General Algorithm for Computing the Theoretical Centering Precision of the Gripping Devices

E.-C. Lovasz, V. Mesaroş-Anghel, C.M. Gruescu, C.E. Moldovan and M. Ceccarelli

Abstract The paper shows a study about the theoretical centering precision for gripping devices. The deviation of the absolute axial centering is taken into account as a centering precision parameter and a general computing algorithm is developed for it. For previously developed gripping devices, using parallelogram and four-bar linkages with coupler driven jaws is computed the variation of the axial centering deviation.

Keywords Centering precision · Axial centering deviation · Gripping device · Four-bar linkage

1 Introduction

The industrial gripping devices usually use a reduced number of jaws 2 or 3 with equivalent dexterity of 40–90 % in comparison with the human hand having 5 fingers [1]. In [2], the gripping devices are classified in regard with the motion type of the jaws in translating, rotating (oscillating), planar motion and combinations of them. Konstantinov in [3] systematized the mechanisms used in gripping devices, which contains structural linkages, gears and screw-nut mechanisms. In [4] are

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shown some examples, which use in addition cam mechanisms in the structure of
the gripping devices.

For all of these gripping devices an important industrial characteristic is the
capability of centering precision. The centering precision is implicitly fulfilled in
the case of the translational jaws and can be minimized for other motion types of the
jaws. This aim is pursued by Qingsen in [5], and Brukher in [6], through proper
designing of the gripping device mechanism provided by Pankin in [7] or through
shaping the jaws. Recent researches develop special gripping devices used in soft
robotics for performing gentle tasks [8] or for handling highly elastic objects [9].
For simple or complex anthropomorphic structures, underactuated grasping devices
are used [10, 11], etc.

In [5], Qingsen presents a study of designing a grooved cam profile for
increasing the centering precision. Simionescu in [12] shows a study of the cen-
tering precision of a conveniently chosen four-bar linkage used for acting a gripping
device.

2 General Algorithm for Computing
the Axial Centering Deviation

The centering is defined as the property of the gripping device to superpose the
characteristic axis of the grasped object with his characteristic axis. The centering
precision implies the computation of the axial centering deviation between the
characteristic axis of the cylindrical grasped object and the characteristic axis of the
grasping device. For this purpose it is considered the bisecting line of the prism in
the top point M of the prism-jaw. The absolute axial centering deviation is the
distance from the intersection of the bisecting line with the Ox-axis to the origin of
the reference system axes xOy, identical with the characteristic axis of the grasping
device (see Fig. 1).

Fig. 1 Axial centering
deviation
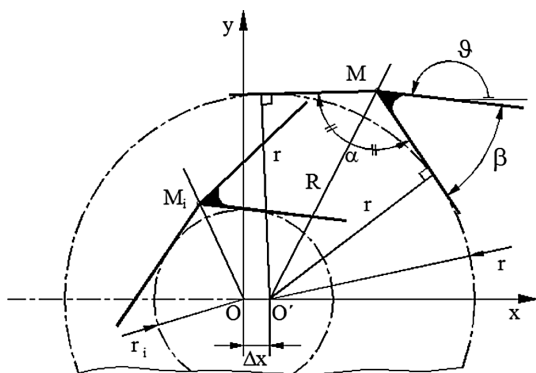
The absolute axial centering deviation Δx computation, based on the notations in Fig. 1, follows by considering the vector equation:

$$M = \Delta x + \frac{r}{\sin(\alpha/2)} \cdot e^{i(\vartheta - \beta - \alpha/2)}. \tag{1}$$

The coordinates x_M and y_M of the top point of the prism-jaw M and the pose angle ϑ of the coupler connecting element depend on the structure of the gripping mechanism. The prism angle of the jaw α (usually $\alpha = 120°$) and the connection angle β of the coupler with the jaw are imposed by design conditions.

From the Eq. (1) can be computed the radius of the grasped object and the corresponding absolute axial centering deviation:

$$r = y_M \cdot \frac{\sin(\alpha/2)}{\sin(\vartheta - \beta - \alpha/2)}, \tag{2}$$

$$\Delta x = x_M + \frac{r}{\sin(\alpha/2)} \cdot \cos(\vartheta - \beta - \alpha/2).$$

2.1 Gripping Device Using Parallelogram Linkages

The grapping device contains 2 parallelogram linkages symmetrically placed in respect with the axial direction of the structure and uses a symmetrical acting chain [13], as shown in Fig. 2. The motion of the coupler keeps parallel with the axial direction of the gripping device. The jaws prisms are fixed with the couplers.

