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## The state of the modular element structure of a prehensor through virtual prototyping

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# The state of the modular element structure of a prehensor through virtual prototyping

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**Abstract.** The paper presents the study of the geometric scheme of the structure of a prehensor module. The prehensor has the role of generating the force required to manipulate an object respecting the prehensor's plan with the manipulated object. It is proposed the static concept of the prehensor according to the geometric parameters of the prehensat object. Starting from the structural scheme of the proposed module, the 3D component structure is generated using the Catia software. The kinematics of the studied structure is presented and the system modeling prerequisites are created through the Adams program. Importing the system into Adams simulates the kinematics of the proposed structure. The state of stresses and deformations of the prehensor module is determined and presented. The prehensor module of this type is designed for the reliability of the prehensor.

## 1. Introduction

The role of the prehensor in a robot is to achieve the prehension of various objects with specific design. Depending on the shape of the prehensat object, modeling of the constructive form of the prehensor occurs so that the phases of prehension are fulfilled. The gripping of the object must comply with the minimum prehension conditions. The quality of prehension is given by the degree of sliding of the prehensat object. In order to achieve good prehension it is necessary to perform the self-adaptive control function of the robot, respectively of the prehensor. Ever since the design phase, there must be a close link between the elements of the prehensor structure and the sensory system to highlight the quality of prehension by self-adaptive control. The geometric shape of the prehensat object imposes the prehensor structure. The paper presents the geometric and constructive form of an anthropomorph with 5 flanks. From the anthropomorphic prehension analysis results different types of prehensors depending on the number of fingers, the number of phalanges, the type of command and control system adopted.

Mechanical prehensors with 5 fingers are complex systems that imitate a human hand, and the hand is an ideal prehensor. The prehensors have the role of transporting objects in a controlled and well-determined manner in a defined space. The required conditions of this type of prehensor are the planarity to the prehensat object and to the position on the work table, and the movement must be very precise with 1 Kg of prehensat, '[1]'.

## 2. The schematic concept establishment of the prehensor module

To establish a concept, the necessary details are needed in order to achieve it. In the case of a prehensor module it is required to establish the principle and the functioning mode. Under the



conditions imposed, the prehensor system created fulfills the parallelism function of the prehensat object and the function of parallelism to the work table on which the object is located.

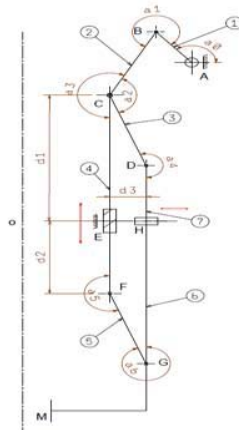
This type of prehensor is very similar to functionality with that of a griper, only the prehensor system exerts forces on the controlled object.

### 2.1. The kinematic scheme of the prehensor module

According to the conditions, the dynamic scheme of the prehensor module was created, "Figure 1", where the structure and its functioning are represented.

The prehensor module is made of 8 kinematic joints where the joint (A) is the primary rotation joint that engages the secondary joint (B) and the joint (C). This rotation chain allows the freedom to perform a translational movement in (E) and (H). With the help of the segments (1), (2), and (3), which are connected by the passive joints (B), (C) and (D), the translational movements of (E) and (H) are assured, without this system blocking angularly due to the length of the levers. By the angular modification ( $\alpha_0$ ) which is described by the horizontal of point (A) and segment (1), the variable angles and distances ( $d_1$ ), ( $d_2$ ) si ( $d_3$ ) change between the joints (C) and (E), (C) and (F), respectively (E) and (H), to move the point (M) to the axis (O).

This prehensor mode works on the principle of the parallelogram where the active side (4) is the side trained by the joint (C), the passive sides (3) and (5) are equal and parallel, as are the sides (4) and (6). It also fulfills the angular condition where the angle ( $\alpha_4$ ) and the angle ( $\alpha_5$ ) are equal. Under these conditions, it it assured the planarity of the prehensor module against the prehensat object, '[2]'.



**Figure 1.** The kinematic scheme.

## 3. 3D modeling and execution of prehensor modul kinematic in the Catia software

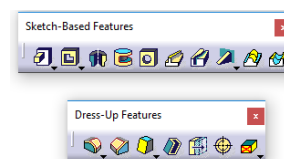
### 3.1. The stages of execution the 3D model of the prehensor module:

- Sketcher Module

It is the module in which the geometric description of the desired piece is created in plan, and the geometric shapes of the pieces can be determined or undetermined. For making the shape, the commands in "Figure 2" are needed, where we can use the "Profile" commands and we can dimension or constrain using commands from "Constraint".



