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DESIGN OF A ROBOT MANIPULATOR WORKING SCREW REVOLUTIONS

M. Blatnický*, J. Dižo*, M Blatnická, M. Svoboda*****

Abstract: *The paper deals with a constructional design of a versatile adaptive gripper for a robot manipulator. More specifically, it is a constructional design of a motional kinematics of fingers, which are controlled by a working screw, and also there is a design of a belt gear from the engine to the gripper working screw. This solution has its base in previous analytical computation of forces and is substantial for the further correct selection of an engine transmission and gearing considered for achievement of required manipulator fingers kinematics.*

Keywords: Handling machinery, Belt gear, Kinematics, Gripper.

1. Introduction

An important role of engineers is to analyse used and new-designed working processes for finding an optimal way of execution of an existing operation. In the development, design and production process of machines and their subsystems there are nowadays used various methods and approaches. In these processes computational simulations are utilized, which allow to identify structural and dynamic properties of structures by means of virtual reality tools (Lack, 2014a, Lack, 2014b, Lack 2013, Soukup, 2014), measurements and experimental methods on prototypes or finished products) or also by special equipment in laboratories (Gerlici, 2013, Gerlici, 2014). The best working process is generally considered that one, at which the costs on output are minimalized, what can be achieved by mechanisation (Besekerskij, 1970).

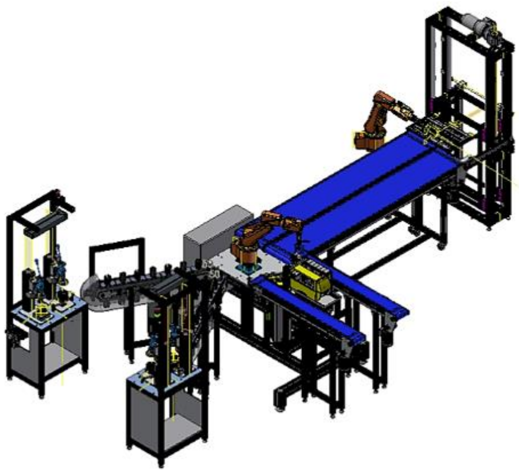

Fig. 1: Locating of designed robot on the automatic line.

* Ing. Miroslav Blatnický, PhD., Ing. Ján Dižo, PhD.: Department of Transport and Handling Machines, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1; 010 26, Žilina; Slovak Republic, miroslav.blatnicky@fstroj.uniza.sk, jan.dizo@fstroj.uniza.sk,

** Ing. Mária Blatnická: Department of Applied Mechanics, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1; 010 26, Žilina; Slovak Republic, maria.blatnicka@fstroj.uniza.sk,

*** Ing. Martin Svoboda, PhD.: Department of Machines and Mechanics, Faculty of Production Technology and Management, Jan Evangelista Purkyně University in Ústí nad Labem, Pasteurova 3334/7; 400 96, Ústí nad Labem; Czech Republic, svoboda@fvtm.ujep.cz.

Mechanisation is an important means of increasing productivity, quality and production competitiveness. For successful introduction of mechanisation is necessary to know and understand physical dependencies of executed operations. Operations are executed by transfer of mechanical, electrical, pneumatic or hydraulic energy. The aim is to make individual working processes as short and simple as possible, easy to learn and at the same time minimal man-power consuming. Mechanisation significantly relieves the man of heavy manual labour for instance in dangerous or harmful environment. These days can be characterised by developed production and automation (Fig. 1). Automation is a process of a replacement of a man control function by operation of various machines and devices.

Automation is a highly complex process including very simple control operations, which are performed automatically at a relatively simple device, as well as very complicated control of big production units. Control is a purposeful action of valuation and processing of information about controlled object or process, actions in the process (these may include measurement device data, signalling equipment states) and according to them related machines are controlled so that prescribed aim is reached – handling piece loads of maximal weight m = 25 kg in this instance.

