Applied Mathematical Modelling 38 (2014) 3175–3181

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Synthesis of an adaptive gripper

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ARTICLE INFO

Article history:
Received 2 November 2012
Received in revised form 20 June 2013
Accepted 29 November 2013
Available online 19 December 2013

Keywords:
Adaptive gripper
Structure
Synthesis
Analysis

ABSTRACT

The problem about synthesis of an original adaptive gripper with simplified structure is formulated and solved. The synthesized gripper is mainly oriented to automatic manipulation devices, which are designed for carrying, and assembly work-pieces under production of appliances and electrical-industrial articles.

A developed example illustrates the application of the compound mathematical models for gripper synthesis and results evaluation.

1. Introduction

Grasping devices interact with the work-piece and thus facilitating interaction between robotic systems and complexes and their working environment [1]. The grasping can be done mechanically (force, geometric, mixed), by keeping (vacuum, magnetic, electrostatic), adhesion (using the chemical element), and by means of grasping penetration into the surface of the work-piece (with needle and hook etc.) [2].

The information about grippers with different functions ranges albums [3], monographs [2,4–6], and papers devoted to structural–functional problems of the grippers [7,8], different approaches in their analysis and synthesis [9–14].

Gripper mechanisms as end-effectors of different technical means (including industrial robots and manipulators) [15] convert input motion and force into necessary output motion and grasping force. Therefore some authors call them converting mechanisms [7,9].

The known mechanical grippers with two symmetric situated slider-crank mechanisms do not possess necessary adaptability at grasping of manipulation work-pieces that are inaccurately situated [4,8,16]. There are known grippers possessing adaptability, which is achieved at the expense of their complicated structure [5].

The purpose of the work is to be synthesized an original adaptive gripper with simplified structure [17,18], which is orientated to automatic manipulation devices designed for carrying and assembly work-pieces under production of appliances and electrical-industrial articles.

2. Structure and working principle of the gripper

The adaptive gripper (Fig. 1) consists of carrier 1 with fixed to it pneumatic cylinder 2 and stem 3, ending with roller 4, which presses flat spring 5, that is jointly connected to grasping links 6 and 7, which are connected to the carrier

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0307-904X/$ - see front matter
http://dx.doi.org/10.1016/j.apm.2013.11.038

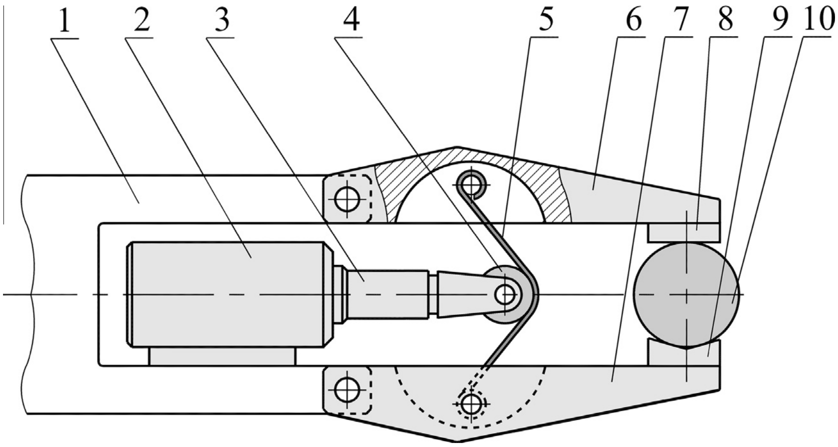

Fig. 1. Constructional scheme of the gripper.

1 by bearings. Two grasping links end with fixed to them removable jaws 8 and 9 for grip on the manipulated work-pieces 10.

The piston motion is transformed into rotational motion of the grasping links by the follower and a flat spring. When the piston moves forward, the grasping links begin to close and grasp the manipulated work-piece, and opposite – when the piston moves backward the grasping links start opening under the action of the elastic force of the flat spring. If the manipulated work-piece is inaccurately situated, one of the jaws reaches it. Then that jaw stops moving but due to the centrode pair between the follower and flat spring and the action of the piston force, the follower rolls about the spring and by stretching it additionally sets in additional rotation another grasping link while its jaw touches manipulated work-piece. On this way, a passive gripper adaptation toward inaccurately situated grasping work-pieces is achieved. The grasping links restore their symmetric position after realizing of the work-piece from its socket, due to the recovery of the equilibrium of the inner about gripper static forces.

3. Force and geometrical characteristics

For the synthesis purpose, the gripper‘s force characteristics are transformed into geometrical using the virtual power (work) principle. By the equality of the griper force power F_σ (Fig. 2) and piston force power $F_S = 0.25\eta_C D^2 p$ of the leading cylinder, the necessary for the synthesis first transfer function is obtained:

$$S'' = dS/d\varphi = c_S F_\sigma, \quad c_S = 2H/F_S. \tag{1}$$

Here $c_S = const$, if the working pressure p of the leading cylinder having diameter D of the piston and efficiency η_C, is accepted constant. By H is denoted the length of the grasping links, which are rotated toward an initial position (Fig. 2a), that is defined by free parameter (varying) parameter $\varphi = \varphi_0 + \Delta\varphi$ to angles $\Delta\varphi = -\delta$, $\Delta\varphi = 0$, $\Delta\varphi = \delta$, where δ is given angle. These three angles are determined by corresponding three values of the diameter Φ of the cylindrical part of the grasping work-piece along which the grasping is realized. The initial position when $\varphi = \varphi_0$, respectively $\Phi = \Phi_N$ and the grasping links are parallel, is also called nominal position. In fact, the angle $\Delta\varphi$ is an angle of the opening of the grasping links. The function $S = S(\varphi)$ determines the position function, where S determines the piston shifting (Fig. 2a), $S'' = \frac{dS}{d\varphi}$ determines first transfer function, its second derivative $S'' = \frac{dS}{d\varphi}$ – second transfer function, and so on.

For the synthesis purpose, we use the following transfer functions

$$S'' = d^2S/d\varphi^2 = c_S F'_\sigma; \tag{2}$$

$$S''' = d^3S/d\varphi^3 = c_S F''_\sigma. \tag{3}$$

The synthesis task includes three values ($F_\sigma(\Delta\varphi = -\delta)$, $F_\sigma(\Delta\varphi = 0)$, $F_\sigma(\Delta\varphi = \delta)$, $\delta > 0$), of the necessary grasping force that are conformable with the mass and inertial loading of the grasping work-piece as the diameter Φ. The grasping force can be described by the parabolic function

$$F_\sigma = F_\sigma(\Delta\varphi) = a_0 + a_1\Delta\varphi + a_2\Delta\varphi^2 \tag{4}$$

where the coefficients

$$a_0 = F_\sigma(\Delta\varphi = 0), \tag{5}$$