

Modeling in ADAMS of a 6R industrial robot

Mariana Ratiu^{1,*}, Alexandru Rus¹, and Monica Loredana Balas²

¹University of Oradea, Department of Mechanical Engineering and Automotive, 410087 Oradea, Romania

²Transilvania University of Brasov, Department of Product Design, Mechatronics and Environment, 500068 Brasov, Romania

Abstract. In this paper, we present the first steps in the process of the modeling in ADAMS MBS of MSC software of the mechanical system of an articulated robot, with six revolute joints. The geometric 3D CAD model of the robot, identical to the real model, in the PARASOLID format, is imported into ADAMS/View and then are presented the necessary steps for building the kinematic model of the robot. We conducted this work, in order to help us in our future research, which will consist of kinematic and dynamic analysis and optimization of the robot motion.

1 Introduction

Today, in the context of using of the robots in the most industries, due to the benefits related to the reduction of the costs and increasing productivity, there is, as stated by the [1], a special interest of the companies and researchers concerning the modeling and optimization of these mechatronic systems. In recent decades, alongside with the traditional methods of design and modern physical prototyping, the modeling and virtual prototyping are new trends in the industry and become more and more complex and powerful, thanks to the many advantages that they bring. As presented in [2], there are a large number of studies and multiple and complex software packages used for the modeling of the industrial robots. One of the most widely used Multi-Body System (MBS) software for the modeling, analysis, and simulation of the complex mechanical systems' motion, is ADAMS (Automatic Dynamic Analysis of Mechanical Systems) from MSC software, because of the benefits which it offers: performance, safety, and comfort, good visibility and good results in real-time, consistent with the results of the physical model. In this paper, we present the process of the modeling in ADAMS of the mechanical system of a 6DOF (degree of freedom) robot, with six revolute joints. This work is the first step in a longer research related to the modeling and optimization of the motion of this kind of robot, and that will be applied on a physical robot ABB IRB 1600-6/1.2, which exists in one of our laboratory, integrated into a flexible manufacturing cell.

2 Geometric and structural presentation of the robot ABB IRB 1600-6/1.2

The ABB IRB 1600-6/1.2 robot is a 6R robot (also called articulated robot, or revolute robot, or anthropomorphic robot) having the six revolute joints arranged as shown in Fig. 1. In accordance with the manufacturer's

specifications [3], the main applications of this robot are: machine tending, material handling, arc welding, cutting, dispensing, assembly, palletizing and packaging, measuring, die casting, injection moulding.

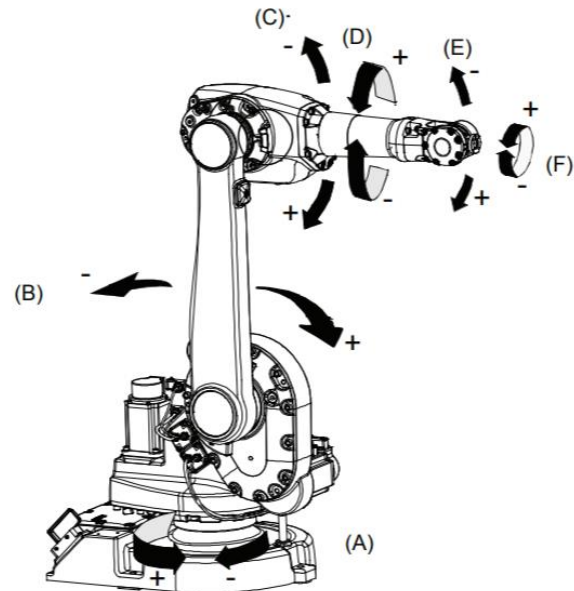


Fig. 1. Geometric model of the robot ABB IRB 1600-6/1.2.

The types of motion and the range of movement, according to [3], are presented in Table 1.

Table 1. Type of motion and range of movement.