The particularity of this parallelogram linkage consists in the constant value of the coupler angle:

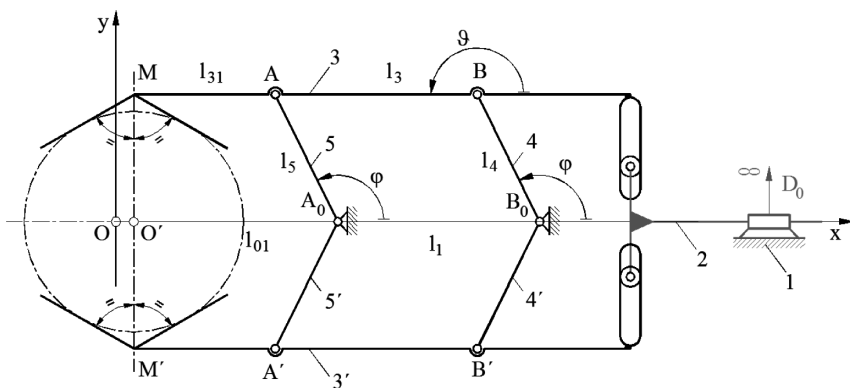$$\vartheta(\varphi) = \pi \tag{3}$$

Fig. 2 Kinematic schema of the gripping device using parallel linkages

and the same positional angle of the both cranks.

The coupler point M coordinates of the parallelogram linkage in the xOy coordinate system of the gripping device results from the vector equation:

$$M = l_{01} + l_1 + l_4 \cdot e^{i \cdot \varphi} + (l_3 + l_{31}) \cdot e^{i \cdot \vartheta(\varphi)}, \tag{4}$$

and by considering the relationship (3) as:

$$x_M = (l_{01} + l_1) + l_4 \cdot \cos \varphi - (l_3 + l_{31}), \quad y_M = l_4 \cdot \sin \varphi. \tag{5}$$
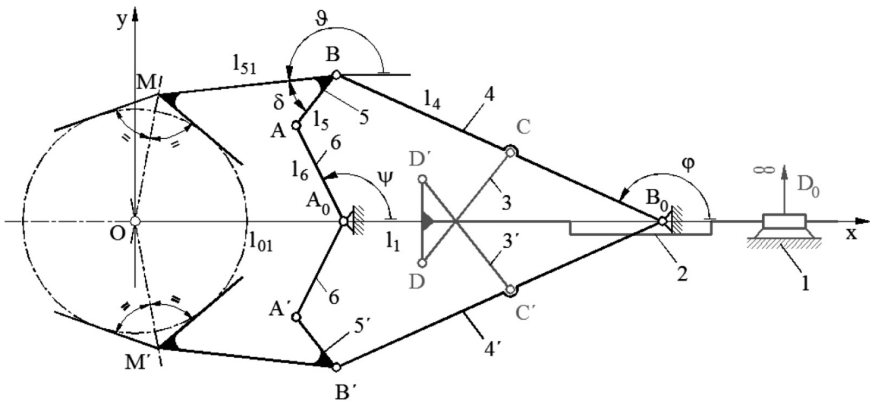
2.2 Gripping Device Using Four-Bar Linkages

This type of gripping device (see Fig. 3) contains also 2 symmetrical four-bar linkages with coupler driven motion of the jaws and using symmetrical actuating chains [1, 14].

