular position of the axes 4 (between Elbow and Forearm) of six axes industrial robot.

The error signal in Fig. 11 can be rectified by using the perturbation theory. The parameters can be modified to reduce the error.

### VI. CONCLUSIONS

The methodology presented of ADAMS-MATLAB co-simulation has allowed us to control and simulate the mechatronic system. The six axes industrial robot is used to illustrate our approach. The control system in Simulink environment affects the behaviour of mechatronic system. Thus the mechatronic system as six axes industrial robot can be simulated as a virtual prototype of the Staubli© TX40.

The co-simulation technique can be very useful for the development of this mechatronic system. Several simulation studies can be implemented to study the virtual behaviour of real mechatronic systems. A simple PID controller yield the satisfactory results.

This virtual prototyping technique can be very efficient for modern mechatronic systems in terms of cycle time and accuracy.

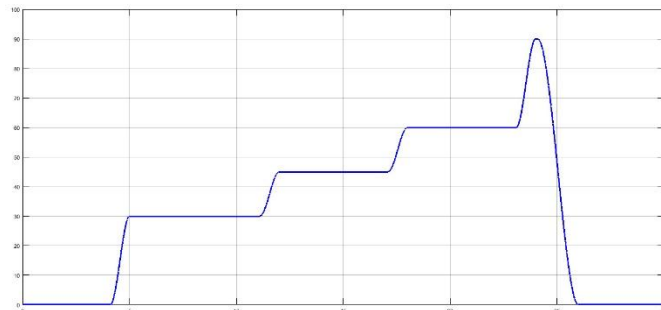


Fig. 9 Angular position of the axes 5 (between Forearm and Wrist) of six axes industrial robot.

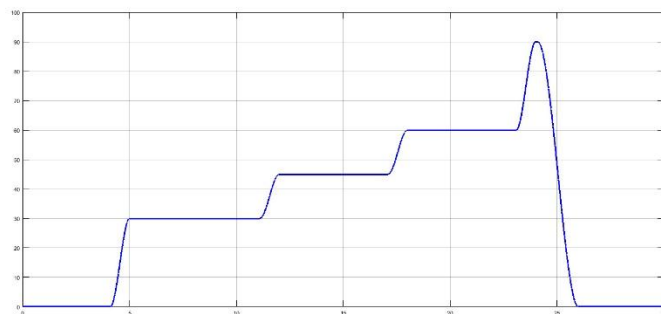


Fig. 10 Angular position of the axes 1 (between Wrist and Tool Flange) of six axes industrial robot.

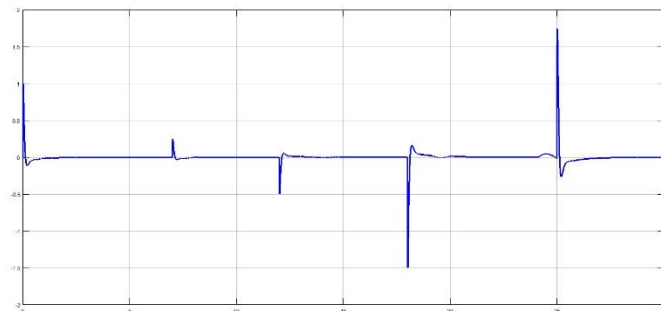


Fig. 11 The generated error signal.

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