Axis	Type of motion	Range of movement
A	Rotation motion	+180° la -180°
B	Arm motion	+110° la -63°
C	Arm motion	+55° la -235°
D	Rotation motion	+200° la -200°
E	Bend motion	+115° la -115°
F	Turn motion	+400° la -400°

* Corresponding author: mratiu@uoradea.ro

3 Modeling in ADAMS of the robot's mechanical system

The virtual prototyping process in ADAMS, respectively [4, 5], comprises the following steps:

- Building the model using: bodies, forces, contacts, joints, motion generators
- Testing the model using: measures, simulations, animations, plots
- Validating the model by: importing test data, superimposing test data
- Reviewing the model by adding: friction, flexible parts, forcing functions, control systems
- Iterating the model through variations using: parametrics, design variables
- Improving the model using: design of experiments, optimization
- Automating the modeling process using: custom menus, custom dialog boxes, macros.

As we have already mentioned, in this paper we will build the kinematic model of the robot, which contains the bodies (also called parts or kinematic elements) of the robot, connected through the revolute joints, and the geometric parameters specific to the mechanism, in fact, the locations of the joints; the inputs are made by using kinematic restrictions and motion generators, which controls the position or velocity of the elements [6]. Then, we will run a kinematic simulation, will animate simulation results and will plot results values from the simulation run.

In continuation, there are shown the necessary steps for building the kinematic model of the robot. There is the possibility to create the model of the robot directly in ADAMS/View or to design it in others virtual environments and then to transfer the 3D CAD model in ADAMS/View, as was done in [7, 8 and 9].

In this work, the geometric 3D CAD model of the robot, identical to the real model, in the PARASOLID format, is taken from the manufacturer's website and imported into ADAMS/View and the robot's bodies are identified, as can be seen in Fig. 2.

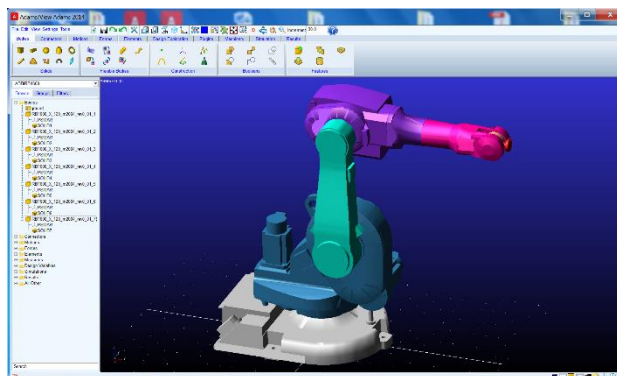


Fig. 2. Identification of the robot bodies in ADAMS/View

The necessary characteristic points (geometric parameters specific to the mechanism, in fact, the locations of the joints) are created, as can be seen in Fig. 3.

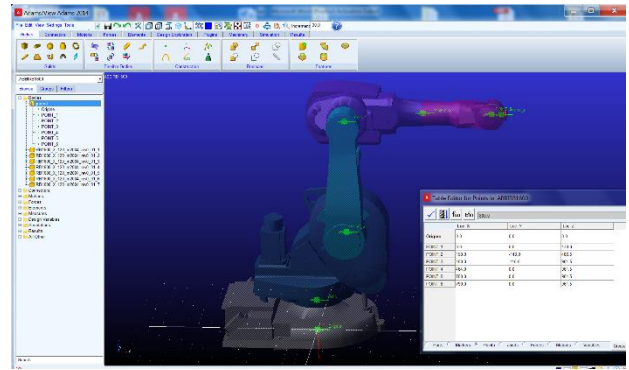


Fig. 3. Creating characteristic points

Then the kinematic elements are connected through six revolute joints, and the robot is fixed on the ground, like in Fig. 4.

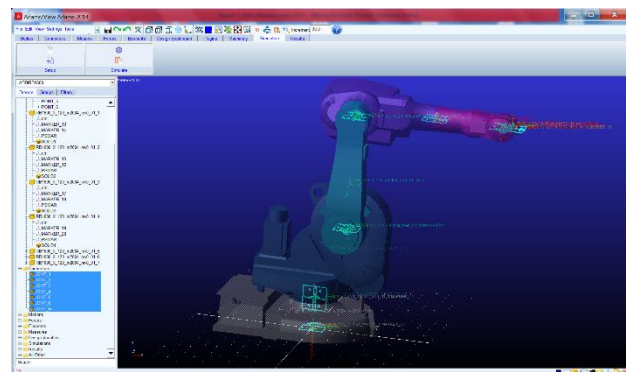


Fig. 4. Creating revolute joints

The material from which the robot is made is selected (aluminum), thereby obtaining the mass and inertia properties of the component elements (Fig. 5).

