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Experimental determination of forces that occur on a workpiece grasped by a pneumatically driven robotic gripper

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The paper presents the manner of determination of forces that act on a workpiece grasped by a pneumatically driven robotic gripper. The starting point consists of experimental determination of the pushing force necessary to move the workpiece held between the gripper's fingers. Then, by using theoretical relations, the friction force between the workpiece and the fingers, and the prehension force (also called gripping force) are computed, for different values of the pneumatic driving system pressure.

***Keywords**: pneumatic, robotic gripper, experimental determination, prehension force, gripping force, friction*

1. Introduction

In the robotic manipulation applications, the maintaining of workpiece position-orientation is a primary requirement for carrying out the handling task.

Modeling and simulation [6], [7], [9], [10], [15], [16], and experimental determinations [3], [8] are used in robotics field research.

The pneumatic driving system is preferred in various cases for robot gripper, because it confers high speed and elasticity to the grasping process [1], [5], [12].

From the multitude of gripper types [2], [4], [11], [13], [14], a 2-fingered gripper, pneumatically driven, is used for the experimental determinations.

2. Theoretical considerations

The forces that occur on the workpiece handled by robotic grippers in manipulation processes are as follows: the workpiece weight (W), friction forces between the workpiece and the fingers (F_f), and prehension forces (F). In dynamic conditions, inertial forces (F_i) occur, with direction and way depending on the handled workpiece motion.

Figure 1 presents the forces that occur on the workpiece handled by 2-fingered robotic gripper; the normal reaction acts on the bottom of the workpiece, when the gripper is pushing down the workpiece on a fixed body.

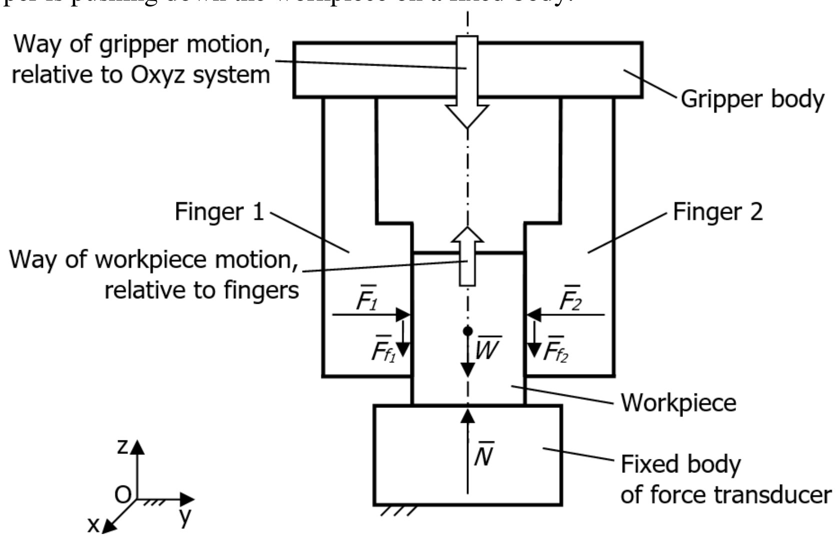

Figure 1. Forces that occur on the workpiece handled by 2-fingered robotic gripper: F_1, F_2 - prehension forces; F_{f1}, F_{f2} - friction forces between the workpiece and the fingers; W - the weight of the workpiece; N - normal reaction force when the gripper pushes the workpiece on the fixed body.

In equilibrium conditions, the following relation can be written:

$$\sum \overline{F} = 0; \tag{1}$$

$$\overline{F_1} + \overline{F_2} + \overline{N} + \overline{W} + \overline{F}_{f_1} + \overline{F}_{f_2} = 0. \tag{2}$$

The projections of forces on y axis are as follows:

$$\sum F_y = 0; \tag{3}$$

$$F_1 - F_2 = 0; \tag{4}$$

$$\Rightarrow \quad F_1 = F_2 = F. \tag{4'}$$

The projections of forces on z axis can be written:

$$\sum F_z = 0; \tag{5}$$

$$N - W - F_{f_1} - F_{f_2} = 0\,; \tag{6}$$

$$\Rightarrow \; F_{f_1} + F_{f_2} = N - W\,. \tag{6'}$$

The friction forces are given by the following relations:

$$F_{f_1} = \mu_s \cdot F_1 = \mu_s \cdot F\,; \tag{7}$$

$$F_{f_2} = \mu_s \cdot F_2 = \mu_s \cdot F\,; \tag{7'}$$

$$\Rightarrow \; F_{f_1} = F_{f_2} = F_f = \frac{N - W}{2}\,, \tag{7''}$$

where $\mu_s = 0.61$ is the static friction coefficient between the workpiece and the gripper's finger (steel / aluminum) [17],

$$\Rightarrow \quad F_1 = \frac{F_{f_1}}{\mu_s} = \frac{F_{f_2}}{\mu_s} = F_2 = F\,. \tag{8}$$

3. The experimental stand

The experimental stand, presented in figure 2, consists of 2 main parts: an industrial robot and the measuring equipment.