2. Requirements imposed on manipulator

Basic imposed requirement is a simple control, a necessity of a control by an operator, provided compatibility with operative system. Appliance load capacity is 25 kg and gripping force results from it according to material contact. A number of gripping fingers is 3. Mechanism drive is electrical (AC servomotor) for two mechanisms, because of the fact that one of the fingers has one degree of freedom and the remaining two fingers have two degrees of freedom. Required operative finger range is 0 – 60° (depends on a size of load) and 1.05 rad when rotating of two fingers at change of load shape. Permitted finger length at maximal gripping force is 150 mm. Maximal finger folding pace is 25 $mm.s^{-1}$ and finger rotation speed 1.57 $rad.s^{-1}$. Designed robot manipulator will be a part of an automatic line in Fig. 1. Function of the robot is loading movable containers with ready products.

3. Manipulator working screw

A selection of the manipulator working screw results from the loads imposed on the screw at robot operation. Computation of the gripping force and an engine output was designed for gripping two basic objects i.e. circle shaped objects and direct planed objects (Fig. 2) (blocks, cubes).

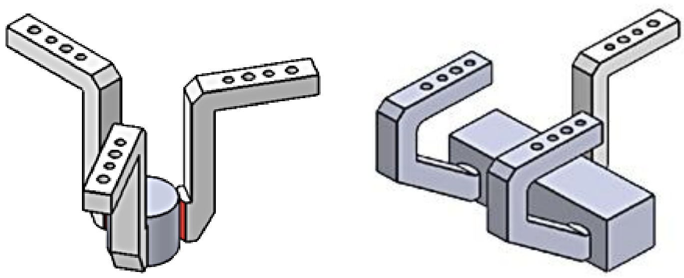

Fig. 2: Orientation of the gripping fingers at manipulating the rotational shaped objects (left) and the direct planed objects (right).

When body equilibrium conditions and friction condition between normal and friction forces were taken into account, we found out in previous calculations that normal force F_{N1} acting on the most loaded finger (in Fig. 2 right - non-rotating finger, i.e. the finger acting by a reaction against a force action of the oppositely oriented pair of fingers) is F_{N1} = 1 720 N. After evaluation of the gripping forces sizes of both gripped objects was found that at gripping the object of non-circle shape, the force acting on the non-rotating finger is greater. Hence each next computation was realized at gripping such loads. Subsequently, a constructional design of the robot manipulator finger with components allowing achievement of the required movement possibilities was created (Fig. 3 left). Gripper motion kinematic is provided by knuckle mechanism of joint sphere with thread. At mechanism motion kinematic is necessary to provide two degrees of freedom at two active fingers. This motion was assured by usage of articulation (Fig. 3 right). At mechanism motion in vertical direction, there is a curve motion. This motion was ensured by acceptable slope of connecting ball with thread, which is at ball-joint type: RBL 10D – 40°, RBIDL –

25°. For part of finger that makes only vertical motion, there is a fixed arm suspension assured by a screw connection. This way, just one degree of freedom of this part was provided.

For a working screw design is necessary to know a loading force size. In the previous calculations it was found that the resultant loading force acting in the working screw axis is $F_S = 16\,780\ N$. For a correct option of the screw is needed to choose a screw with a higher dynamic load rating than the computed force F_s.

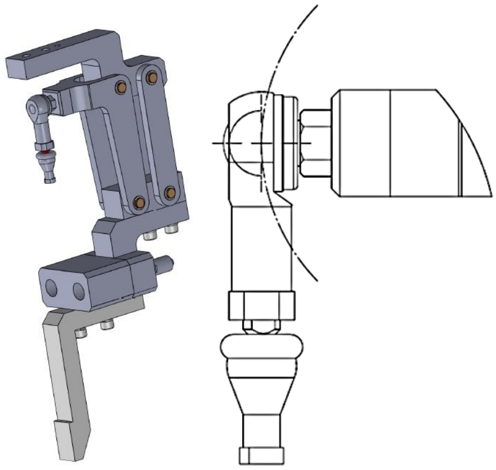

Fig. 3: Constructional design of one of the robotic manipulator finger (left) and Knuckle motion curve (right).