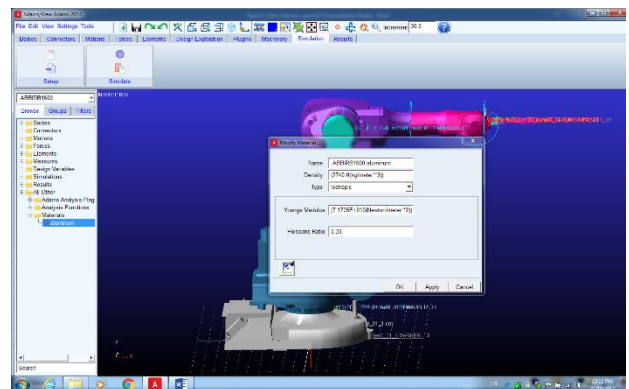


Fig. 5. Selection of the material

The motion generators of the six revolute joints are imposed, after a certain function, predefined in the program ($30.0d * \text{time}$), like in Fig. 6, and so, the MBS model of the robot, in ADAMS/View, is obtained.

It is simulated the motion of the robot, for 1 second and 100 steps and is obtained the position of the robot presented in Fig. 7.

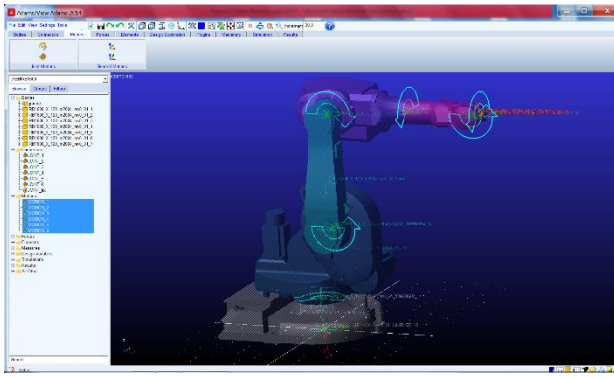


Fig. 6. Imposing the motion generators

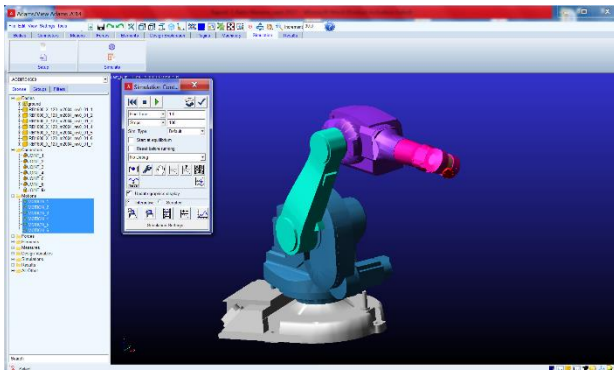


Fig. 7. Simulation of the MBS model of the robot in ADAMS

In order to be in line with those provided in Fig. 1, are changed the sense of rotation of some joints (Fig. 8) and is observed the changing of the robot position after a simulation like before (Fig. 9).

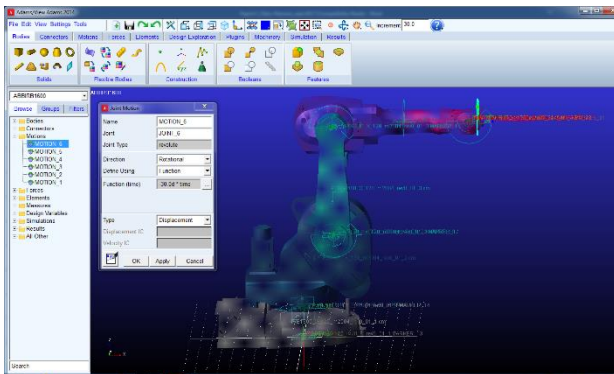


Fig. 8. Changing the sense of rotation for a joint

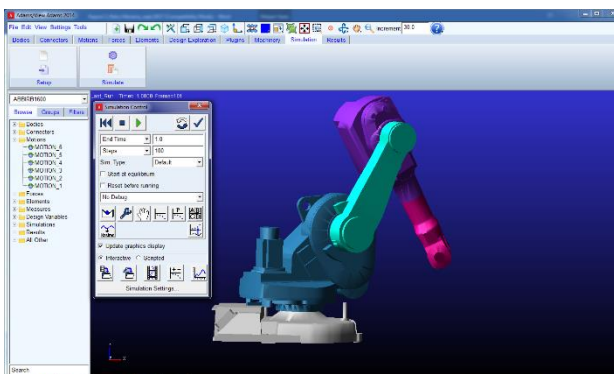


Fig. 9. The changed position of the robot

Using the animation module, the trajectory of the Marker 32, belonging to the end effector, is observed after a simulation of 1s, in Fig. 10.

