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Modeling and Simulation of a 6 DOF Robot

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Abstract. The purpose of this paper is to model and simulate a 6 DOF robotic system with revolute joints in order to optimize the motion law which results in uniform coating deposited by spray pyrolysis. The structure and the complexity of the robotized system are determined by the necessary movements in the spray pyrolysis process. The nozzle (end-effector of the robot manipulator) has two translations, in longitudinal and transversal direction relative to the surface deposition. The mechanical model of the robot mechanism was developed by using the MBS (Multi Body Systems) environment ADAMS of MSC Software.

Keywords: robot manipulator, trajectory planning, inverse kinematics, MBS, spray pyrolysis.

1. Introduction

The major deficiency of the actual manufacturing processes of the solar cells is energy consuming, costly production and their complexity. A new technological production process is desired. Latest the research and manufacture of solar cells is focusing on using spray pyrolysis deposition (SPD). The principle of the SPD technique is: when a precursors' solution is atomized small droplets splash and vaporize on a substrate and leave dray precipitate in which thermal decomposition occurs (figure 1).

A problem consists of to have two movements: one translation on the longitudinal direction and one on the transversal direction, to control all the parameters during the deposition: the surface temperature, the spraying sequences, droplets dimensions, the angle and the direction from which the spraying process is accomplished and the coating process to be a highly efficiency process.

Application of robots in spray tasks results in low-cost production, persistent quality and protects humans from a hostile working environment. Automated planning of applicator's trajectory requires a model of spray deposition onto the surface and formulation of an appropriate criterion for the spraying quality [1, 2, 3, 8].

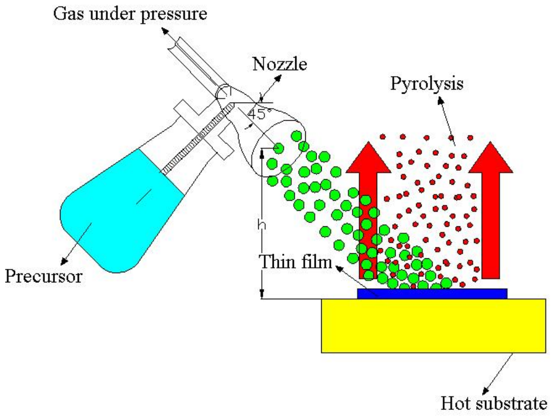

Fig. 1: The principle of the SPD technique.

The problem is the reproducibility of the process, that's why a robotic system of SPD is imposed. The relevance of this paper is represented by the importance for the field of thin films. It is mainly relevant because using a robot manipulator is obtaining better results in the deposited films. On the other hand a better uniformity upon the deposited film increases solar cell efficiency.

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Film thickness depends on the distance between spraying nozzle and substrate, substrate temperature and spraying rate. A trajectory in the spraying process includes the spraying direction and the velocity with which this is shifted.

To achieve a uniform accumulation of spray, it is recommended a constant speed motion of the nozzle [6], keeping the nozzle axis orthogonal to the surface. The trajectory planning problem in robotic is defined: find a motion law along a given geometric path, taking into account predefined requirements, so as to be able to generate suitable reference inputs for the control of the robotic system [7]. Uniform deposition of the layer depends on the process steps which follow the deposition. Step coverage is the capability of a process to deposit equally thick films on steep slopes and on surfaces.

The research efforts were concentrated on the determination of the trajectory that provided the best quality of spraying [8]. The need of a better design of the system like in robotics has led to the development of methods for the dynamic analysis of multibody system. So, the inputs of the trajectory planning are: the geometric path, the kinematic and dynamic constraints and the output is the trajectory of the joints or of the end-effector, expressed as a time sequence of position and velocity values.

In the serial robotics, the inverse kinematic problem is a more difficult problem than the forward kinematics due to the possibility of multiple solution or no solutions. The main contribution of this paper is the control of the robot in order to optimize the motion law for increase the uniformity of thin film.

2. Kinematics simulation using ADAMS/View

Inverse kinematics problem (IKP) consists in determining the joint motion corresponding to a prescribed end-effector motion [4, 5]. Determining the inverse kinematics solution for a robot manipulator can be a very difficult task. The application is made for a 6 DOF system by using a virtual prototyping model that contains specific software solutions in the engineering concept as follows: CATIA for developing the geometric model of the robotized system and ADAMS/View for analyzing the system. The modelling activity involves the creation of geometric models with attributes representing physical properties. The 3D CAD model for the robotic system has been converted into a multibody model. For the multibody model, revolute joints are used between parts. In figure 1 is shown the ADAMS model which was developed by using MBS (Multi Body Systems).

