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Orientation Modeling of Bernoulli Gripper Device with Off-Centered Masses of the Manipulating Object

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Abstract

The article presents the mathematical model for the calculation of the optimal orientation of the gripper device which provides minimal energy consumption for holding the object in the process of manipulation. The case of the transportation of the manipulating object with off-centered masses along the rectilinear trajectory taking into account frontal resistance force and inertial forces during the re-orientation is examined. The formula for finding out the minimal necessary attractive force along all the segments of the rectilinear trajectory has been deduced. Off-centered masses of the manipulating object forcing relatively to the symmetry axis of the gripping device and frontal resistance forcing on the necessary minimal attractive force of the object has been investigated.

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Keywords: Bernoulli gripper device, manipulating object, uninterrupted transportation, manipulator, orientation, industrial robot

1. Introduction

The task of reducing energy consumption during the transportation and manipulation of the industrial objects is a problem of high significance. Objects of manipulation are gripped by the device of an industrial robot and transported from one position to another. In gripping devices of Bernoulli kind [1–3] lifting force is created on

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Nomenclature

A	length of object manipulation
B	width of object manipulation
H	height of object manipulation
E	distance from the center of mass object manipulation and center gripping device projection axis Oy
d	distance from the center gripping device and friction element of gripping
R	distance from the center of mass object manipulation and center gripping device
a	acceleration which moves the object manipulation
β	the angle between the trajectory and the global plane XOY
F_{in}	inertial force
F_{in}^{n}	normal force of inertia
F_{in}^{τ}	tangent force of inertia
F_{at}	attractive force

N_1, N_2 and N_3 normal reaction acting as points of contact

account of aerodynamic effect of attraction which is provided by the compressed air usage. Efficiency of such devices working significantly depends on the quantity of the compressed air used to keep the balance of the manipulating object relatively to the gripping device while transportation. Thus, the task is to find out optimal orientation of the gripping device which allows uninterrupted transportation of the manipulating object with minimal consumption of the compressed air for different transportation conditions (given trajectory, movement velocity and acceleration). In paper [4, 5] the formulas for the defining of the allowable acceleration of the gripping device while its vertical movement at the conditions of uninterrupted transportation of the manipulating objects have been deduced. In the study [6] the method of the optimization of the Bernoulli gripper device orientation with MO while its movement along the rectilinear trajectory when the center of the masses of the object coincides with the symmetry axis of the griping device is suggested.

The goal of the article is to get and deduce the conditions for providing the uninterrupted transportation of the manipulating object taking into account the frontal resistance force and inertial forces in the event when its masses centre is offset relatively to the symmetry axis of the gripping device and lie beyond the verges of the plane of gripping device and manipulating object, as well as to find the optimal orientation of the gripping device for the rectilinear trajectory at the condition of the minimal energy consumption for keeping the manipulating object.

2. Methodology

At given parameters of the gripping device of the keeping type, the manipulating objects and the trajectory, to find out the optimal orientation of the gripping device at which the energy consumption for the keeping of the object could be minimal. The modeling will be conducted for the event when the manipulating object centre masses is offset relatively to the symmetry axis of the gripping device taking into account the frontal resistance force and inertial forces during the re-orientation.

The minimalization of the energy consumption of the compressed air by Bernoulli gripping device of keeping type NCT (non-contact transport unit) [1–3] (Fig. 1a), that is the minimalization of the attractive force, will be provided when the reactions in the resistances of the gripping device will be minimal while ensuring the uninterrupted transportation of the manipulating object. This needs fulfilling the requirements for balancing all the forces affecting the manipulating object.

Let us consider the example of the transportation along the rectilinear trajectory of the manipulating object (Fig. 1b). The movement along the given straight line is conducted with the help of the manipulator IRB 1200 (ABB), and data for checking the model have been obtained with the help of the software RobotStudio (ABB) [7].

The frontal resistance force in general is calculated with the help of the formula:

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