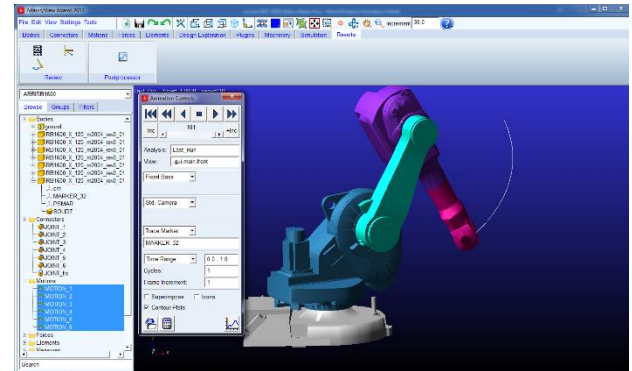


Fig. 10. Trajectory of the end effector

Now, the model of the robot is prepared for kinematic analysis using ADAMS MBS software.

4 Kinematic analysis of the robot

The goal of the kinematics is to describe the motion of the robot without to take into consideration the forces and torques causing the motion.

There are two types of kinematic analysis, forward kinematic analysis, and inverse kinematic analysis. In this work, we will do a simple forward kinematic analysis, in which we will plot the position and orientation of the end effector, its velocity and acceleration, under the imposed motion generators of those six revolute joints. So, through the forward kinematic analysis, we will determine the cumulative effect on the end-effector of the entire set of joint variables. In contrast with the forward kinematic analysis, the objective of the inverse kinematic analysis is to determine the values for the joint variables, given the position and orientation of the end effector [10].

In the next five figure, we present the charts of variation of some kinematic parameters of the end effector after the above simulation run, in fact position (Fig. 11), velocity (Fig. 12), acceleration (Fig. 13), angular velocity (Fig. 14) and angular acceleration (Fig. 15) of the mass center of the end effector.

