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USAGE OF A TWO-CHAMBER PNEUMATIC MODULE FOR CUTTING CONTOURS IN CARDBOARD SCANS

The article describes a new method of cutting contours in cardboard scans and a device for its implementation.

Keywords: cardboard scan; cutting knife; ejector cushion; compressed air; perforation groove; pneumatic chamber.

Introduction

The development of the modern printing market requires increasing the speed of production and simplified, economically explained technological processes of this manufacture. The efficiency of printing and packaging production depends on the improvement of existing methods of processing semi-finished products, as well as the introduction of new methods with improved technical characteristics.

Energy-saving and high-performance systems which based on computer and pneumatic modules are now widely used in printing and packaging engineering. A special place in the modernization and introduction of new technologies is occupied by printing and post-printing equipment.

It will not be a secret that packaging equipment has long been intertwined with printing and post-printing and is used comprehensively in one production line. Therefore, the issues of finishing the packaging in the production process are relevant and very important.

For example, one of the options to make the technological process of cutting contours in cardboard blanks less energy and resource consuming is the use of modular pneumatic systems. This will allow you to solve an important issue regarding the accelerated deterioration of cutting knives and supporting contact elements. And especially, it is necessary to consider that pneumatic modules are operated on the basis of compressed and rarefied air and practically do not have negative effect on ecology.

Methods

Currently, methods of die-cutting are widely used, which carried out in printing and die-cutting equipment separately or with the process of printing. Thus, the method can be implemented with automatic feeding of cardboard scans in the area of cutting and removal from it in a crucible type machine [1].

The contours of the cardboard scan are cut in the contact zone of two parallel plates, one of which is fixed (carriage), the other —

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movable (crucible). A die-cutting form is mounted on the plate. A cardboard scan is pre-placed on the working plane of the crucible, which is moved to the cutting zone. And the crucible completes a complex movement. The cardboard scan is laid out by sheet-feeder or manually from a stack on a counterplate of a crucible and is aligned on forward and lateral limiting stops. The crucible transports it to the punching form and the die-cutting occurs when the cardboard scan approaches its left extreme position in the area of contact with the carriage. Then, the cardboard scan is removed to the receiving table.

The crucible type of machine contains a massive cast iron body, which is its basis. On the front part of the frame the supporting surface is attached to the die form. The crucible is made as a form of a rigid hollow structure, on the working surface of which the counterplate is attached. With its working shaped surface, the crucible provides a certain positioning and movement in the certain directions. In a die-cutting machine, the crucible is driven by connecting rods connected to the pins on one side and the crank fingers of the gears on the other. The gears are driven by the intermediate and main shaft.

Technological changes in the area of die-cutting the contours of the cardboard scan and changes in their size are regulated by distance between the crucible and carriage. A pressure mechanism is mounted on each of the connecting rods, which consists of an eccentric thimble mounted on the crucible pin and a turning mechanism.

Due to the large size and large specific amount of metal, significant inertial loads occur and, as a result, crucible machines are unproductive. The machines are effective only for small products. The counterplate, which is mounted on the working surface of the crucible and in contact with the cutting knives, quickly fails and needs to be replaced.

At native printing companies widely used press punching machine, which provides a technological operation of cutting scans along the contour and perforation of bending lines [2]. It consists of a flat punching form, which is attached to a fixed plate, a pressure moving plate, two pairs of lever wedge and eccentric mechanisms.

Initially, the pressure plate is located in the lower position. After the carriage supplied the cardboard scan into the working area of the press, the eccentric mechanism actuates the levers of the wedging mechanisms, which provide the pressure plate vertical movement. There is a working course of a plate for performance of operation of cutting of contours in a cardboard. The extreme upper position is occupied by the pressure plate under the condition of vertical alignment of the levers and overcomes the technological load created in the punching zone.

During idling, the pressure plate is shifted vertically down, and the carriage transports a cardboard sheet with cut scans to the next technological section.

The use of lever eccentric mechanisms creates difficulties in the installation and operation of the device. Lever wedging mechanisms further complicate the drive. The pressure plate in contact with the cutting knives has a negative effect on their durability and high-quality technological operation of such cutting sections.

