The state of stress and deformation by the finite element method of the mechanical structure for a self-adaptive prehensor

I C Frincu[1] and I Stroe[1]

[1]Product Design, Mechatronics and environment Department, Transilvania University of, Brașov, Romania

cezarfrincu@yahoo.com

Abstract. The paper presents the state of stress and deformation of the component elements of the mechanical state of a self-adaptive prehensor. The theoretical and experimental model puts into evidence the links between the component elements and the forces acting on the two axes of symmetry of the physical model. The forces generated by the objects'prehension determine the state of stresses and deformations of the elements subjected to these forces. The 3D analysis of the prehensor structure is realized with the finite element method using the CATIA software. The structural elements of the prehensor are studied on each component by applying different forces in the three directions. The forces and moments that act upon the base elements of the prehensor's components are studied in the angular displacement generated by the drive motors. The composition of forces and moments for each component of the prehensor reveals the reaction forces appearing in the mechanical components of the proposed structure. It is taken into account that each module of the prehensor does not influence the state of tension and deformation of the prehensor assembly during the tightening of the objects.

1. Introduction

In a robotic system, the prehensor has the role of gripping objects of different shapes and sizes. The prehensor can be made of different mechanical structures and can be operated in different ways (electric, pneumatic, hydraulic) so that it can grip the desired object. Mechanical prehensors designed with 5 fingers are complex systems that imitate a human hand [1].

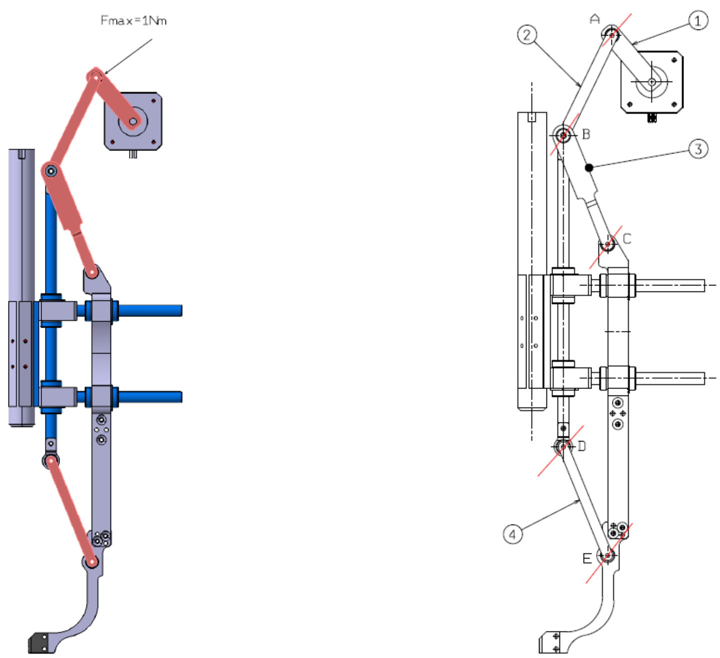
Generally, there are prehensile systems that generate a rotation movement with the "fingers" and, those are created in particular about gripping a single object. The deformation analysis is performed in the Catia program for the construction components of a self-adaptive prehensor module. The self-adaptive prehensor generates with its fingers a translation motion, and it can be used in many processes without it being mechanically modified by a particular object, as it adapts to the shape and weight of the object. The deformation analysis is performed only on components with higher stress with parallel and perpendicular forces, on advance and retreat [2].

2. The following steps were taken to analyze the mechanical components:

- Selecting the most wear-resistant components;
- Applying parallel and perpendicular forces for advance and retreat on selected mechanical components;
- 3D realization of deformations by finite element method;
- Generating some deformation parameters and calculation error;
- Geometric component modification based on results.

2.1.Selecting the most wear-resistant components

The prehensor module is driven by an electric stepper motor that generates a torque of 8.2 Kg*cm, which means it exerts a force on the components of 0.911 Nm‘Figure 1’ a).



a) b)

Figure1. The representation of rotation joints and the selection of the most wear-resistant components.

