

# SIMULATION AND MOTION CONTROL OF INDUSTRIAL ROBOT

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**Abstract:** This research proposes a simulation of a Stäubli TX90 robot based on Simulink Toolbox of Matlab. The goal is to predict the position and trajectory of its end-effector, with high reliability. The simulator takes into consideration loading, deformations, calibrated kinematic parameters, and all eventual sources of disturbance. A comparison between real and simulated data reveals the reliability and the accuracy of the simulator.

**KEYWORDS:** SIMULATION, PID CONTROL, STÄUBLI TX90, INDUSTRIAL ROBOT

## 1. Introduction

This robot has six degrees of freedom; all of them are rotational, driven by servo motors. The robot has the appearance that can be seen in Figure 1:

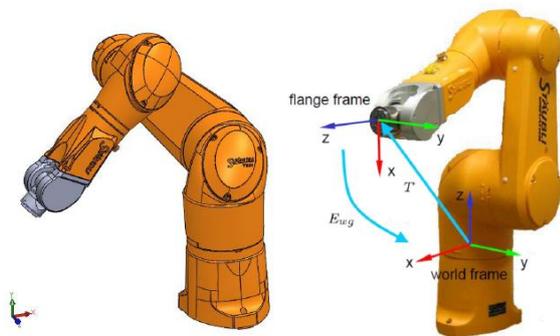


Figure 1: Stäubli Robot TX90 Real view and SolidWorks Design

The simulation should provide an accurate position of the robot's end-effector. The TX90 robot is a serial manipulator robot with six rotational joints. The link frames and the kinematic parameters of the TX90 robot, following the notations of the modified Denavit and Hartenberg method proposed by Khalil and Kleinfinger [1], are shown in Figure 2.

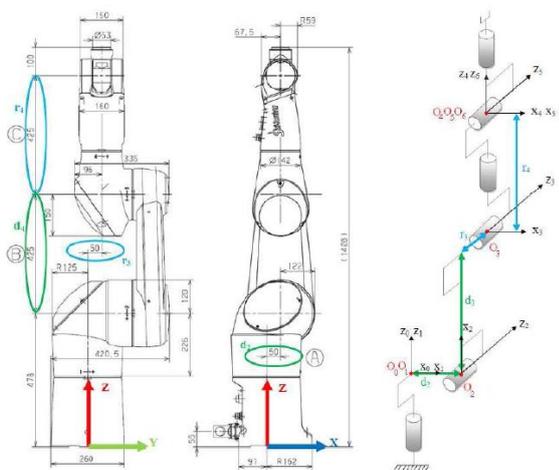


Figure 2: Kinematic description of the Stäubli TX90 robot

The kinematic parameters ( $\alpha_j$ ,  $d_j$ ,  $\theta_j$ ,  $r_j$ ,  $\beta_j$  [5]) were calibrated previously by using an autonomous calibration method [2, 3, 4] which aims to identify the difference between the nominal and the real values of the kinematic parameters and then to have a better knowledge of the position of the end-effector (rate of knowledge improvement is about 94 %). The nominal values of the kinematic parameters (in bold) D-H are shown in Table 1.

Table 1. The Standard Kinematic model in Denavit-Hartenberg Convention

j	$\alpha_j$	a	$\theta_j$	$d_j$
units	[rad]	[mm]	[rad]	[mm]
1	-1.5708	50	0	350
2	0	425	0	50
3	-1.5708	0	0	0
4	1.5708	0	0	425
5	-1.5708	0	0	0
6	0	0	0	100

Previously, identification of the dynamic parameters, and identification of the elastic parameters and the joint stiffness matrix were carried out on the TX90 robot [4]. These parameters are taken into consideration in the simulator for the nearest representation of the reality.

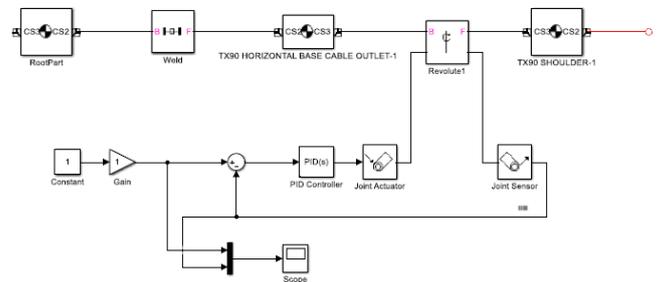


Figure 3: PID Controller diagram in Simulink

## 2. Description of the Simulation Tool

To model the dynamics and the control of the robot, the simulation tool must be coupled with Simulink blocks and use Matlab functions in order to compute for example: The inverse kinematic model, the trajectory generation and the control blocks.

