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DESIGN METHOD FOR SELF-CENTERING GRASPING MECHANISM

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Abstract: *the paper concerns about some aspects regarding the self-centring grasping mechanisms in order to improve the object positioning accuracy. The main goals are the synthesis computation and the FEM analysis using CATIA environment. The dimensional constraints of the three-dimensional model were established as the synthesis results by imposing nine positions. From the FEM analysis we infer the maximum tensions for each element. We have taken into consideration the entire assembly having eight parts and we have analysed the stress influence between each of them.*
Key words: *grasping mechanism, FEM analysis, synthesis computation*

1. INTRODUCTION

The grasping mechanisms have to attend some very accurate positions during their labor activity in order to move the objects from one work point of the manufacturing process to another. The main condition is to choose the right grasping mechanism structure and after that to design and manufacture the most suitable active surfaces for fixing the object inside the robot hand. (Asada, 2006).

There have been considered some specific criteria for the grasping mechanisms with rigid fingers used for cylindrical shaped objects. The self-centering mechanisms bring up the advantage of active surface, which does not depend on the object diameter inside an imposed range. As a state of art, the static determined grasping mechanisms for cylindrical objects could have two fingers with three active surfaces plane or cylindrical, which mean three geometrical generators. Due to the easier way of manufacturing, a plane surface is preferably.

Our work was focused on two main activities: the synthesis computation method for a mechanism with plane active surfaces whose bisecting line has to have a point coincident with the center of the cylindrical shaped object; the FEM analysis of the whole assembly of such mechanism. Finally, as supplementary choice we have realized this mechanism using the laser manufacturing method, in order to attend the right values for computed lengths and angles.

2. MATHEMATICAL MODEL

The main goal of synthesis computation is to establish the appropriate dimensional constraints of the self-centering grasping mechanism with the scheme presented in Fig. 1. The method affords the imposition of the coordinates of nine points along the trajectory of a point P positioned on the BC element and this point has to attend ideal positions over a line passing through the cylindrical object center point. (Bone & Du, 2001).

We have used the method that consists in the coordinate system transformation, so that we have to write each rotational matrix belonging to each element with its own coordinate system, all of them referring to the fixed coordinate system Y_0OX_0. There are four mobile coordinate systems and for each

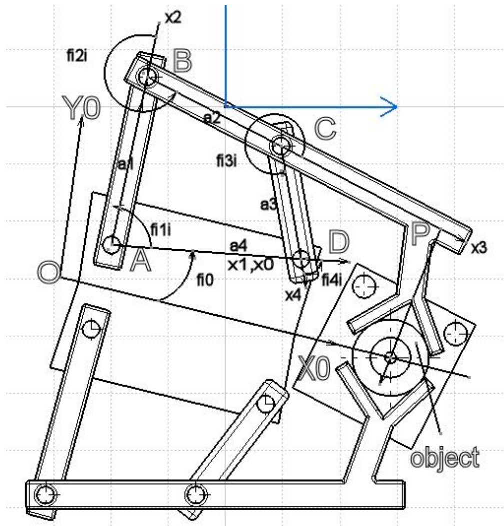

Fig. 1. The scheme of the self-centering grasping mechanism

of them the O_jx_j axis has been chosen along the element direction (j - the number of the mobile element). The main advantage of this solution is the using of rotational angles between elements, which improve the control of motion parameters. According to these axis systems, we have written the following matrix where i is the number of imposed position for P point; j – the number of mobile element:

$$A_{ji} = \begin{vmatrix} 1 & 0 & 0 \\ a_j \cdot \cos(\varphi_{ji}) & \cos(\varphi_{ji}) & -\sin(\varphi_{ji}) \\ aj \cdot \sin(\varphi_{ji}) & \cdot \sin(\varphi_{ji}) & \cos(\varphi_{ji}) \end{vmatrix} \quad (1)$$

The rotational matrix of the zero coordinate system belonging to the fixed element AD of is given below:

$$A_0 = \begin{vmatrix} 1 & 0 & 0 \\ a_0 \cdot \cos(\varphi_0) & \cos(\varphi_0) & -\sin(\varphi_0) \\ a_0 \cdot \sin(\varphi_0) & \cdot \sin(\varphi_0) & \cos(\varphi_0) \end{vmatrix} \quad (2)$$

Finally, the entire vector equation should be closed, so the equation (3) should be satisfied (Simionescu et al., 2008):

$$A_{1i} \bullet A_{2i} \bullet A_{3i} \bullet A_{4i} = I \quad (3)$$

Meantime, the equation expressing the position of P point is written as:

$$A_0 \bullet A_{1i} \bullet A_{2i} \bullet X_3 = X_i - \begin{vmatrix} 0 \\ 0 \\ Y_0 \end{vmatrix} \quad (4)$$

where the position of the point P considering the fixed coordinate system is given by:

$$X_i = \begin{vmatrix} 1 \\ X_{Pi} \\ Y_{Pi} \end{vmatrix} \quad (5)$$

Taking into account that the matrix equation (3) for closing the entire vector outline has some particular values, only three equations given below may be part of the nonlinear mathematical system:

$$f_{1i} = b_{21i} = 0\,;\ f_{2i} = b_{31i} = 0\,;\ f_{3i} = b_{22i} = 1 \quad (6)$$

The other two numerical equations that are part of the nonlinear system too, are given by the following equations:

$$f_{4i} = c_{1i} - X_{Pi} = 0\,;\quad f_{5i} = c_{2i} - Y_{Pi} + Y_0 = 0 \quad (7)$$

where i – the number of imposed positions for the P point.