Results

The purpose of this research is to propose a new way of die-cutting contours in cardboard scans and create a device for its realization. The task is to start the technology of contactless method of cutting cardboard scans. That is, without supporting contact elements such as: counterplate, cheek, counter knife, etc. To perform the cutting process, a two-chamber pneumatic module for cutting contours in cardboard scans is offered.

Discussion

The technological operation of cutting contours in paper and cardboard products is quite consuming, so a number of scientific papers have been published on this topic [3–9].

The use of rotary assemblies in transport systems with cutting knives sequentially fixed in the rotating drum, which significantly increases the productivity of the production line. Knives carry out sequentially gradual cutting of valve contours in material. The rotating drum of the rotary assembly accommodates knife holders along the edge of its radius. Accordingly, cutting knives are fixed alternately in the knife holders. The lower rotating drum is used as a support element (counter knife). The supporting base is made as a form of a marzan, mounted on the circumference of the lower drum. Due to the same direction of rotation of the rotary drums of the cutting knives and the cheek, alternate cutting of the material contours is ensured.

From the given examples of rotary cutting it is possible to conclude that blunting of cutting knives can occur through contact with the basic cylinder. Similarly, the cheek will work due to interaction with cutting tools. It also should be taken into account the complexity of making a cylindrical die-cutting mold and the complexity of installation of knife holders and die-cutting knives.

Qualitative technological process of die-cutting of complex contours in paper-cardboard materials with the use of pneumatic systems depends on the parameters of installation of actuators of their trajectory and the material, which is processed [10, 11].

For exploratory research, a new device for die-cutting contours in cardboard scans, containing an alignment system and redented conveyors, is proposed. The device has a clamping plate with built-in cutting knives, guides and a crank drive. As a counterweight, a two-chamber pneumatic module with contour grooves in the working area is used to create resistance with compressed air.

A general view of the device for die-cutting contours in cardboard scans is shown in figure *1*. The device includes feed *2* and output *3* redented conveyors, intermediate tables *8*, *10* for holding and moving the cardboard scan *1* and the tool unit. The tool unit of the device includes a drive made in the hinged connection of the crank *11* with the connecting rod *12*, guides *7* for moving the pressure plate *4* with fixed at its base cutting knives *5* and ejector cushions *6* and two-

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chamber pneumatic module *9*, motionless fixed, receives forced reversible movement of the piston *13* by the pillar *14* and the compression spring *21* and provides the movement of compressed air from the lower pneumatic chamber *15* to the upper pneumatic chamber *16* through the intermediate wall *17* with proportionally spaced contour grooves *18* to the desktop *19* with contour grooves *20*.

The device that implements the method of die-cutting contours in cardboard scans works as follows. Cardboard scan *1* is fed into the area of die-cutting of its contours by the feed redented conveyor *2* with a speed VKR on the intermediate table *8* in the direction of the tool unit. By cycling the crank *11*, the connecting rod *12* and the guides *7*, the pressure plate *4* with cutting knives *5* and ejector cushions *6* is lowered to the cardboard scan *1*, which is placed on the desktop *19* and pre-fixed by the output gear conveyors *3*.

Simultaneously in the two-chamber pneumatic module *9* (fig. 2) the pillar *14* moves the piston *13* displacing compressed air from the lo-