The chosen tool to simulate the TX90 is SimMechanics [6,7,8] which is a sub-tool of Simulink®. Consequently, its models can be interfaced with ordinary Simulink block diagrams which speed up the simulation and integrate everything in the same environment. Moreover, it is simple to use and its block set consists of seven sub-libraries that represent the following: bodies, joints, sensors (joint sensors, body sensors), actuators (joint actuators, body actuators), gearboxes, constraints and drivers, and force elements.

SimMechanics tool allows to:

Model all the elements of a multi-body system (i.e. bodies, joints, connections, forces) in Simulink;

Import full models from CAD systems (i.e. Stäubli SolidWorks CAD [9]), with the properties of inertia, lengths, angles;

Generate a 3D animation to visualize system dynamics.

### 3. Trajectory Generation, Control and Simulation in SolidWorks

The approach used for the generation of trajectories in the case of the TX90 was not provided by the manufacturer for reasons of confidentiality. The study of the position and the velocity signals (given by the "Stäubli recorder") and the calculation of the accelerations (derivation of the velocity) show that the approach is applied in the joint space using the trapezoidal velocity law. This approach provides during movement: a continuous velocity (ensures a minimum time by saturating the velocity and acceleration at the same time) and a continuous acceleration (replaces the acceleration and braking phases by a law of the second degree and therefore the position is a law of the fourth degree) [10].

On the other hand, only the name of the controller used by Stäubli has been provided by the manufacturer through a confidential agreement and so it is not possible to present it in this paper. The controller and the trajectory generations blocks are designed under the environment of Simulink.

We can see the control sequence of Stäubli Robot Tx-90 in Figure 4 and the Simulink Diagram with PID controllers in the following Figure 5.

