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CONTENT
SADRŽAJ

APPLICATION OF VIRTUAL MODELS IN THE DESIGN OF A ROBOTIC GRIPPER

Ivan Milicević[1], Vojislav Vujičić[1], Milan Marjanović[1], Nedeljko Dučić[1], Marko Popović[1]
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ABSTRACT:
The development of the design of complex mechanisms using virtual models obtained by integrating different software packages is presented in this paper. The design, analysis and simulation of movement of the considered mechanism is carried out on the example of a robotic gripper. The SolidWorks software package is used to generate the 3D model. The virtual model and the control algorithm is realized in the MATLAB software package. An analysis of the required movements in order to achieve the production cycle of the mentioned mechanism is also carried out. By analysing certain parameters of the system, optimal characteristics of individual components were selected to obtain the required characteristics of the mechanism and a simulation of its operation was performed.

Keywords: *robotic gripper, virtual model, analysis, simulation, Matlab, SolidWorks*

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1. INTRODUCTION

The robotic gripper is the essential device or working part of an industrial robot. It has the task of picking up a work object and manipulating it during the execution of a task. [1] The gripper should be designed in such a way as to ensure the most accurate possible positioning of the object within the gripper, and therefore in relation to the entire robot. Additionally, the design of the gripper should provide a firm enough grip to maintain positioning accuracy during manipulation of the object to perform the work task. [2]

The basic function of each robotic gripper consists of a three-phase process (Fig. 1):
1. Grasping of the object;
2. Holding the object during manipulation (positioning);
3. Releasing the object.

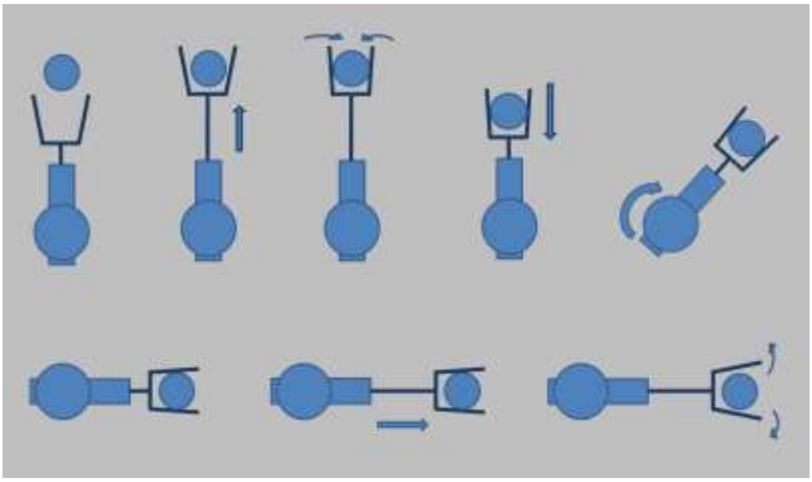

Fig. 1. Operation of the robotic gripper

Robotic grippers can be divided according to several criteria [3] (Table 1):

Table 1. Types of robotic grippers according to criteria

Types of robotic grippers based on:				
Type of fingers	***Numbers of fingers***	***Movement of fingers***	***Position of grasping***	***Grasping method***
- mechanical - vacuum - magnetic - customizable	- two - more	- linear - rotational	- outside grasping - inside grasping	- friction - geometric shape

In addition, a virtual model of a robotic gripper with two mechanical fingers, with rotary movement and external gripping of the work object with a geometric shape, was developed.

2. DESIGNING A VIRTUAL MODEL OF THE ROBOTIC GRIPPER

The *SolidWorks* software package was used to generate the model geometry. The gripper is designed so that it consists of the following elements: a base, a slider, a pneumatic or hydraulic cylinder, two connecting rods and two jaws that together form a moving mechanism.

