Exploring the CAD model of the manipulator using CAD Translation and Simscape Multibody

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Abstract. The possibilities of the dynamic research of the manipulator CAD-model after its translation into Simscape Multibody using CAD Translation are considered. The results of the simulation are presented. The described approach to modeling allows you to reproduce the dynamics of a real physical object.

1 Introduction

The high development of computer-aided design (CAD) systems [1], capable of performing strength calculations of the designed mechanisms, allows eliminating full-scale models and experiments.

The mechanism designer needs to know how the developed mechanism will behave in practice, that is, to know its kinematic and dynamic characteristics.

The data obtained after the corresponding calculations allow us to select the necessary drives, which is relevant for various systems, including mechatronic ones.

To solve the tasks set, it is convenient to use simulation modeling. Simulation modeling is a method of studying objects because a simulating object replaces the object under study. Experiments are conducted with the simulating object and as a result, information about the object under study is obtained.

To simulate the movement of various objects, you can use such programs as SolidWorks, MatLAB Simulink, and others.

In the process of designing and creating a solid-state model, the SolidWorks CAD system allows you to determine the design parameters that directly affect its dynamics: mass, moments of inertia, the position of the center of mass, etc.

The Simscape software-modeling package is part of the Simulink/MATLAB software package and provides block simulation of complex dynamic systems based on visually oriented programming technology. Simscape Multibody is able to interact with other components of the Simulink/MATLAB library, increasing the simulation capabilities.

The process of simulating a dynamic system in Simulink / MATLAB can be complicated due to the need to determine some parameters: the moment of inertia and the coordinate of each connected element of the system.

To solve this problem, MathWorks has developed a plugin for exporting CAD models, which allows you to create dynamic models in the Simscape Multibody environment based

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on a three-dimensional model developed in the SolidWorks computer-aided design system using Simscape Multibody Link.

Compared to the traditional modeling approach, SimMechanics has a number of advantages: ease of model construction and parameterization, fast debugging, and flexible measurement and visualization tools.

2 Material and methods

Highly specialized modeling programs do not always allow you to simulate the designed mechanism because they are difficult to master or do not have the ability to repeat the mechanism with the required parameters.

The environment of dynamic interdisciplinary modeling of complex technical systems and the main tool for model-oriented design Simulink can help to get out of this situation.

Simulations and simulations allow you to test the behavior of the system in critical conditions or emergency scenarios. This reduces the cost of expensive physical prototypes.

The system is tested using semi-natural modeling and rapid prototyping [2]. Simulink also allows you to convert a CAD model to an equivalent Simscape Multibody flowchart [3].

The conversion is based on the smimport function, which uses the file name of the multi-body XML description as the main argument. The XML file passes the Simscape Multibody program the data needed to recreate the original model or approximate it if the model has unsupported constraints.

The CAD model is translated in two stages: export and import (Fig. 1). At the export stage, the CAD assembly model is converted to a multi-part XML description file and a set of STEP or STL part geometry files. At the import stage, the part description and geometry files are converted to the SLX Simscape Multibody model and the M-data file. The model gets all the input parameters of the block from the data file [4].