**Figure 2.** Sketcher tools.



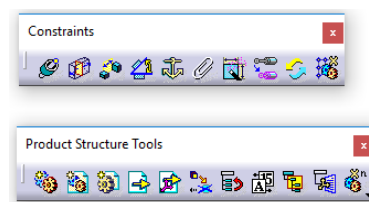
**Figure 3.** Part Design Module tools.

- Part Design Module

It can only be used after it has been dimensioned and described the piece in plan in Sketcher Mode, then 3D modeling is realised in Part Desing module. In the making of the 3D model of a piece there are considered many details regarding the processing and assembling. To make a 3D shape of a piece the commands in "Figure 3" are used.

- Assembly Design Module

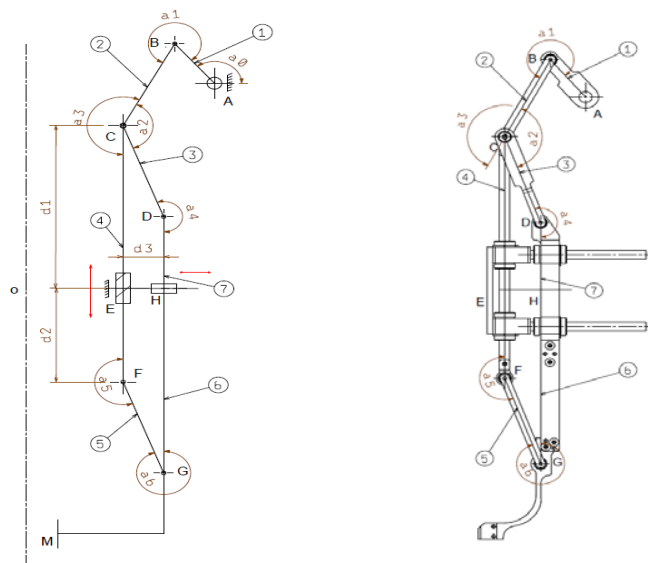
In Assambly mode, all the pieces are inserted after they have been created to make the prehensor module. The pieces will be mounted according to the degree of freedom required to achieve the proper movement of the prehensor module without simulating it. Initially, the fixed pieces are positioned and declared, and then the other pieces are moved. To achieve the constraints and general structure of the prehensor module, the commands in "Figure 4" were used.



**Figure 4.** Assambly Design tools.

After completing 3D modeling and respecting the kinematic conditions, the prehensor module was created. In "Figure 5" is represented the kinematic scheme with the mechanical respecting and realization so that kinematic joints have a necessary degree of freedom. The rotation joints (A), (B), (C), (D), (F) and (G) are made of a bearing type between the parts that form the lever arms and the radial-axial bearings, to reduce the friction from the movement of the prehensor module.[8,9]

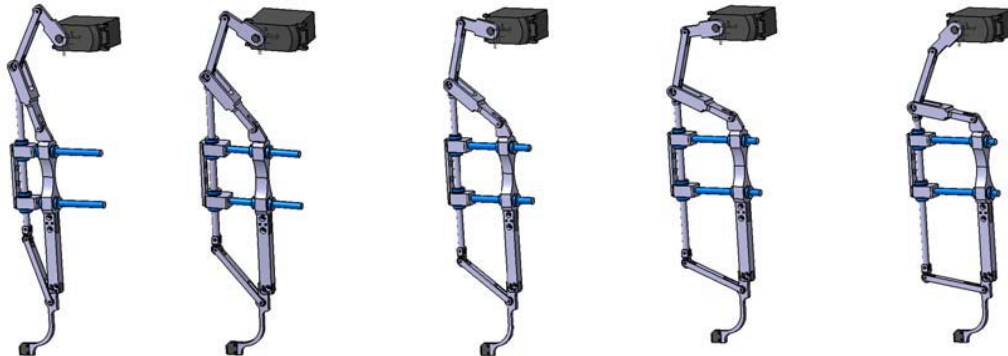
The translational movements are performed by means of linear ball guides (E) and (H), which allow a very good continuity in the movement of the prehensor module. With roller bearings and guides we get a friction very small between joints, which helps us in 3D simulation. Whereas simulation is ideal, it means friction is neglected.



**Figure 5.** Schematic representation of the kinematic scheme.

### 3.2. Kinematics execution in the Catia software

To achieve cinematics in the Catia software, it is necessary to enter DMU Kinematics mode, where constraints and joints are required to implement. As in the kinematic scheme, in Catia there is a primary joint and the rest of the secondary joints. The primary joint exerts the movement, and the secondaries ones follows it until it stops or is in a moment of mechanical limitation. In “Figure 6” are represented the kinematic stages of the prehensor module, ‘[4]’.



**Figure 6.** The kinematic stages of the prehensor module.

### 3.3. Structural analysis generating of the prehensor module

This type of analysis is done when we want to structurally analyze deformations of bodies or assemblies when applying a force. This analysis is done in the Generative Structural Analysis module and is used to verify the structure, the time reliability of the mechanical components and to determine the solicited areas. By determining the solicited areas, we can establish the sensors implementation areas.



