



SCIENTIFIC BASIS OF INNOVATION

<https://doi.org/10.15407/scine20.01.068>

KARMALITA, A. K. (<https://orcid.org/0000-0003-4397-2988>),
PUNDYK, S. I. (<https://orcid.org/0000-0001-5832-5527>),
ONOFRIICHUK, V. I. (<https://orcid.org/0000-0002-2914-4986>),
SMUTKO, S. V. (<https://orcid.org/0000-0002-7344-3799>),
SHPAK, O. L. (<https://orcid.org/0000-0003-3319-8730>),
HORIASHCHENKO, S. L. (<https://orcid.org/0000-0001-6623-2523>),
and BILYI, L. A. (<https://orcid.org/0000-0002-9538-6908>)

Khmelnytskyi National University,
11, Instytutska St., Khmelnytskyi, 29016, Ukraine,
+380 38 267 0276, nauka@khmnu.edu.ua

ORGANIZATION OF THE OPERATING ENVIRONMENT FOR INDUSTRIAL ROBOTS PROCESSING FLAT OBJECTS THAT HAVE ASYMMETRY OF PART SURFACES

Introduction. *Orientation of flat parts with asymmetry of their surface properties is a necessary condition for the use of industrial robots to feed these parts for machining.*

Problem Statement. *After each machining operation, the parts may be found in a disordered state, therefore, in order feed them for the next operation, it is necessary to control their position and properly reorient them.*

Purpose. *The purpose of this research is to experimentally determine the coefficient of asymmetry of topographic properties of surfaces for controlling the position of flat parts by the air jet method.*

Material and Methods. *The method of determining the speed of air by measuring the pressure in it, with the help of a Pitot-Prandtl tube, has been used. The standard MathCad package has been employed for mathematical calculations of experimental results. Sheet steel for the manufacture of air chambers and fluoroplastic with high anti-friction properties have been used as material for the experimental stand for the base.*

Results. *As a result of experimental studies, a list of the parts for which the control method using air jets has high reliability has been formed. Through research, the coefficient c has been established for parts made of different materials. This coefficient affects the regularity of the motion of parts, and knowing it we may calculate the necessary parameters of devices for control. The necessary air pressure to create a force sufficient to move these parts from the control position at a given speed, that is, to create control conditions has been established.*

Conclusions. *The use of compressed air to control the position of flat parts with asymmetric surfaces can be successfully implemented for organizing the operating environment of industrial robots that work according to a rigid algorithm, with the help of pneumatic devices, the parameters of which can be determined based on the results of this research, or for creating sensor grippers for adaptive industrial robots.*

Keywords: flat part, surface roughness, nozzles, air jets.

Citation: Karmalita, A. K., Pundyk, S. I., Onofriichuk, V. I., Smutko, S. V., Shpak, O. L., Horiashchenko, S. L., and Bilyi, L. A. (2024). Organization of the Operating Environment for Industrial Robots Processing Flat Objects That Have Asymmetry of Part Surfaces. *Sci. innov.*, 20(1), 68–73. <https://doi.org/10.15407/scine20.01.000>

© Publisher PH “Akademperiodyka” of the NAS of Ukraine, 2024. This is an open access article under the CC BY-NC-ND license (<https://creativecommons.org/licenses/by-nc-nd/4.0/>)

Industrial robots occupy an increasing share in the technical equipment of enterprises of various industries, including light industry. Most of them are non-adaptive software robots that work according to a rigid program. The smaller part is adaptive robots that have sensory grips. For the software robots it is necessary to organize the environment of processing objects, while for the adaptive robots, sensor grippers that recognize the position of the same objects are needed. In both cases, it is necessary to create systems to control the position of robotics objects in relation to the working bodies of machines or grippers of industrial robots.

In various industries, there are many flat parts to be machined with which industrial robots can work. Among such parts, there are many those that have asymmetry of the physical and mechanical properties of the surfaces. The shoe-making industry is one of such industries.