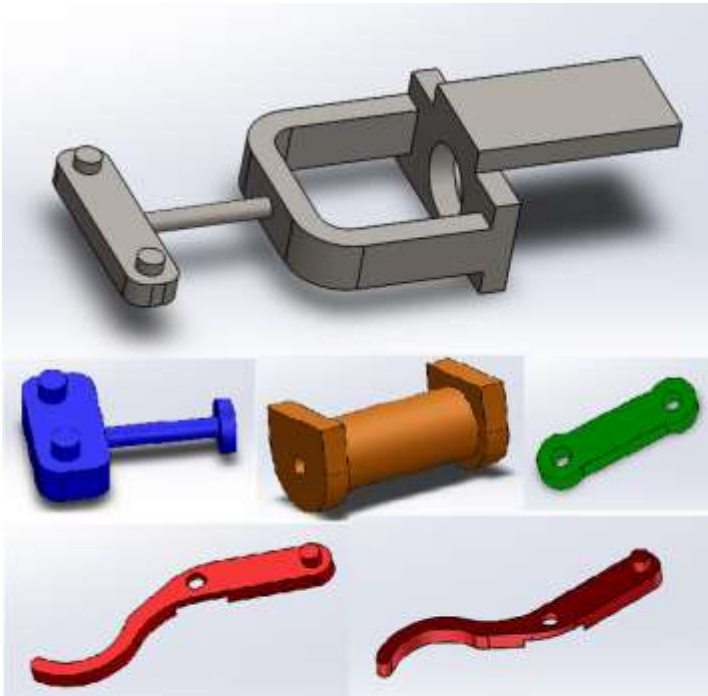

Fig. 2. Generated 3D model parts of the robotic gripper: base, slider, pneumatic/hydraulic cylinder, connecting rod, right and left jaw (respectively)

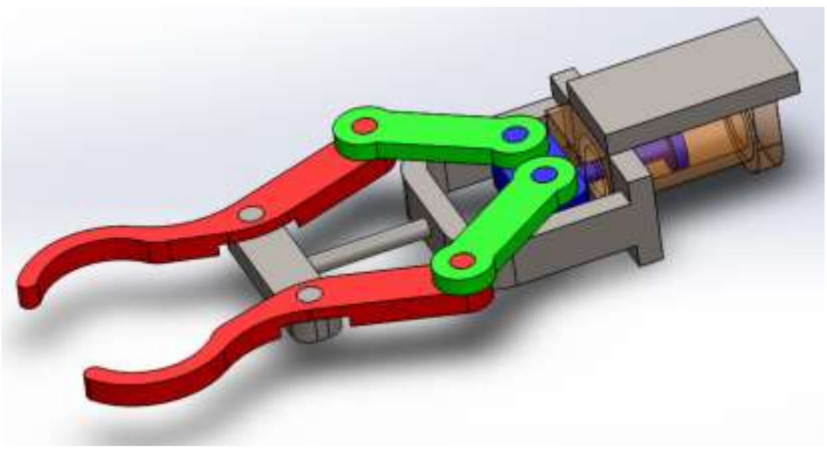

Fig. 3. 3D assembly model of the robotic gripper

Table 2 shows the masses, surfaces, volumes and moments of inertia (measured from the center of mass) of individual gripper elements.

Table 2. Geometrical and mass characteristics of gripper assembly and its elements

Part name		Base	Cylinder	Slider	Connecting rod	Left Jaw	Right jaw	Assembly
Mass (g)		886.01	405.74	176.95	91.71	164.63	164.63	1981.38
Volume (mm^3)		112867.67	51686.53	22541.76	11682.41	20972.39	20972.39	252405.56
Area (mm^2)		33534.76	17356.55	6728.12	5077.85	8516.85	8516.85	84808.83
Moment of inertia ($g*mm^2$)	Px	607295.76	82822.3	34213.11	4072.53	11875.28	11875.28	1623505.01
	Py	3251083.75	368940.09	58400.06	49832.64	374325.33	374325.33	9354402.33
	Pz	3646909.7	369372.15	84297.45	53045.42	382920.05	382920.05	10533412.84

All the 3D models together with the assembly were first saved as *.stl* files (*StereoLitography* or *Standard Tessellation Language* - one of the standard formats used to describe the geometry of a three-dimensional object), before converted to *.xml* (*Extensible Markup Language*) format in order to be imported into the *Matlab* environment.

3. DEFINING THE VIRTUAL MODEL OF THE ROBOT GRIPPER

A library of standard components is available in *MatLab* for generating models of any mechanism in *Simulink*. [4] *Matlab Simulink* stores the model information necessary to run the simulation by converting *.xml* files to *.slx* (*Simulink Extension*) files.