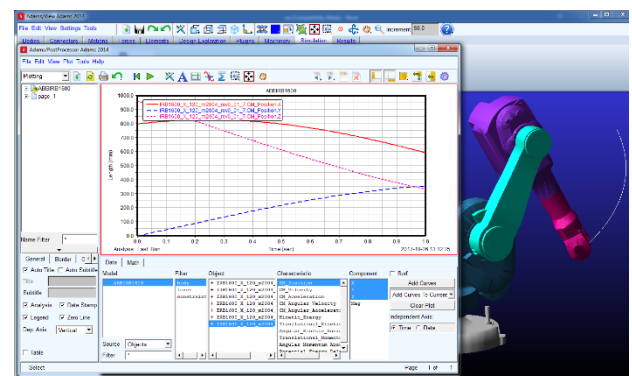


Fig. 11. Position of the end effector

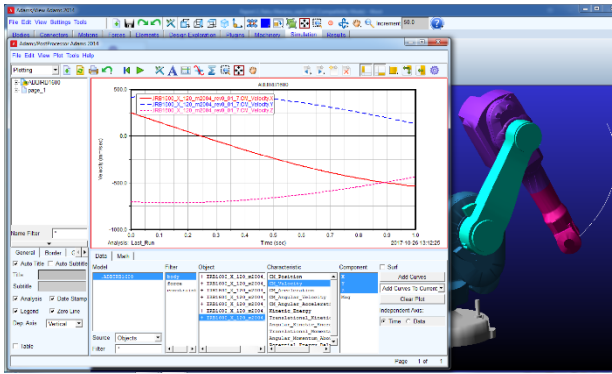


Fig. 12. Velocity of the end effector

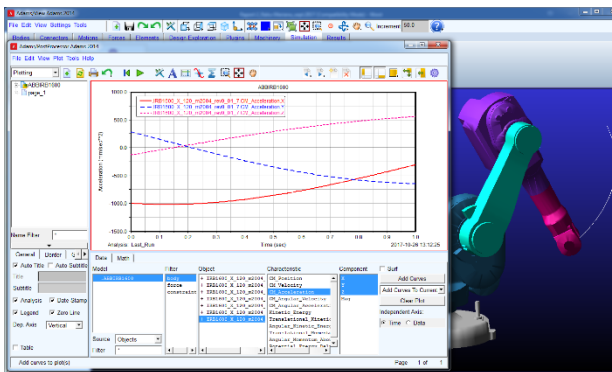


Fig. 13. Acceleration of the end effector

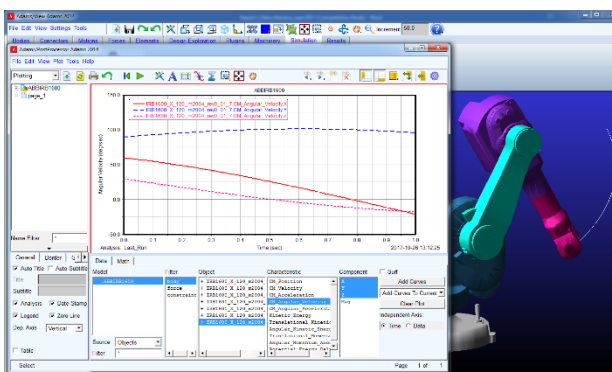


Fig. 14. Angular velocity of the end effector

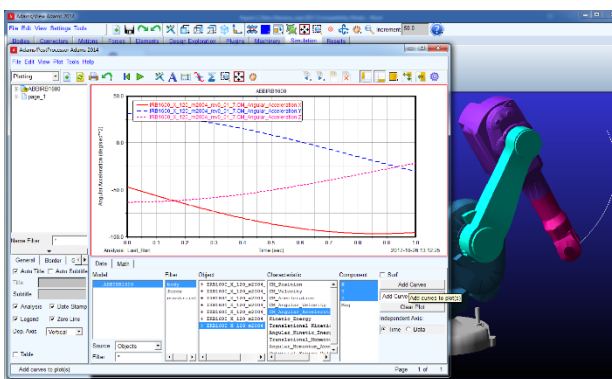


Fig. 15. Angular acceleration of the end effector

5. Conclusion

We conducted this work, which represents a first and small step in modeling in ADAMS MBS software of a 6R articulated robot, in order to help us in our future research, which will consist of kinematic and dynamic analysis and optimization of the robot motion. We hope that this example will be useful to students or other interested people who want to start learning to model such mechatronic systems in ADAMS.

References

1. M. Ratiu, Short literature review on the kinematics and dynamics of the industrial robots, Annals of the University of Oradea, Fascicle of Management and Technological Engineering, ISSUE #2, pp. 49-52 (2016)
2. M. Ratiu, A. Rus, Modeling of the trajectory-generating equipments, IEEE publication, 14th International Conference on Engineering of Modern Electric Systems (EMES), DOI: 10.1109/EMES.2017.7980418 (2017)
3. www.abb.com/robotics
4. Getting started using ADAMS/View, MSC Software (2014)
5. Adams Tutorial Kit for Mechanical Engineering Courses (Third Edition), MSC Software
6. C. Alexandru, Modeling in mechatronic concept and virtual testing of orientation mechanisms used in solar panels, Mechanism and Manipulators Magazine, vol. 2, nr. 2, pp. 49-54 (2006)
7. M. Enescu, C. Alexandru, Modeling and simulation of a 6 DOF robot, Proceedings of 2011 International Conference on Optimization of the Robots and Manipulators (OPTIROB), Sinaia, Romania (2011)
8. M. L. Enescu, C. Alexandru, Parametric optimization in virtual prototyping environment of the control device for a robotic system used in thin layers deposition, 7th International Conference on Advanced Concepts in Mechanical Engineering, IOP Publishing Ltd, Series: Materials Science and Engineering, 147, doi:10.1088/1757-899X/147/1/012087 (2016)
9. V. Singh, S.S. Dhama, Robot Position Optimization for a Pick and Place Operation, International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 5, Issue 12, pp. 63-70 (2017)
10. M. W. Spong, S. Hutchinson, M. Vidyasagar, Robot modeling and control, Wiley (2006)