Most of the flat parts of shoes have asymmetry of frictional properties and unevenness of the surfaces, which makes it possible to create mechanical means of controlling the position based on the surface properties, which are notable for simple design and reliability in operation [1]. The most promising way, in our opinion, is to control the position of flat parts with the help of air jets.

The purpose of this research is to determine the parameters of the process of controlling the position of flat parts with asymmetry of the topographic properties of surfaces, with the use of air jets.

In [1], we have obtained the equation of motion of part in the control process, which contains the coefficient c that characterizes the difference in the surface irregularities of the parts, on which the control process itself depends.

The task of experimental research is to determine the coefficient c for flat parts of shoes made of the most common materials.

Figure 1 shows the scheme of controlling the position of flat parts of shoes by asymmetry of unevenness and surface roughness, with the use of air jets [1].

The scheme shows two pneumatic chambers 1 having nozzles 3 for connecting to the compressed

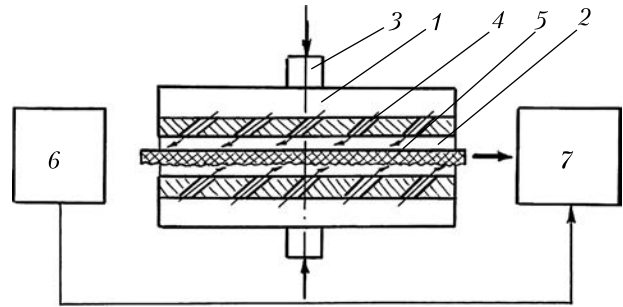


Fig. 1. The scheme of controlling the position of flat parts of shoes by asymmetry of surface roughness, with the use of air jets

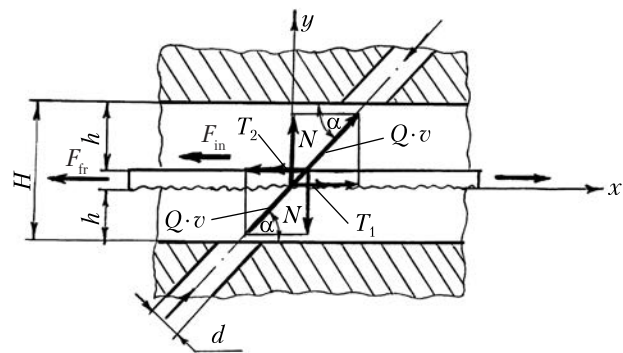


Fig. 2. Scheme of forces acting on a flat part in the process of controlling the position by the surface properties, with the use of air jets

air supply system, which are installed on the surface of base 2. In the wall of each chamber, which faces the opposite chamber (referred to as the supporting surface of the chamber), there are made evenly distributed over the entire surface holes (nozzles) 4, whose axes are located at the same angle to the wall surface. At the same time, the axes of the holes of one chamber are parallel to the axes of the holes of the other chamber and the sum of the hole areas in the walls of the chambers are equal to each other.

Control is carried out in the following way. Part to be controlled 5 is installed with its smallest edge on the surface of base 2 between two chambers 1. Compressed air is fed into the chambers through nozzles 3 and exits from there through holes 4, acting on the surface of the part. As a result of this, the part is moved to position 6 or reorientation 7.

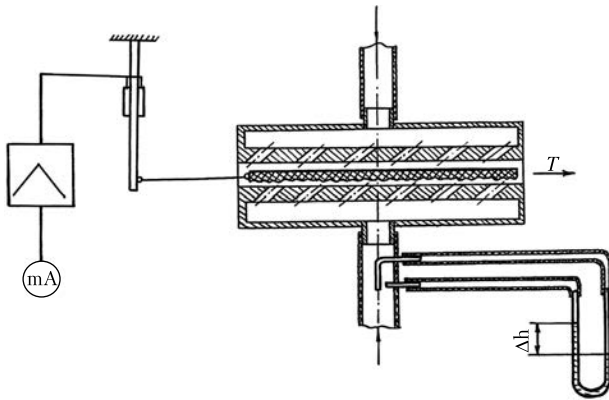


Fig. 3. Scheme of the experimental stand for determining the force moving the part to the control position

The scheme of the action of the force components from the air jet on the flat part at the initial moment of control, when the part covers all the nozzles, is shown in Fig. 2 [1].