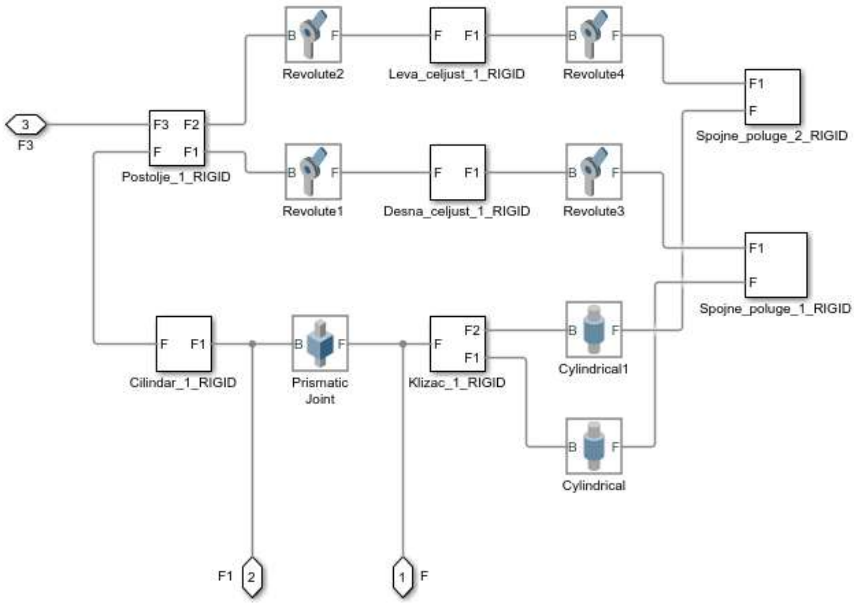

Figure 4. Block diagram of the robotic gripper subsystem

Blocks with the suffix *RIGID* shown in the Figure 4 correspond to the 3D models of the robot gripper, i.e. the base, cylinder, slider, left and right jaws and two connecting rods. The number of inputs/outputs to the blocks depends on the mutual physical connections between the parts.

Revolute type blocks define the rotary movement between the elements, *Prismatic Joint* blocks define the linear movement of the slider through the cylinder opening, while *Cylindrical* blocks define both the rotary and linear movement between the slider and the connecting rods.

The letters *B* and *F* at the blocks represent the *base* and *follower* inputs, respectively.

The hexagonal blocks marked with the letters *F* represent outputs from the subsystem, which are connected to the basic (configurational) blocks as well as to the starting blocks of the scheme.

Configuration blocks are also obtained during the conversion of the model from *.xml* to *.slx* format. They are used to define the physical connections between the elements as well as the model and the environment in which the simulation is run.

Actuator blocks are blocks that simulate a physical actuator. In this case, it is a hydraulic actuator. These blocks are manually inserted and connected into a complete scheme.

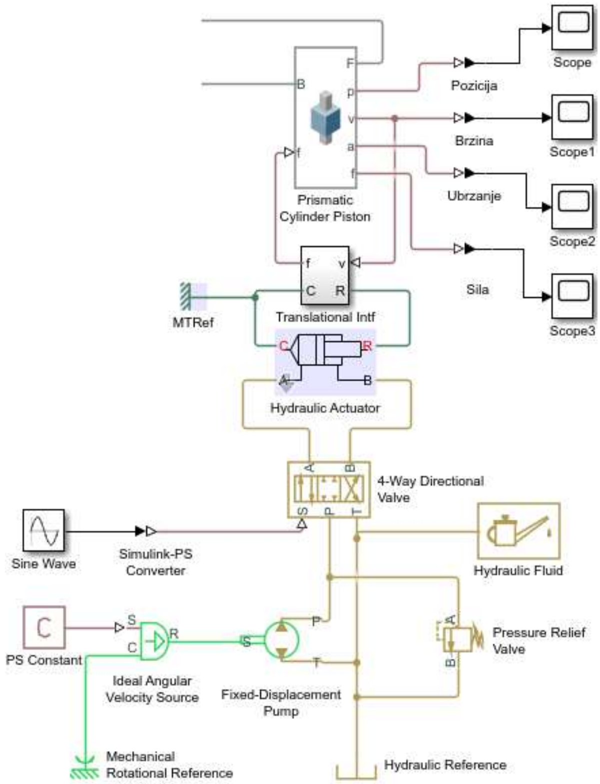

Figure 5. Subsystem block diagram with the actuator blocks

A hydraulic actuator is intended as the drive for the virtual model [5]. The *4-way directional valve* controls the flow of working fluid from the pump to both sides of the hydraulic cylinder. The motor will drive the pump shaft at a controlled speed (*Ideal Angular Velocity block*) and the control system will regulate the valve position. [6], [7].