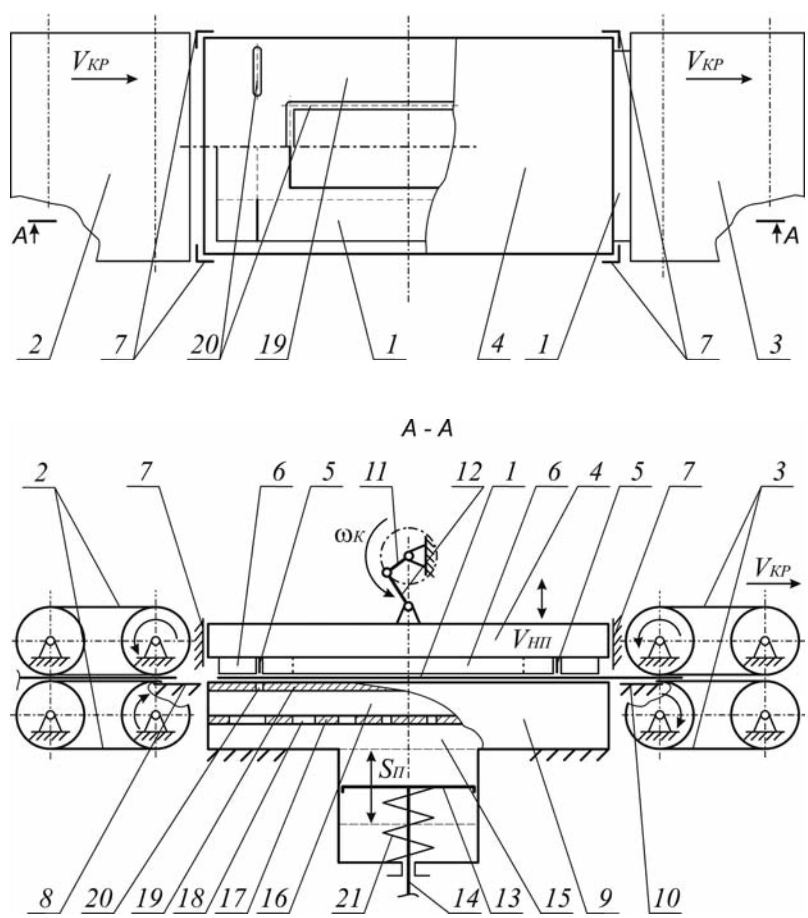

Fig. 1. General view of the device for die-cutting contours in cardboard scans

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wer pneumatic chamber *15* through equidistant from the piston center perforation contour grooves *18* in the walls of the intermediate chamber *17* to the upper *16* of the pneumatic chamber. When lowering the ejector cushions *6* on the cardboard scan *1*, it is additionally fixed on the desktop *19*, the prepared compressed air evenly creates the necessary resistance to the penetration of cutting knives into the forming contour grooves *20* provides a high-quality process of cutting contours in the cardboard scan. During the idling of the pressure plate *4*, the material is further moved by means of the intermediate table *10* and the output conveyor belts *3*, and the compression spring *21* of the two-chamber pneumatic module *9* returns the piston *13* to its initial position.

After passing the area of action of the tool unit on the contours of the cardboard scan, slits are formed, which contribute to their quality further bending and the formation of three-dimensional structural elements of cardboard packaging. Die-cutting of contours and preparation of a cardboard scan for further technological processes occurs in one kinematic cycle of the tool unit without the use of support elements.

It is clear that this technology of cutting cardboard scans can be used for machines of different formats. You can change the pressure plates with cutting knives and workbenches on which are placed work areas — contour grooves.

When passing the knife into the cardboard and its division into the blade, such components will act: the resistance force to the destruction of the cardboard under the action of the knife; the compressive force of the side chamfers of the knife, which occurs due to the deformation of the cardboard in the horizontal direction and the resistance force to deformation of the cardboard in the vertical direction.

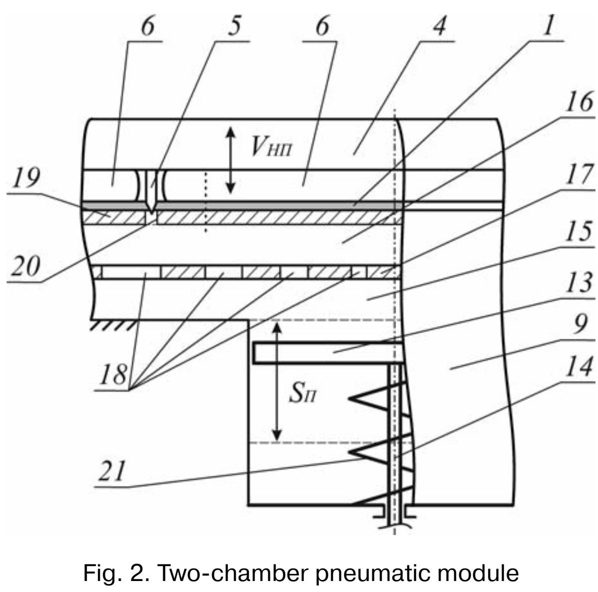

Fig. 2. Two-chamber pneumatic module

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In each case, to determine the force that must be applied to the knife to perform the process of cutting cardboard material should take into account the characteristics of the material (deformation properties, thickness), geometric characteristics of the cutting knife (angle between flanks, sharpening angle, grind, etc.):