If the air jet acts on the part and is directed at some angle α to its surface, the action force can be divided into the two components: normal to the surface of part N and along its surface T . Here it should be noted that when the air jet meets the surface part at an angle $\alpha \neq 90^\circ$, air spreads over the surface of the part in all directions in different quantity. The amount of air flowing in a certain direction depends on many factors and, above all, on the angle of inclination α , the gap h between the surface of the part and the bearing surface of the chamber, and on the size of the surface irregularities. Therefore, force T shall be considered the resultant of the forces identical in nature with it and directed in different directions. Force T acts as a driving force in the direction of transportation.

Force N acts as a repulsive force that contributes to the creation of a gap h between the part and the bearing surface of the chamber.

Having conducted an analytical study of this method [1], we obtain the equation of motion of the part during the control process:

$$T > F_{fr} + F_{in}$$

or

$$cQ\vartheta\cos\alpha > mgf + \frac{d^2x}{dt^2}m, \quad (1)$$

where Q is the air mass flow per second; v is the air speed; f is the coefficient of friction; m is the mass of the part; $\frac{d^2x}{dt^2}$ is the acceleration.

The friction forces of the part surfaces against the air cushion can be neglected, because they are two orders of magnitude less than the friction force of the surface of the base against the surface of the platform made of any antifriction material [2].

The coefficient c has been experimentally determined with the use of the experimental stand shown in Fig. 3.

Force T acting on the part and moving it is determined by the method of electro-tensometry.

With such a scheme of measurement, there are no inertia forces. Therefore, it follows from the equilibrium condition of the part:

$$cQ\vartheta\cos\alpha - F_{fr} - T = 0$$

then

$$c = \frac{T + F_{fr}}{Q\vartheta\cos\alpha}, \quad (2)$$

where T is the measured force; F_{fr} is the frictional force between the part and the surface of the base of the control device.

The speed of air and its mass flow through the nozzles per second are determined from the mass flow of air entering the chamber per second and the number of nozzles. The mass flow of air entering the chamber per second is determined by the speed of air entering the chamber and the diameter of the inlet nozzle [4]:

$$Q_1 = \gamma \cdot U \frac{\pi D^2}{4}, \quad (3)$$

where γ is the jet compression coefficient, with [3] $\gamma \approx 0.7$.

In turn, the speed of air entering the chamber is determined by the well-known formula [4]:

$$U = \sqrt{\frac{2\Delta P}{\rho_n}}, \quad (4)$$

where ρ_n is the air density that is chosen according to the table from [5] for a temperature of 18 °C and a pressure of 108 kPa.

$$\Delta P = \Delta h \rho_p g, \quad (5)$$

where Δh is the reading of a differential manometer connected to a Pitot-Prandtl tube made of specially sharpened medical needles and placed in the air stream at the chamber inlet; ρ_p is the specific gravity of the measuring liquid (water).

The air mass flow per second through each nozzle as well as the air speed at the exit from each nozzle are different and depend on the position of the nozzle relative to the inlet nozzle. However, since at the initial moment of control (when the part moves from the control position) all the nozzles are blocked by the part, and the air jets coming out of all the nozzles affect the part, for the calculation of the displacement forces we take the average speed of the air at the exit from the

nozzle, calculated based on the average mass flow of air per second through one nozzle:

$$v = \frac{4Q}{\gamma \pi d^2 \rho_n n}, \quad (6)$$

where n is the number of nozzles; d is the nozzle diameter.

The coefficients of friction of the sample – the surface of the base of the control device pair f have been determined experimentally by the known method [6].