**Figure 7.** Structural analysis of the prehensor module.

“Figure 7” shows the mechanic deformation of the prehensor module, where this analysis is performed in order to implement the sensors. Solicited areas are represented in red and least solicited in blue. The prehensor module is subjected to a 5 N force both at closing and at opening.

## 4. Prehensor module importation and simulation in the Adams software

### 4.1. Importing the prehensor module into Adams

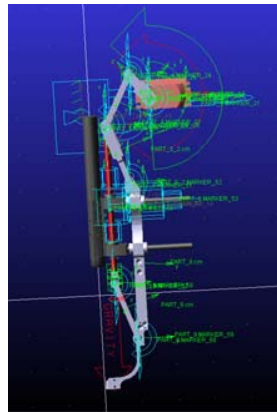
After executing the design in a software like Catia, the parts are imported into Adams. Depending on the version of Adams, the prehensor module can be directly imported. Once imported the prehensor

module, the type of material for each piece is declared in order to apply the constraints. The first constraint is the fixation of the fixed objects, then the constraint of the following pieces with the tools in "Figure 8".



**Figure 8.** Tools for constraint of bodies.

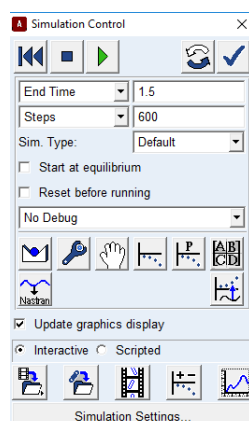
With these tools, all the components of the prehensor module have been constrained, "Figure 9", so that the movement can be realised. Following constraints, the primary joint and the secondary joints must be declared, '[3]'.



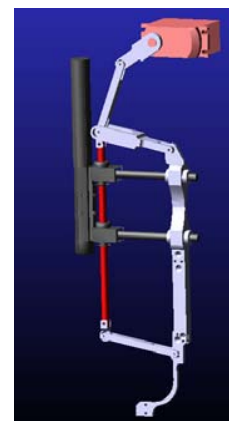
**Figure 9.** Representing the joints in Adams.

#### 4.2. Performing simulation in Adams

Once all the joints have been applied to the components of the prehensor module, the forces required to move have been implemented. One of these forces is constant, namely the gravitational force. By fulfilling all the functional conditions, the 3D simulation of the prehensor module can be applied. In "Figure 10" is presented the simulation window, where we can control the number of steps in a given time, '[9]'.



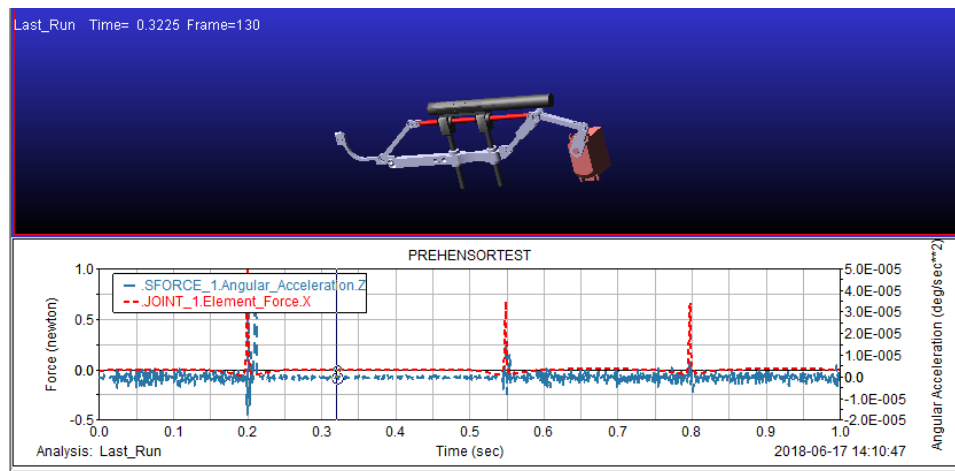
**Figure 10.** Control panel.



**Figure 11.** Kinematic execution in Adams.

After determining the time and steps required to generate the complete movement of the prehensor module, it set to start and the prehensor module will move to the forward position relative to the origin, as in “Figure 11”.

Once with the movement of the prehensor module, acceleration sensors and force sensors can be introduced. As it can be seen in the graph in “Figure 12”, the angular acceleration fluctuations are influenced by the applied force.



**Figure 12.** Angular acceleration graph.

## 5. Conclusions

This prehensor module is designed to create a complex prehensor with 3 or 5 modules. The prehensor allows the capture of small objects and objects with a larger gauge. This particularity is due to the parallelogram system and the translational movements the prehensor has.

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