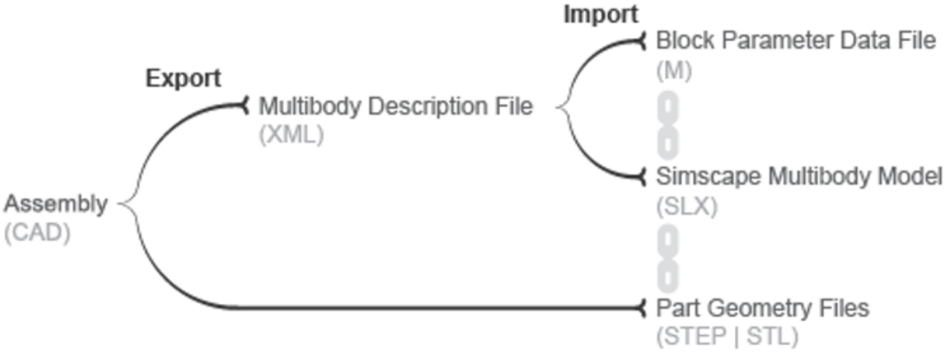


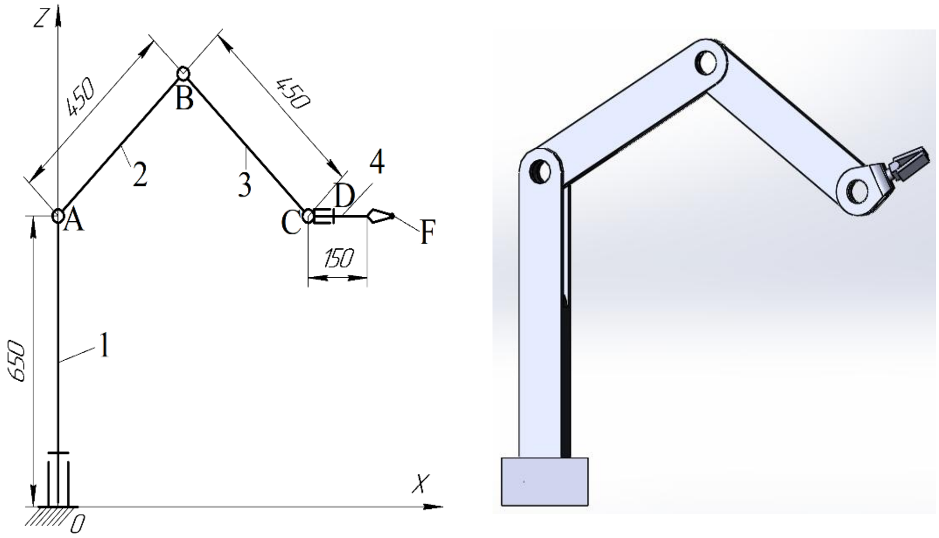
Fig. 1. Stages of CAD translation.

It should also be noted that this method of translation takes into account and affects the characteristics of the materials selected during the construction of the CAD model.

3 Results and discussion

Let's look at the simulation process using the manipulator as an example.

It is necessary to design and study the manipulator of the following kinematic scheme and dimensions (Fig. 2, a). First, you need to build a model of the manipulator in a suitable CAD program (Fig. 2, b).



a *b*

Fig. 2. The investigated manipulator: *a* – kinematic scheme: 1-4-manipulator links; A, B, C, D – hinges; F – point of the executive body; *b* – CAD-model of the manipulator.

For this example, the SolidWorks program was selected. The process of converting a CAD model to is shown in Figures 3-5.

```
fx >> smimport('example.xml')
```

creating model and build files

creating and installing an extension for MATLAB and the selected CAD program

converting files to XML by translator

import the resulting file to MATLAB and create a model

Fig. 3. Model conversion process.

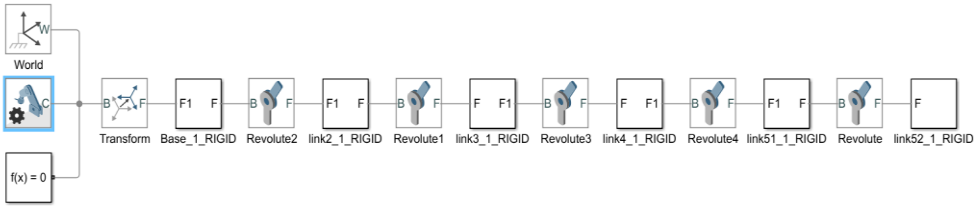


Fig. 4. Block diagram of the model in Simscape Multibody obtained after conversion.

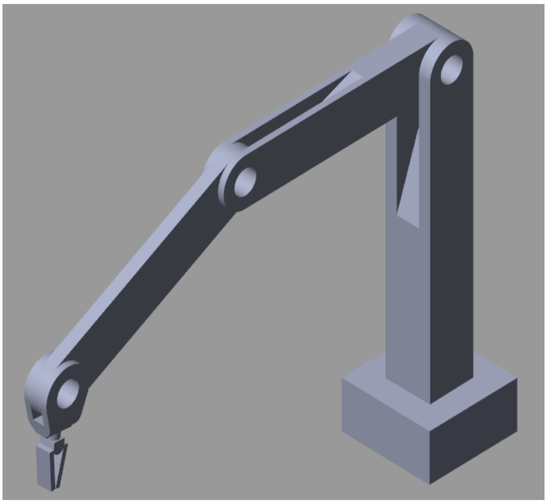


Fig. 5. Three-dimensional representation of the transferred model in Simscape Multibody.