The samples are weighed by laboratory scales with an error of up to 0.0001 N.

Then

$$F_{fr} = QF, \quad (7)$$

where Q is the sample weight.

Table 1. The Experimental Results

The material of the part	Pressure at the to the chamber inlet ΔP , Pa	Air speed at the chamber inlet U , m/s	Mass flow at the chamber inlet per second Q_r , kg/s	Average mass flow rate through the nozzle per second Q , kg/s	Average speed of the air at the exit from the nozzle v , m/s	$\cos \alpha$	Mass of the part m , kg	Coefficient of friction, f	Moving force T , N	Force of friction F_{fr} , N	c
1. Leather for the bottom after tousling the buff side	7056	107.1	$6.5 \cdot 10^{-3}$	$0.4 \cdot 10^{-3}$	120	0.705	0.067	0.33	0.153	0.21	0.66
2. Artificial fur							0.045	0.28	0.38	0.12	0.91
3. Artificial leather upper on a long fiber base							0.058	0.35	0.052	0.19	0.44
4. Monolithic rubber with grooves on one surface							0.085	0.47	0.08	0.39	0.85
5. The fabric is doubled with velor							0.061	0.29	0.23	0.17	0.73
6. Velvet							0.052	0.3	0.19	0.15	0.61
7. Baize							0.049	0.29	0.16	0.13	0.53
8. Suede							0.062	0.31	0.09	0.19	0.51
9. Ratteen							0.059	0.29	0.26	0.17	0.78
10. Velvet art. 64048							0.054	0.32	0.19	0.15	0.6
11. The canvas is non-woven, backed with a fable							0.06	0.33	0.07	0.19	0.48
12. Microporous rubber with a pattern on the running surface							0.075	0.41	0.05	0.3	0.63

The experiments have been carried out with parts from various, most common shoe materials that differ in the unevenness and roughness of the opposite surfaces.

The sample size is 80×200 mm.

The parameters of the control device model are as follows:

- 1) the angle of inclination of nozzles is $\alpha = 45^\circ$;
- 2) the nozzle diameter is $d = 2$ mm;
- 3) the number of nozzles in each chamber is $n = 16$;
- 4) the inner diameter of the inlet pipe is $D = 8$ mm.

The nozzle diameter and the number of nozzles are chosen in such a way that the sum of the cross-sections of the nozzles is equal to the cross-section of the inlet pipe.

The angle of inclination of the nozzles $\alpha = 45^\circ$ is the optimal angle at which the parts during the control process do not touch the bearing surfaces of the chambers.

The surface of the base of the control device model is made of fluoroplastic that has high anti-friction properties.

The intermediate calculations and experimental results are listed in Table 1.

As a result of experimental studies, for the parts listed in Table 1 under Nos. 3, 4, 8, 11, and 12, in which the force is small, respectively 0.052 N; 0.08 N; 0.09 N, 0.07 N; 0.05 N, unstable motion of the parts at the control position has been observed. That is, not all parts move, some of them stop during the experiment. The control reliability is low, so this control method is not recommended for the parts made of these materials.

Knowing the coefficients c of the specified materials for shoe parts (or close to them in terms of surface characteristics), it is possible to find the necessary parameters of devices for control, as well as the necessary air pressure to create a force sufficient to move these parts from the control position at a given speed, that is, to create control conditions.

The method of controlling the position of flat parts with asymmetry of surface properties using compressed air can be successfully applied to organize the environment of industrial robots that work according to a rigid program, or to create sensor grippers for adaptive industrial robots.