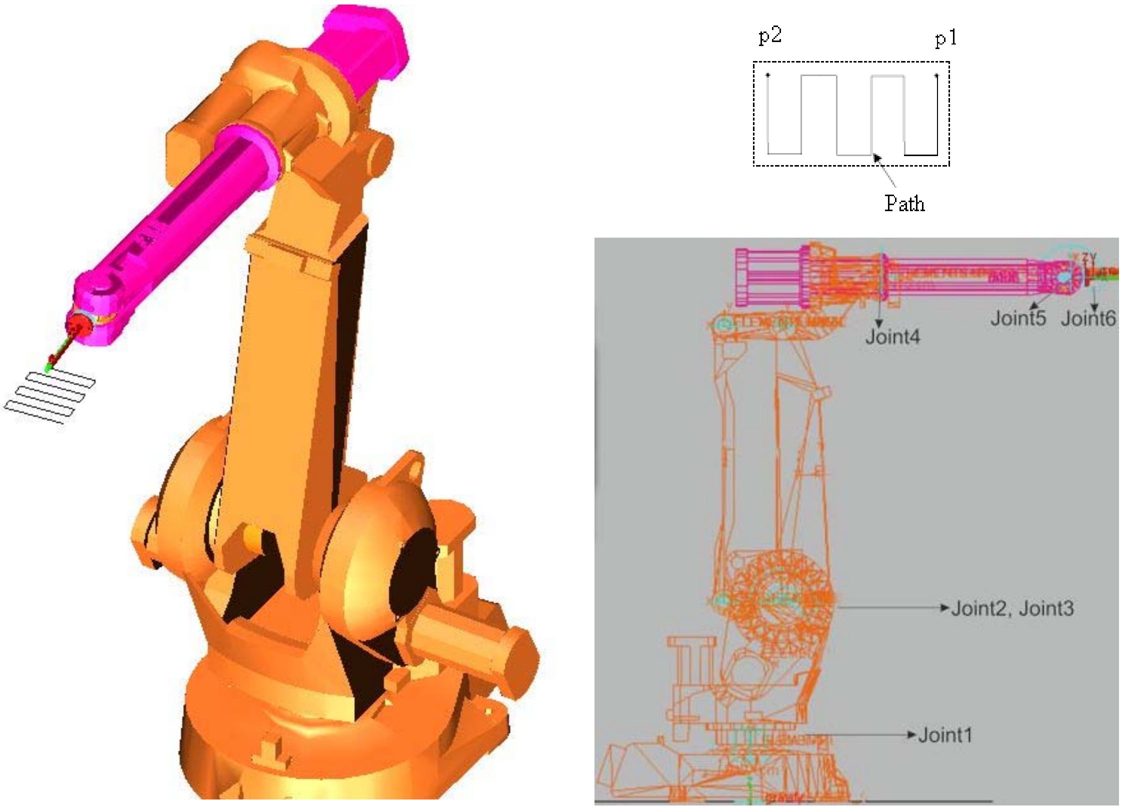


Fig. 2: The desired trajectory by using IRB 2400L robot.

The torque in the air gap drives rotor to the motor. The angular rate of the motor is transformed to lower speed by means of the gearbox, which drives the joint of the next arm. Robotic bodies, joints and rotors are modelled as a rigid MBS.

During the spraying the nozzle moves along a prescribed continuous planar trajectory. Position and orientation of robot's end-effector is defined by six-dimensional vector of external coordinates: $\boldsymbol{X(t)} = [x(t), y(t), z(t), \varphi(t), \theta(t), \psi(t)]^T$. Three Cartesian coordinates $x(t), y(t), z(t)$ are necessary to place the nozzle to desired point of the space, while three rotations $\varphi(t), \theta(t), \psi(t)$ are required to provide to the surface [1]. Thus, a six degree of freedom (DOF) robot is sufficient for spraying a surface.

In order to determine the motion of the joint is need to impose the motion to the end-effector. The imposed motion defines the relative motion between to bodies. The justification for robot used in simulation is based on ability to control the parameters during the deposition process. It's used ADAMS/View for simulating a 6 DOF robot (IRB 2400L) which is moving along a defined path (figure 2).

In this case of the anthropomorphic spraying robot the number of joints is $n=6$ and all coordinates are rotation angles. The driving torques result from the applied robot actuators. DC motors are used to drive robot joints. The drive requirements of the robotic system are determined from inverse kinematic analysis within MSC ADAMS.

The inverse kinematic analysis is developed as a simulation where the trajectory of the robot is prescribed. The inverse kinematic analysis is executed to record the joint motions corresponding to the prescribed nozzle trajectory. The inverse kinematics analysis of the robot in ADAMS follows as shown in figure 3.