We study the trajectory of the working body.

The coordinates of the point F change according to the following equations:

$$F = \begin{bmatrix} \sum_{i=0}^{5} a_i \cdot t^i & \sum_{i=0}^{5} b_i \cdot t^i & \sum_{i=0}^{5} c_i \cdot t^i \end{bmatrix}^T, \tag{1}$$

Where, depending on the time interval, the boundary conditions change and the coefficients $a_{0\text{-}5}$, $b_{0\text{-}6}$, $c_{0\text{-}6}$ are recalculated by solving the SLAE using the matrix method [5].

The required trajectory is shown in Figure 6.

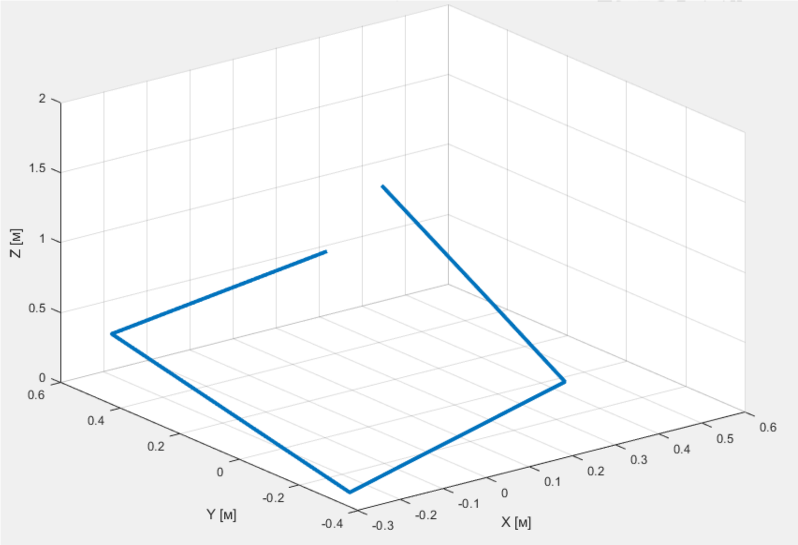


Fig. 6. Trajectory of the working body movement.

Let's solve the inverse kinematics problem.

Finding the vector of generalized coordinates $\overline{q} = (q_1, q_2, q_3, q_4, q_5,)^T$(the five angles of rotation of the links in this case) is carried out by solving the inverse problem of velocity kinematics [6]:

$$\dot{q}(t) = J^{-1}(q) \cdot \chi(t). \tag{2}$$

Denote $\overline{F_F}(\overline{q})$, which defines the values corresponding to the point *F* as a function of the generalized coordinates:

$$\overline{F}_F(\overline{q}) = [F_X(q), F_Y(q), F_Z(q)]^T. \tag{3}$$

Let's introduce a vector function:

$$\overline{\Phi}_F(t) = [F_X(t), F_Y(t), F_Z(t)]^T. \tag{4}$$

Denote the pseudoinverse Jacobi matrix:

$$J^+ = \left(\frac{\partial \overline{F}_F}{\partial \overline{q}}\right)^+ \cdot \tag{5}$$

Then, in discrete form, we rewrite the expression in the form:

$$\overline{q}^{k+1} = \overline{q}^k + J_F^+ \Delta \overline{\Phi}_F(t), \tag{6}$$

where $\Delta\overline{\Phi_F}(t)$ – the increment of the function $\overline{\Phi_F}(t)$in the time step Δt.

The obtained relation allows us to find the vector of generalized coordinates $\overline{q}$ at the *k*+1 time step by a known value $\overline{q}$ at the *k* step.

Figure 7 shows graphs of changes in the found generalized coordinates.