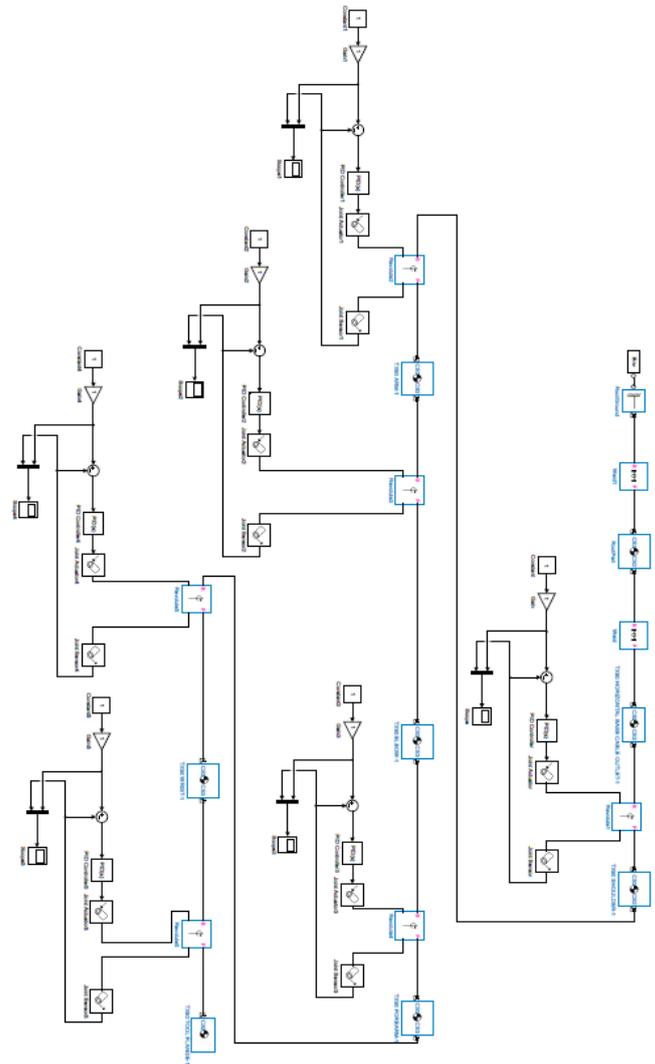


Figure 5: Simulink Diagram with PID controllers



Figure 4: Control Diagram of Stäubli Robot Tx-90

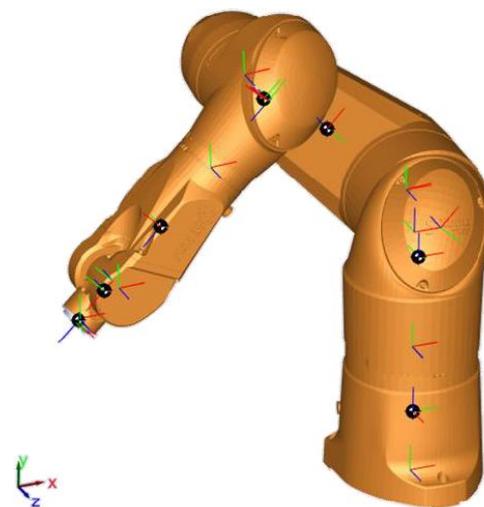
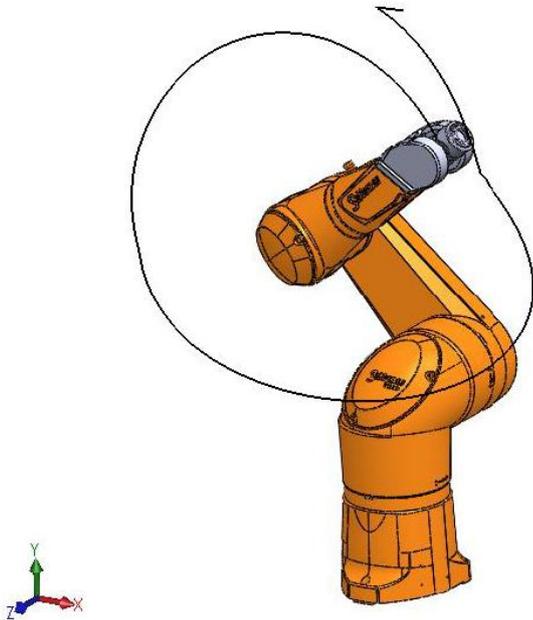
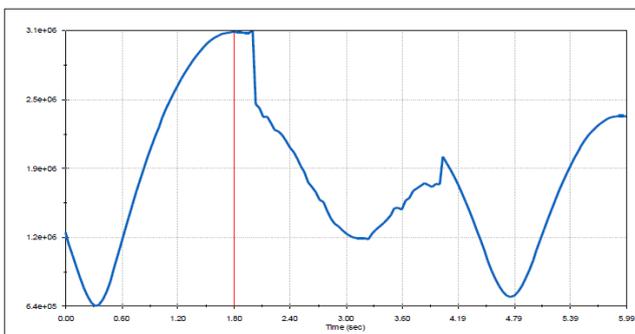


Figure 6: Three-dimensional animation of the TX90 robot in Simulink

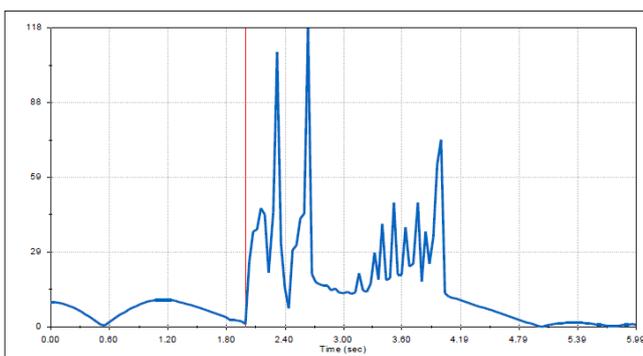
We built three dimensional model from technical drawings for Stäubli Robot TX90 and after making the proper assembly mates we could make motion analysis. we can see the simulation results for tracking this arbitrary trajectory (3600 mm length) in a time of 6 seconds that means total velocity is 0.6 m/s Figure 7.



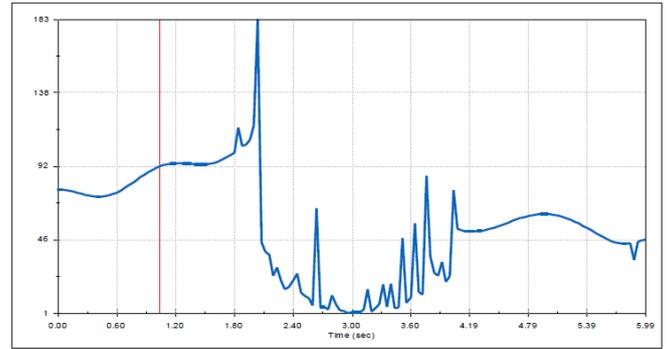
**Figure 7: SolidWorks Trajectory tracking and Motion Simulation**



**Figure 8: Angular Momentum**



**Figure 9: Motor Torque**



**Figure 10: Angular Acceleration**

### 4. Conclusion

This research has presented the implementation of the Stäubli TX90 simulator using Sol idWorks and SimMechanics which is an interactive three-dimensional modeling of mechanical systems in Simulink®. It allows building simulations and automatically generates 3D animations of multi-body systems such as robots. Blocks representing all external perturbations (deformations, cutting forces, flexibilities, loads) have been integrated into this simulator. This simulator is able to predict the position and trajectory of the end-effector according to the loading and deformation in order to represent reality with high reliability.

The simulation results indicate that SimMechanics can be used for modeling other robots with the same morphology as the TX90, (i.e. anthropomorphic, open, series). Block parameters defining for example the different bodies, joints, kinematic models (i.e. MGI, MGD) can be easily modified to be adapted to other robots. Moreover, the simulator can be used to validate the feasibility and to predict errors of other maintenance operations that need high precision such as welding.

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