The basic concept of this approach is that we make in ADAMS a master and slave model. In the master model the inverse kinematic analysis is executed to record the joint motions corresponding to the desired end-effector trajectory. In the slave model the joint motion data is imported and imposed on the joints, and payload is also attached to the end-effector. Then the inverse calculation is performed to solve the required joint torques for actuating the robotic system. This procedure can be applicable to other parallel and serial robotic systems. With the kinematic setup the end-effector can be positioned within the workspace of the robotic system.

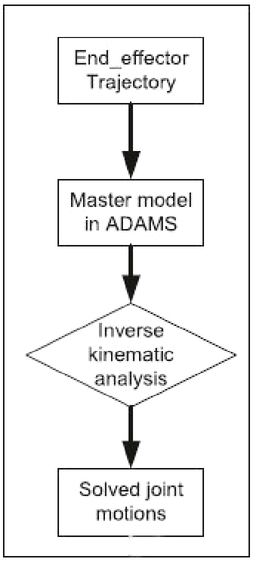


Fig. 3: The procedure of inverse kinematics simulation.

In ADAMS/View to generate the desired trajectory it was used the General Point Motion [9].To specify the motion was used step expressions for the longitudinal and transversal directions at the end-effector robot. To observe the end-effector motion it was inserted measures for the both directions (longitudinal and transversal). The basic concept of the approach is that we record the joint motions at the master model that correspond to the desired end-effector motion, and then imposed these motion laws to a slave model.

It needs to export the time diagram of the joint variable. For the each joints the time and the Q-components are inserted. The motion laws were saved in the slave model. The discrete function values are interpolated by smooth curve using Create Spline. When the product reads the property saved file, it populates the spline with data. This mechanism lets us to generate and to use splines with data stored within database structure by simply selecting the property file that stores the data and defining the data block.

In figures 4 and 5 are presented the positions and velocities obtained from ADAMS/View simulation for the desired trajectory. The positions and velocities are determinates from longitudinal and transversal direction which are generated to coverage plane. The velocity and trajectory planning plays an important role in achieving uniform coverage.

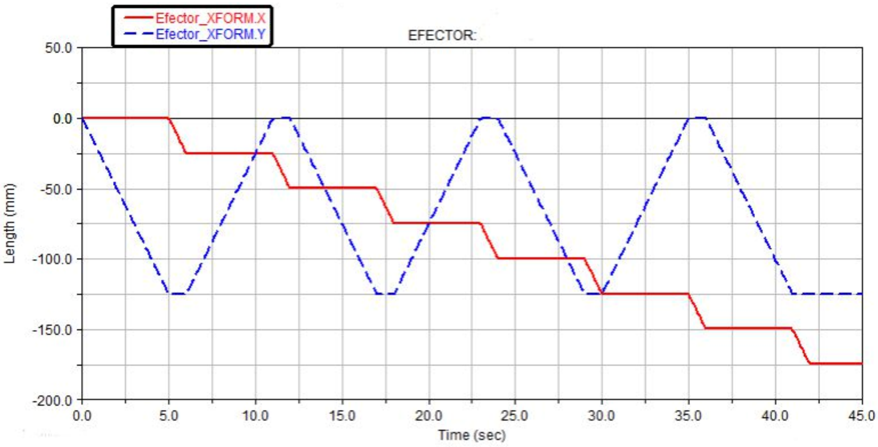


Fig. 4: Position profiles on the longitudinal and transversal directions of the end-effector.