The self-adaptive prehensor consists of 5 arms that are independently controlled both mechanically and sensory, and each arm is composed of several joints that have constant wear over time.The greatest stresses are found in the rotation joints, and they are marked with a red line passing through the center of the joint.In the 2D representation of the prehensor module are shown the rotation couplers (a red line in points A, B, C, D, E) where the components can be mechanically blocked and numbered.The mechanical component 1 is locked in joint A, the mechanical component 2 is locked in joint B, the mechanical component 3 is locked in joint C, and the mechanical component 4 is locked in joint D or joint E depending on the advance or retreat motion'Figure 1' b) [3].

2.2. Applying parallel and perpendicular forces for advance and retreat on selected mechanical components

The components 1, 2, 3 and 4'Figure 1' (b)are removed separately and are applied the forces and constraints required to simulate locking in points A, B, C, D, and E.

Each component must be positioned, and the applied force must apply for in the sense generated by the whole module, where the Fc is the force comprised of the parallel force and the force perpendicular to the mechanical component analyzed.The application forces are equal and opposite, in our case called Fr (reaction force)'Figure 2'.

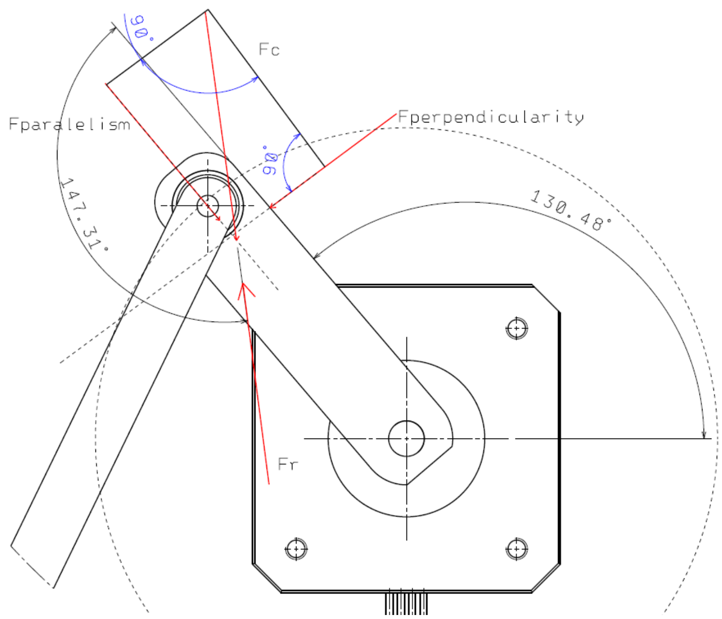


Figure 2. Example of composition of forces for mechanical component 1.

To generate the position of force Fr at an angle of approximately 147°, the values of forces Fx, Fy, Fz, Mx, My and Mz must be summed up. (Table 1.)

Tabel 1. Composition of forces for mechanical component 1

Force	Value of the applied force	Unit
Fx	3*817e-012	N
Fy	-1	N
Fz	-1	N
Mx	2*900e-002	N
My	-2*500e-003	N
Mz	2*500e-003	N

Respecting the conditions of the mechanical component 1, the reaction force Fr can be generated for the other mechanical components 2,3 and 4.

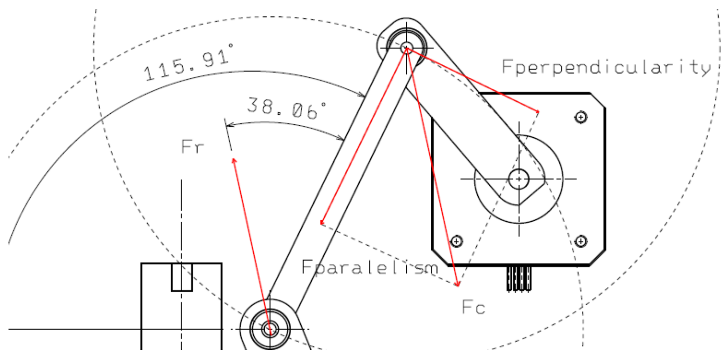
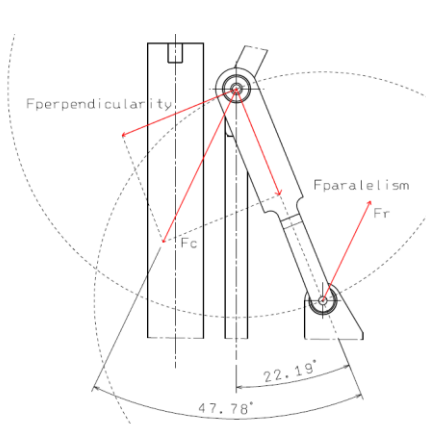