The next condition is that chosen working screw has high efficiency so we select a ball screw for example by company Bosch. Selected screw with dynamic load rating C = 27.5 kN, thread effective diameter d_0 = 32 mm and thread pitch t = 5 mm meets requirements, which will be made on it in operation.

4. Calculation of working screw revolutions

Revolutions of the selected working screw have to reach the specific value in order to meet the condition imposed on the manipulator that the pace of the fingers folding is $v_x = 25\ mm.s^{-1}$. Since, between the finger folding pace v_x and the speed of nut moving on the screw v_y, there is a lever transmission according to the Fig. 4, it can be written that (1):

$$v_y = \frac{a}{c} . v_x \qquad (1)$$

By solving the equation for the speed of the nut motion in the vertical direction we get $v_x=17.0833 mm.s^{-1}$.

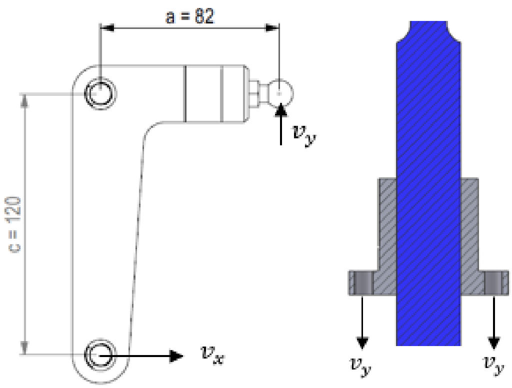

Fig. 4: Lever arm of the mechanism (left) and kinematics of the working screw nut (right).

With acquired value of the nut speed v_y it is possible to calculate correct screw revolutions n according to the screw pitch t (2):

$$n = \frac{v_y}{t} \qquad (2)$$

By solving the equation (2) we find the number of rotations per second, i.e. $n = 3.4166\ s^{-1}$.

5. Conclusion

The aim of this paper is a partial solution of a robot manipulator design. It consists of constructional design of gripping fingers for operation with piece loads of maximal weight 25 kg, of selection of the working screw ensuring mechanism drive and determination of its revolutions needed. It is possible to state that this aim was accomplished. Overall solution of the issue is to reach theoretically function equipment, ready for implementation to the real production. So it is needed a next solution of a knuckle mechanism selection for assurance of a working motion, calculation of fingers speed, transmission design, drive mechanism design, belt gear of rotating fingers design etc.

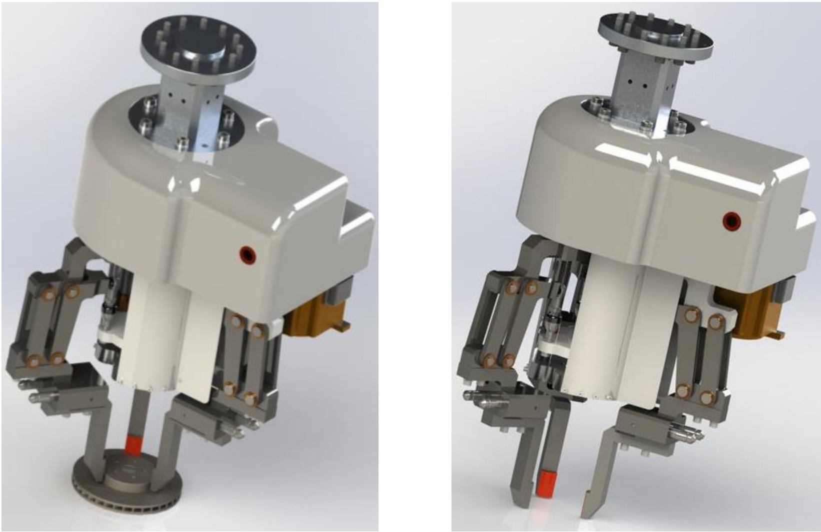

Fig. 5: 3D model of a versatile gripper for a robot manipulator.

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