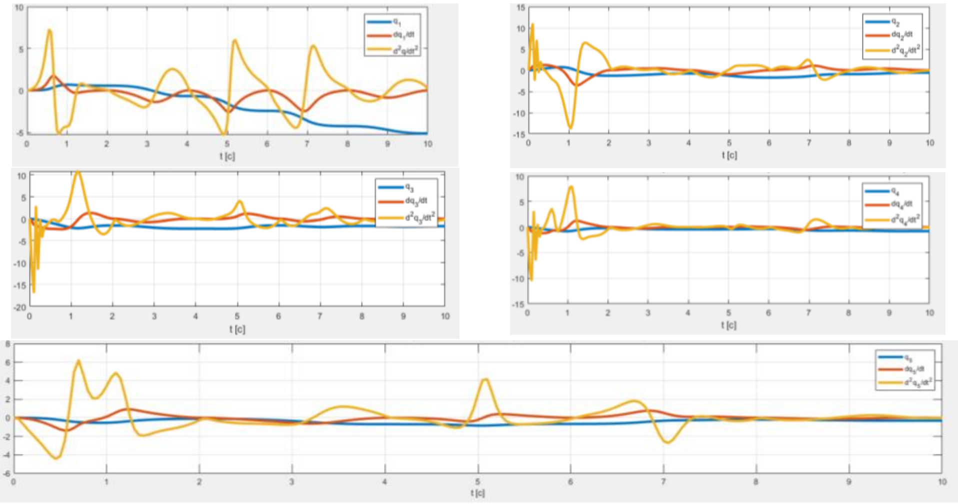
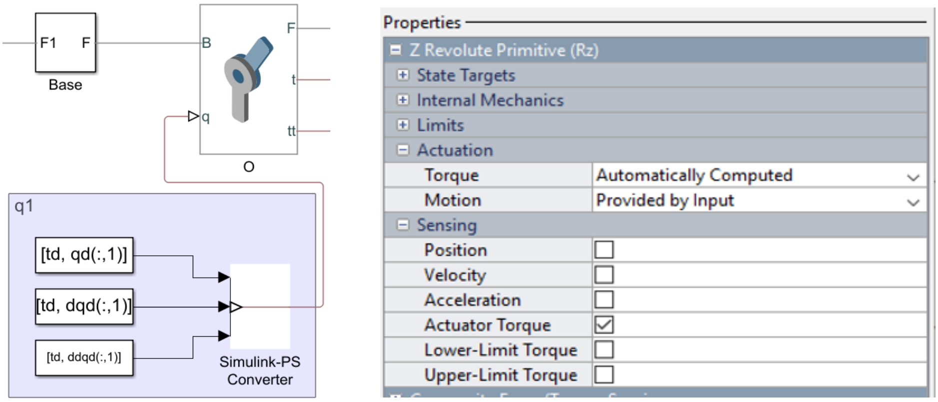


Fig. 7. Graphs of changes in the generalized coordinates: the angle q_i, the angular velocity dq_i/dt, and the angular acceleration d^2q_i/dt^2.

To remove dynamic indicators, you need to pass the previously calculated kinematic characteristics to the model (Fig. 8, *a*) and correctly configure the block that models the kinematic pair. For example, if you need to calculate the actuation moment acting on the slave object in relation to the base object around the base axis of the connection, then select "Actuator Torque" [7] (Fig. 8, *b*).



Properties

Z Revolute Primitive (Rz)

State Targets

Internal Mechanics

Limits

Actuation

Torque	Automatically Computed
Motion	Provided by Input

Sensing

Position	☐
Velocity	☐
Acceleration	☐
Actuator Torque	☑
Lower-Limit Torque	☐
Upper-Limit Torque	☐

a *b*

Fig. 8. Study of the model dynamics: *a* – transfer of kinematic parameters to the joint; *b* – measurement of the rotational moment in the pair.

Figure 9 shows a block diagram of the Simscape Multibody model with the kinematic parameters and settings passed to it for removing dynamic characteristics.