Figure 3. Composition of forces for mechanical component 2.



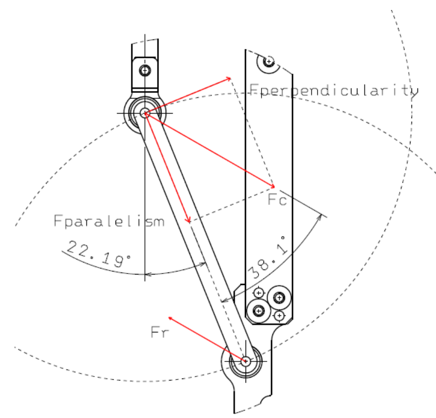


Figure 4. Composition of forces for mechanical component 3.

Figure 5. Composition of forces for mechanical component 4.

2.3. 3D realization of deformations by finite element method;

Summing up vectorially the forces Fx, Fy, Fz, Mx, My and Mz we determine the vectorial orientation of the reaction force Fr.

Once the forces on the mechanical component are used we can apply the finite element method where we can observe the plastic or elastic deformation a), b), c), with an amplification of 10^7‘Figure 6’[4].

a) b) c)

Figure 6. Stages of amplified deformations.

2,4, Generating stress parameters of the mechanical component 1 and geometric modification if necessary;
After the analysis of stress type finite element, an automated report from the Catia program was generated where we can observe the affected areas and subjected to small deformations but also the areas where there are no deformations at all.

The report generated is in the form of a graduated column from red to blue, where red shows the largest deformation and the smallest blue'Figure 7'[5].

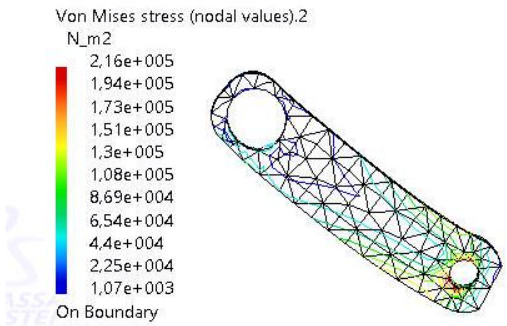


Figure 7. Finite element report.

3. Conclusions

The geometry of the mechanical components resists the maximum force exerted by the stepper motor, on advance and retreat motion.

The joint effort is taken over by the bearings and distributed throughout the system in case of locking.

Bearings depletion over time may be the cause of the grips in the mechanism.

4. Bibliography

[1] Staretu I 1996 *Systems of Prehension(Sisteme de Prehensiune, in Romanian)* (Brasov: Lux Libris)

[2] Dudita F, Staretu I 1988 *Structural synthesis and systematisation of flat elementary mechanisms with articulated bars usable as prehension robots (Sinteza si sistematizarea structurala a mecanismelor elementare plane cu bare articulate utilizabile ca robotomecanismelor de prehensiune, in Romanian)*Cluj-napoca: Buletinulcelui de-al VIII-lea Simpozion National de IR

[3] Frincu C, Stroe I, 2018 The state of the modular element structure of a prehensor through virtual prototyping, Brasov: PRASIC

[4] Ghionea I 2007 *Assisted design CATIA V5. Theoretical elements and applications (Proiectareasistata CATIA V5. Elemente teoretice si aplicatii, in Romanian)*(Bucuresti: BREN)

[5] Ghionea I 2009 *CATIA V5. Applications in mechanical engineering(CATIA V5.Aplicatii in ingineria mecanica in Romanian)* Bucuresti: BREN