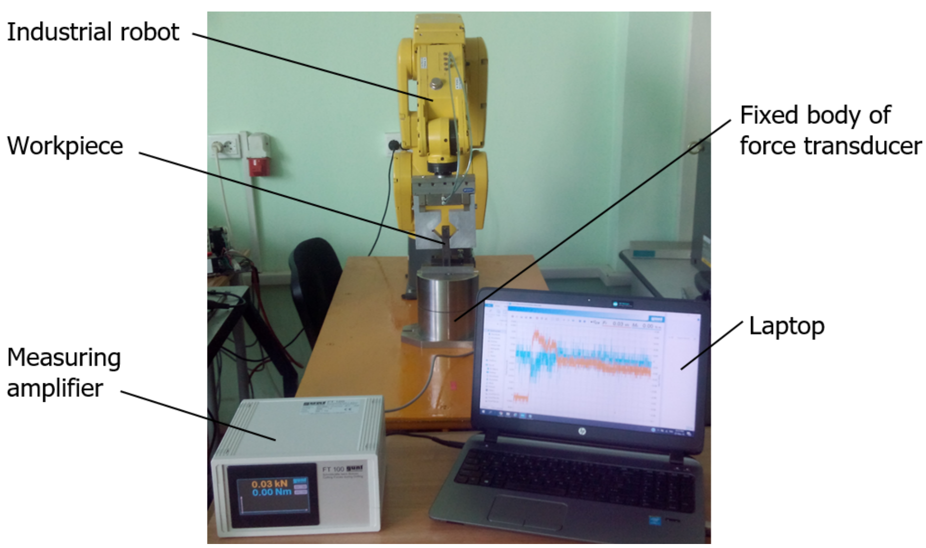

Figure 2. The experimental stand.

The industrial robot type is Fanuc 200iC; it has an electric driving system for joints and a pneumatic system for gripper. The weight of the grasped workpiece is W = 3.51 [N].

As measuring equipment, a G.U.N.T FT 100 system for measuring forces and torques is used.

4. Results

The results, based on the experimental determinations, are presented in table 1. The pressure p is set for the pneumatic driving system, the normal reaction N is measured, the friction force F_f is computed by using the relations (6') and (7''), and the prehension force F is computed with the relation (8).

Table 1. Results based on the experimental determinations

r. no.	p [bar]	N [N]	F_f [N]	F [N]
1.	1	20	8.25	13,52
2.	2	26	11.25	18,43
3.	3	30	13.25	21,71
4.	4	35	15.75	25,81
5.	5	42	19.25	31,55

Figure 3 shows the variation of the prehension force, depending on the pressure in the pneumatic driving system.

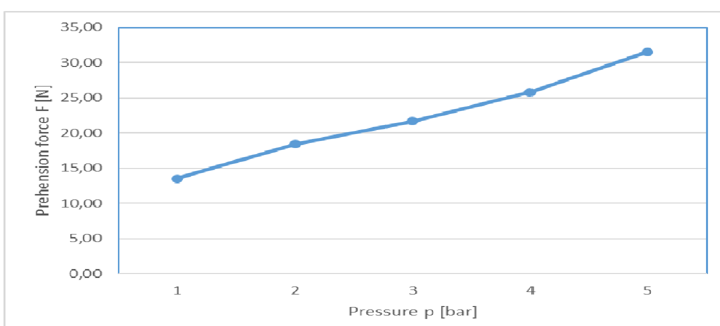

Figure 3. The variation prehension force - pressure in the pneumatic driving system.

5. Conclusion

The prehension force was computed starting from the experimental determination of pushing force necessary to move the grasped workpiece.

The prehension force has an aproximately linear variation, depending on the air pressure in the driving pneumatic system.

This method of prehension force determination can be applied to other types of robotic grippers, if the gripper configuration permits.

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