The final mathematical nonlinear system has 45 equations. The computation results of the synthesis are analyzed in Fig. 2 by pointing out the angular position of P point over a complete rotational period. The variation is presented by comparison with a straight line as an ideal trajectory of P . (Koseki et al., 2002). The maximum deviations from the imposed values are: -0.2^0 for the AB element angular position at 150^0 and 0.2^0 for AB element at 50^0, which is a suitable error.

3. FEM ANALYSIS

The main goal of the FEM work is to analyze the tensions of grasping mechanism as an assembly that consists of eight parts. We have determined the surface contacts as constraints between the elements. The static case analysis was chosen and for all these assembly constraints were defined their nodes and properties (Nedland & Mulineux, 1998).

Moreover, for the element AD we have to remove all the freedom degrees and for the mobile elements we have to allow

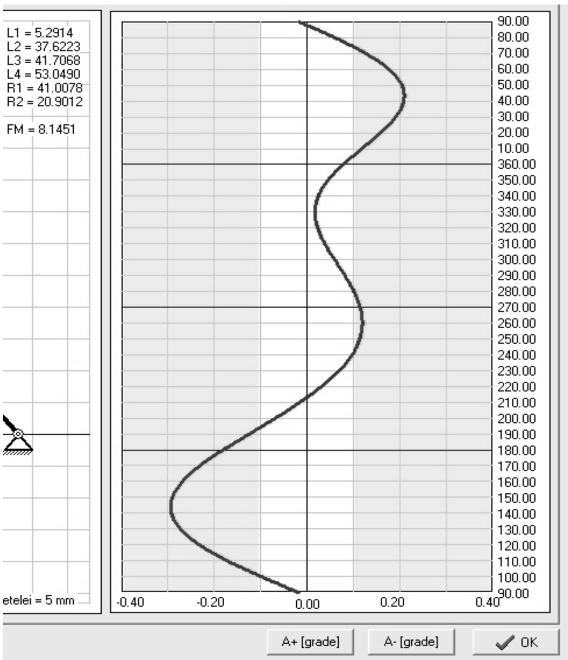

Fig. 2. The variation of angular position for P point.

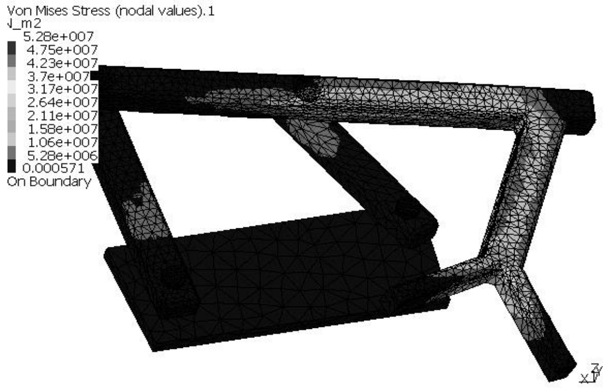

Fig. 3. The static case analysis results

only the Z axis rotational and the suitable translational movements inside the XY plane. The maximum values for grasping forces were given as following: F_X = 20 N; F_Y = 20 N; F_Z = 5 N.

From the results presented in Fig. 3, we may infer that the maximum stress, which is about 4.75e+07 N/m^2, is on the BC element where the grasping force is acting on both active surfaces. A smaller stress is acting on the CD element, so that we have to pay attention on the BC and CD elements with their dimensional and positional constraints.

In order to avoid the break as well as the internal displacement errors, the future work will be focused on improving the CAD constraints between elements by using some special types of joints. The BC element will be FEM analyzed in direct relationship with the cylindrical shaped object from the internal displacement point of view.

4. CONCLUSIONS

We have determined the dimensional constraints of the self-centring mechanism as synthesis computation by imposing nine kinematic positions. These positions given for a specific point of the linkage should ideally be on a straight line passing through the centre of the cylindrical grasped object. The results point out the maximum deviations from the trajectory, which are in a range of $\pm 0.2^0$ as angular values. So, we may consider an acceptable one.

The FEM analysis was made using CATIA environment. The three-dimensional model is based on the synthesis computation method described above. Applying a known value for the grasping force, we have studied the assembly tensions acting on each kinematic element.

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