REFERENCES

1. Karmalita, A. K., Pundyk, S. I., Drapak, H. M., Melnyk, V. I. (2022). Analysis of mechanical methods of controlling the position of flat shoe parts by surface properties. *Bulletin of the Khmelnytskyi National University*, 3, 194–198 [in Ukrainian]. <https://doi.org/10.31891/2307-5732-2022-309-3-194-198>
2. Petrosyuk, M. I. (1970). *Research of pneumatic pulse trays for moving shoe parts*. (PhD) (Technic.). Kyiv [in Russian].
3. Vasylykivskiy, I. S., Fedynets, V. O., Yusyuk, Ya. P. (2020). *Executive devices of automation systems*. Lviv [in Ukrainian].
4. Sribniuk, S. M. (2022). *Hydraulic and aerodynamic machines*. Kyiv [in Ukrainian].
5. Yavorskyi, B. M., Detlaf, A. A., Lebediev, A. K. (2007). *Handbook of physics for engineers and students of higher educational institutions*. Ternopil [in Ukrainian].
6. Zakalov, O. V., Zakalov, I. O. (2011). *Basics of friction and wear in machines*. Ternopil [in Ukrainian].

Received 12.02.2023

Revised 30.05.2023

Accepted 21.06.2023

А.К. Кармаліта (<https://orcid.org/0000-0003-4397-2988>),
С.І. Пундик (<https://orcid.org/0000-0001-5832-5527>),
В.І. Онофрійчук (<https://orcid.org/0000-0002-2914-4986>),
С.В. Смутко (<https://orcid.org/0000-0002-7344-3799>),
О.Л. Шпак (<https://orcid.org/0000-0003-3319-8730>),
С.Л. Горященко (<https://orcid.org/0000-0001-6623-2523>),
Л.А. Білий (<https://orcid.org/0000-0002-9538-6908>)

Хмельницький національний університет,
вул. Інститутська, 11, Хмельницький, 29016, Україна,
+380 38 267 0276, nauka@khmnu.edu.ua

ОРГАНІЗАЦІЯ СЕРЕДОВИЩА ДЛЯ РОБОТИ ПРОМИСЛОВИХ РОБОТІВ З ПЛОСКИМИ ОБ'ЄКТАМИ, ЩО МАЮТЬ АСИМЕТРІЮ ПОВЕРХОНЬ ДЕТАЛЕЙ

Вступ. Орієнтація плоских деталей з асиметрією їхніх поверхонь є необхідною умовою застосування промислових роботів для подачі цих деталей на технологічну обробку.

Проблематика. Після чергової технологічної обробки деталі можуть знаходитися у неупорядкованому стані, тому для подавання їх на наступну технологічну обробку потрібно виконати контроль їхнього розміщення та переорієнтувати в необхідне положення.

Мета. Експериментальне визначення коефіцієнту асиметрії топографічних властивостей поверхонь для процесу контролю положення плоских деталей за допомогою струменів повітря.

Матеріали й методи. Використано метод визначення швидкості руху повітря через вимірювання тиску в ньому за допомогою трубки Піто-Прандтля. Для математичних розрахунків результатів експериментів використано стандартний пакет *MathCad*. Як матеріал для експериментального стенду використано листову сталь для виготовлення пневмокамер та фторопласт з високими антифрикційними властивостями для основи стенду.

Результати. Експериментальним шляхом складено перелік деталей, для яких спосіб контролю за допомогою струменів повітря має високу надійність. Дослідним шляхом встановлено коефіцієнт c для деталей з різних матеріалів, який впливає на закономірність руху деталей, за яким можна розрахувати необхідні параметри пристроїв для контролю. Встановлено величину необхідного тиску повітря для створення зусилля, достатнього для переміщення цих деталей з позиції контролю із заданою швидкістю, тобто для створення умов контролю.

Висновки. Застосування стиснутого повітря для контролю положення плоских деталей з асиметрією поверхонь може бути успішно реалізовано для організації середовища роботи промислових роботів, які працюють за жорстким алгоритмом, з допомогою пневматичних пристроїв, параметри яких можуть бути визначенні за результатами описаних досліджень, або для створення сенсорних захватів для адаптивних промислових роботів.

Ключові слова: плоска деталь, шорсткість поверхні, сопла, струмені повітря.