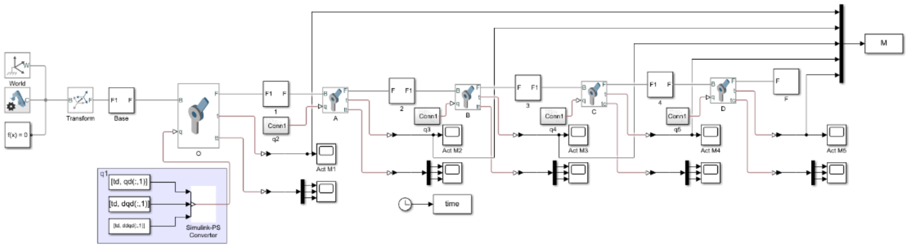
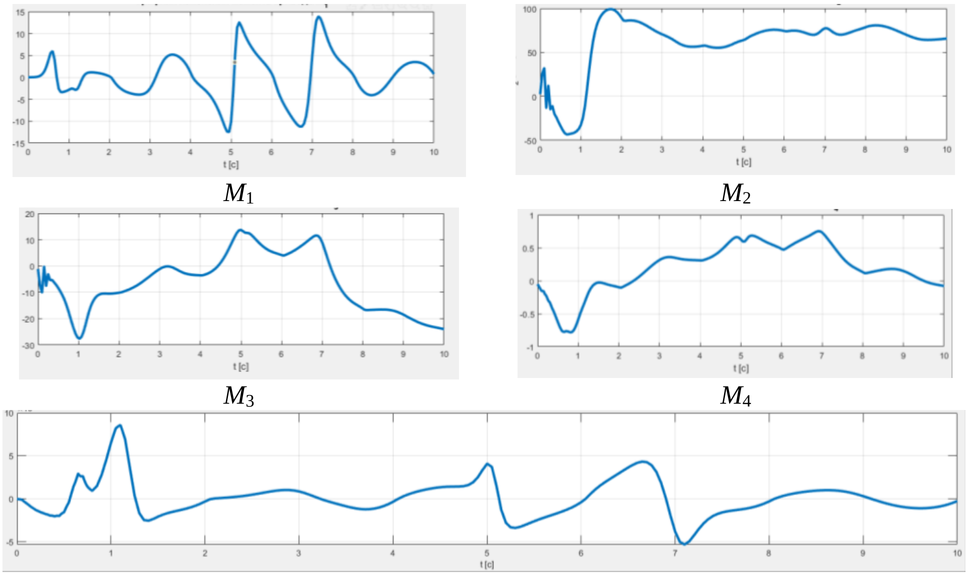


Fig. 9. Block diagram of the model in Simscape Multibody

Figure 10 shows the graphs of changes in the torques in the drives.



M_1 M_2

M_3 M_4

M_5

Fig. 10. Graphs of torque changes in the drives.

The data presented in Figure 10 gives an idea of the numerical value of the torques required to move along a given trajectory. They will also help you select the appropriate drives [8, 9].

4 Conclusions

CAD Translator and Simulink Multibody are convenient tools for studying mechanisms created using CAD programs, allowing you to capture dynamic characteristics and conduct research with changes in the input parameters of the mechanism.

5 References

1. D. Tang, X. Qian. *Product lifecycle management for automotive development focusing on supplier integration*, Computers in Industry. **59**, 2-3 (2008)
2. N. Leon. *The future of computer-aided innovation*, Computers in Industry. **60**, 8 (2009)
3. Simscape Multibody // [MathWorks]. [Electronic resource] URL: https://www.mathworks.com/products/simmechanics.html.
4. CAD Translation // [MathWorks]. [Electronic resource] URL: https://www.mathworks.com/help/physmod/sm/ug/cad-translation.html.
5. Matrix method for solving SLAE: an example of a solution using the inverse matrix // [zaochnik.com]. [Electronic resource] URL: https://zaochnik.com/spravochnik/matematika/issledovanie-slau/matrichnyj-metod-reshenija-slau/
6. O.I. Borisov, V.S. Gromov, A.A. Puirkin. *Methods for managing robotic applications*: Tutorial. – Saint-Petersburg: Editorial and Publishing Department of ITMO University (2016)
7. Get Started with Simscape Multibody // [MathWorks]. [Electronic resource] URL: https://www.mathworks.com/help/physmod/sm/getting-started-with-simmechanics.html
8. E.V. Mishchenko, V.Ya. Mishchenko, A.S. Pechurin. *Modeling the Hay Press Mechanism in MATLAB/SIMULINK/SIMMECHANICS*, Fundamental and Applied Problems of Engineering and Technology. **6** (2020)
9. A.A. Kostoglotov, S.V. Lazarenko, I.A. Nikitin, XIV Int. Scientific-Technical Conf. "Dynamic of Technical Systems" (DTS-2018). **226**, 04031 (2018)