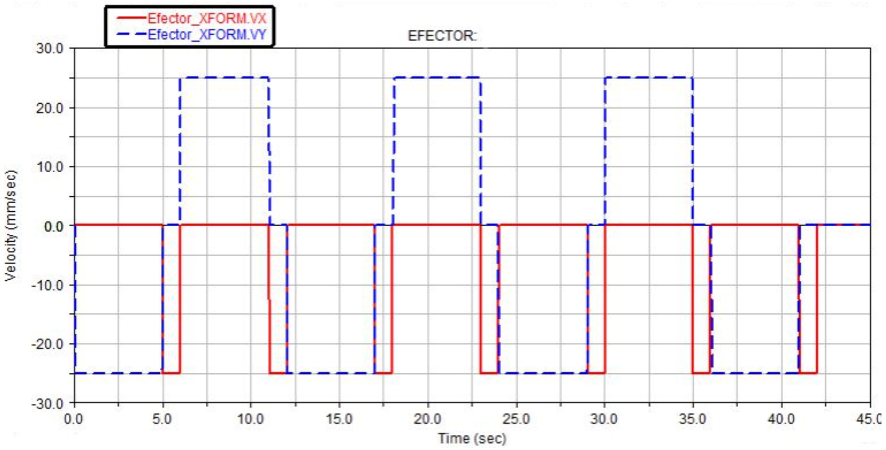
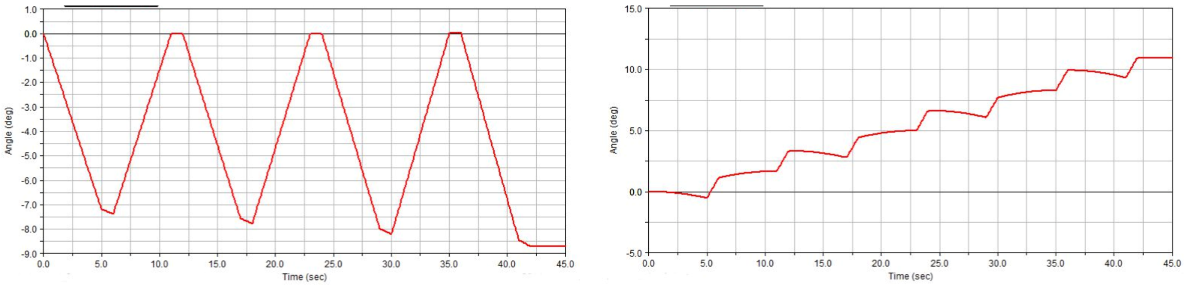
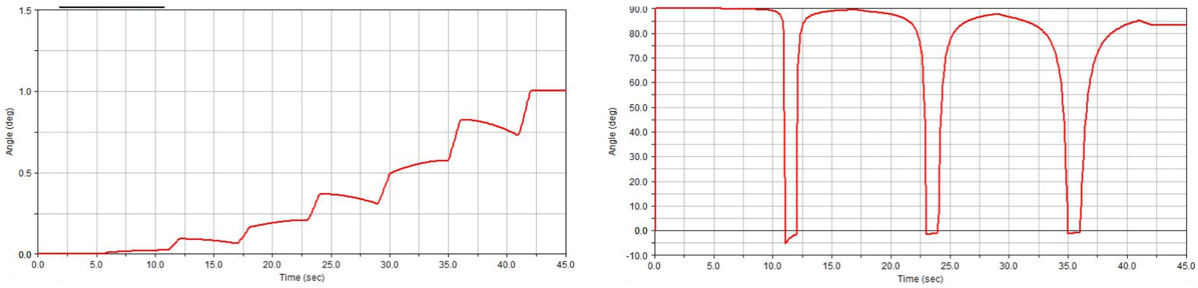


Fig. 5: Velocity profiles on the longitudinal and transversal directions of the end-effector.

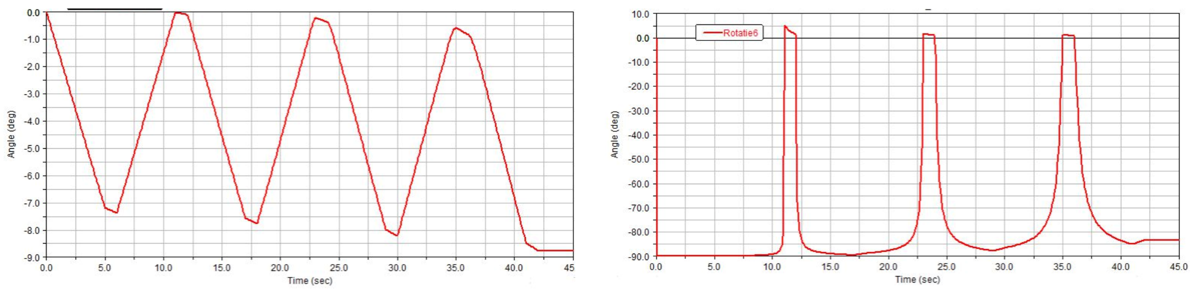
The motion laws are obtained for Joints 1, 2, 3, 4, 5 and 6, as presented in figure 6.



Joint1 Joint2



Joint3 Joint4



Joint5 Joint6

Fig. 6: The motion laws for joints 1, 2, 3, 4, 5 and 6.

3. Conclusions

The novelty if this paper is developed a procedure by using ADAMS/View whereby is obtaining the necessary motion laws to be applied in controlled joints at the robot to achieve prescribed and desired end-effector trajectory in order to deposit. The deposition simulation is made in ADAMS/View for one trajectory. For the plane trajectory is simulated in ADAMS/View the following characteristics: the positions and velocities for the longitudinal and transversal directions, also the motion laws for each of the joints are determined by using ADAMS/View.

The physical robot exists within the Renewable Energy Systems and Recycling Center and the motion laws in joint obtained by simulating the virtual prototype will be implemented on the physical robot for generating the desired trajectory. As for the future work, other trajectories will be described for non-planar surfaces. Different trajectories will be research to obtain a better uniform deposition by diverse overlapping spraying cone in order to achieve the desired deposited surface.

4. Acknowledgements

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