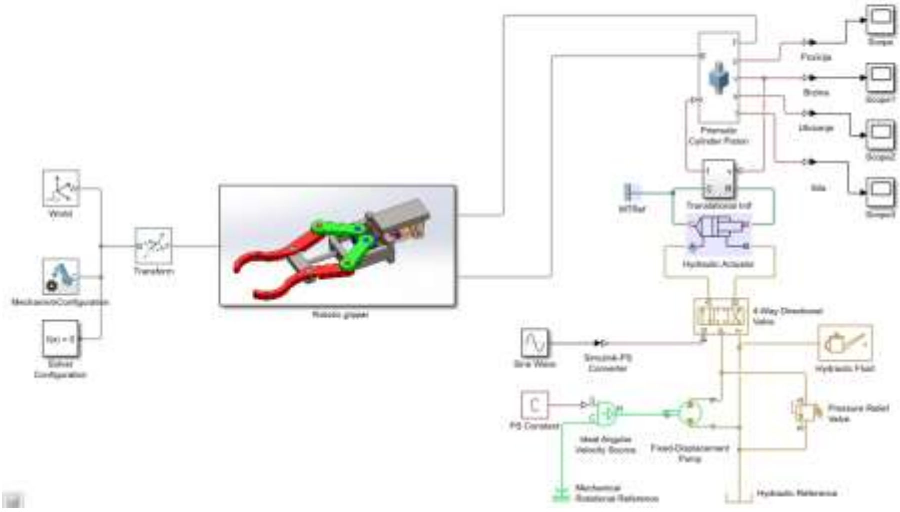

Figure 6. Robotic gripper block diagram

The *Robotic gripper* block represents the subsystem from Figure 4. On the left side of the block diagram are the basic (configuration) blocks, while on the right side are the operating blocks.

4. SIMULATION OF MOVEMENT

Before starting the simulation, a duration of the simulation needs to be defined. After that, a *Simulink* model can be activated by pressing the command *Run*. [8], [9] Simulation is set to 15 seconds, which is enough to complete two cycles of closing and opening of jaws. Figure 7 shows screenshots of the simulation in moments where the piston is in starting position (gripper jaws are fully open) and where the piston is in its last position (gripper jaws are fully closed). During that period, the signals such as physical values, i.e. force, position, velocity and acceleration of the hydraulic piston actuator can be monitored and analysed by using the standard *Scope* block (Fig. 8).

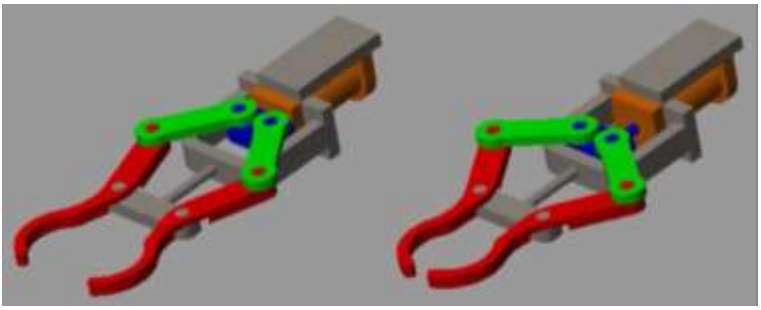

Figure 7. The position of the jaws in the end positions of the piston in cylinder

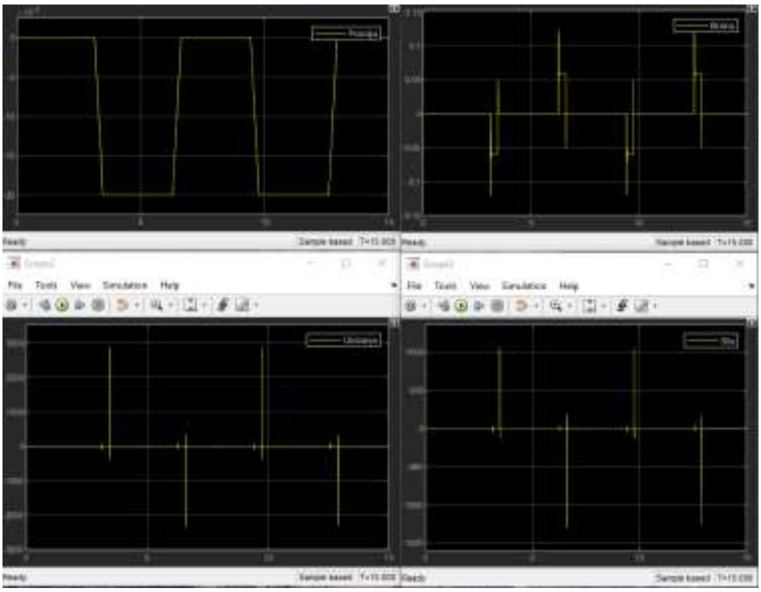

Figure 8. Diagrams of piston position, velocity, acceleration and force as a function of time

5. CONCLUSION

The application of two different software tools enables the analysis of all required elements, their dimensioning, the selection of materials, as well as movement analysis of the entire mechanism.

In the machine designing process, the application of virtual models with an integrated control algorithm enables the simulation of operation and verification of the system properties, before the realization of the physical model. This approach in designing not only provides a visual representation of the design of the individual parts of the mechanism but also enables description and simulation of its physical behaviour. This is of great importance for accurately defining and dimensioning individual segments of the system, as well as observing how the whole mechanism functions. In this way, it is possible to achieve a significant reduction of time and resources required for the production and modification of the physical model.

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