The positional analysis of the four-bar linkage, used for acting the coupler jaws, allows the computing of the coordinates of the top point M according to the kinematic parameters of the linkage. The vector equation of the four-bar linkage A_0ABB_0 in its own coordinate system, shown in Fig. 3, is:

$$l_1 + l_4 \cdot e^{i \cdot \phi} + l_5 \cdot e^{i \cdot (\vartheta + \delta)} = l_6 \cdot e^{i \cdot \psi}. \tag{6}$$

By considering the complex conjugate equation of the vector Eq. (3) follows the coupler (5) positional angle ϑ depending on the rocker (4) angle φ:

Fig. 3 Kinematic schema of the grasping device using four-bar linkages with coupler jaws

$$\vartheta(\phi) = -\delta + \frac{B_1(\phi) + \sqrt{A_1(\phi) + B_1(\phi) - C_1(\phi)}}{A_1(\phi) - C_1(\phi)}. \tag{7}$$

with:

$$A_1(\phi) = 2l_5(l_1 + l_4 \cos \phi), \quad B_1(\phi) = 2l_4l_5 \sin \phi,$$
$$C_1(\phi) = l_1^2 + l_4^2 + l_5^2 - l_6^2 + 2l_1l_4 \cos \phi. \tag{8}$$

The coordinates of the coupler point M of the four-bar linkage in the gripping device coordinate system xOy follows from the vector equation:

$$M = l_{01} + l_1 + l_4 \cdot e^{i \cdot \phi} + l_{51} \cdot e^{i \cdot \vartheta(\phi)}, \tag{9}$$

in the form:

$$x_M = l_{01} + l_1 + l_4 \cdot \cos \phi + l_{51} \cdot \cos \vartheta(\phi),$$
$$y_M = l_4 \cdot \sin \phi + l_{51} \cdot \sin \vartheta(\phi). \tag{10}$$

3　Numerical Examples

The numerical examples show the variation of the absolute axial centering deviation in respect with the grasped object radius $\Delta x(r)$ for the both grasping mechanism devices, presented in Sects. 2.1 and 2.2.

The considered radii of the grasped cylindrical object are in the range of 2.5–35 mm and the angle of the jaws prisms is chosen $\alpha = 120°$ for both examples.

3.1　*Gripping Device Using Parallelogram Linkages*

The geometrical parameters of the gripping device using parallelogram linkages are shown in Table 1.

In Fig. 4a is represented the variation of the absolute axial centering deviation symmetrically distributed for the considered mechanism. The centering condition is fulfilled only for one radius of the grasped object (r = 26.66 mm), as expected.

Table 1 Geometrical parameters of the parallelogram linkage

Parameters	l_1 (mm)	l_{01} (mm)	l_3 (mm)	l_{31} (mm)	l_4 (mm)	l_5 (mm)	β (°)
Parallelogram linkage	70	129.5	70	90	50	50	30
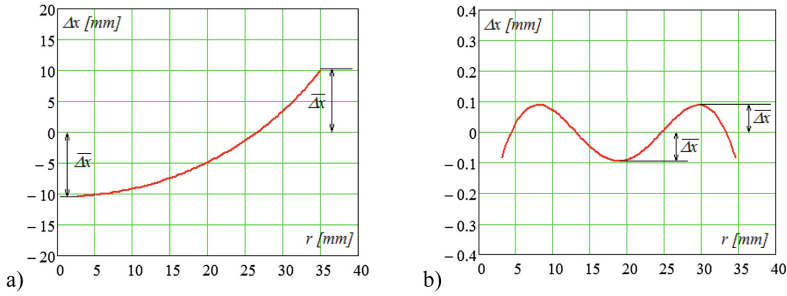
Fig. 4 Absolute axial centering deviation for parallelogram (**a**) and four-bar (**b**) linkage

Table 2 Geometrical parameters of the parallelogram linkage

Parameters	l_1 (mm)	l_{01} (mm)	l_4 (mm)	l_5 (mm)	l_{51} (mm)	l_6 (mm)	β (°)	δ (°)
Four-bar linkage	100	79.79	117.2	9.1	66.36	26.3	10.84	19.162

3.2   Gripping Device Using Four-Bar Linkage

The geometrical parameters of the gripping device using four-bar linkages are shown in Table 2 and the design assembly was patented in [15].

Figure 4b shows the variation of the absolute axial centering deviation for the four-bar linkages. The centering condition is fulfilled for four radii of the grasped cylindrical object. For these radii the four-bar linkage was computed by using four pose synthesis in [1, 14].

4   Conclusions

The paper presents a general algorithm for computing the absolute axial centering deviation, as theoretical precision parameter. Some known gripping devices were considered and numerically analyzed to validate the proposed algorithm.

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