$$P_c = 2r\sigma_d + 2\frac{E_y\lambda^{n+1}}{\delta^n(n+1)}\cdot \cdot\left(tg\frac{\beta}{2} + f\left(\sin^2\frac{\beta}{2} + \mu^n\cos^2\frac{\beta}{2}\right)\right), \quad (1)$$

where r — the width of the knife; σ_d — destructive contact voltage on the knife; λ — the depth of penetration of the knife into the cardboard; δ — the thickness of the cardboard (materials such as cardboard during deformation are subject to a degree dependence $\sigma^m = Ee$,

where: $\sigma = E_y\varepsilon^n : E_y = E^n,\ n=\frac{1}{m}$);

β — the angle between the faces of the knife; $f = tg\varphi$, φ — the friction angle; μ — the Poisson's coefficient.

For our case to carry out die-cutting of the preset technological contours, the certain force is required. As a part of which (F_{fr} — force of friction; F_{comp} — force of compression of lateral chamfers of a knife arising owing to deformation of a cardboard in the horizontal direction; F_{def} — force of resistance to deformation of a cardboard in the vertical direction; F_{dest} — force of resistance of destruction of a cardboard under the knife strip). Theoretically, such a force must be applied to the knife and it must be proportional to the equal force of all forces acting in our pneumatic system.

For further analytical research, we divide the two-chamber pneumatic module into three conditional technological zones. The first zone corresponds to the upper pneumatic chamber, the second — the lower, and the third refers to the working area of the piston. We calculate the volumes of air in the cavities of pneumatic chambers, which will depend on the geometric characteristics of the module (diameters, lengths of channels).

Calculation of the volume of the third technological zone:

$$V_3 = \frac{\pi \cdot d_3^2 \cdot l_3}{4}, \quad (2)$$

where d_3 — the diameter of the channel; l_3 — the length of the channel.

The volume of the second technological zone is:

$$V_2 = a \cdot b \cdot h, \quad (3)$$

where a, b, h — length, width and height of a given plane.

According to the scheme of a two-chamber pneumatic module (figs. 1, 2), the volume in the first zone is equal to the volume of the second. Accordingly, for the total volume, we consider the sum of the three technological zones of the pneumatic module. Therefore $V = V_1 + V_2 + V_3$.

The load on the pneumatic actuator consists of two components: constant, is equal to all constant forces and variable, which varies linearly. That is the function of displacement x and the piston speed $\dot{x}$.

The equation of motion of the piston for a one-way pneumatic actuator:

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$$m\ddot{x} = (p - p_a)F - \\ -c^{п}x - c^{c}\dot{x} - P, \quad (4)$$

where c^n, c^c — coefficients of proportionality; for our case, the back pressure is constant and equal to atmospheric pressure, therefore $(p - p_a)$; $p = p_a$, $\dot{x} = 0$ — initial conditions of integration; x = s — numerical integration continues as long as x will be equal to the piston stroke; F — the area size of the piston; s is the operating stroke of the piston.

The resultant force is considered positive if its direction coincides with the direction of the resistance forces, and negative if it coincides with the direction of the driving forces. Accordingly, P — equal to all constant forces acting on the piston, except for air pressure forces: $P = \pm P_0 + P_1 \pm P_2 \pm P_3$, where P_0 is the force of pretension of the spring; P_1 — friction force; P_2 — force of useful resistance; P_3 — the weight of the piston and all parts with translational motion.

Determine the pressure loss in the pneumatic chambers of the module:

$$P_{mod} = \lambda \frac{l}{d} \cdot \frac{\rho \cdot v^2}{2}, \quad (5)$$

where λ is the coefficient of friction (for smooth surfaces is 0.03); v is the speed of the piston (take the value of 0.2 m/s).

Determination of air pressure is one of the most important technological parameters of the process of die-cutting cardboard scans. The clamping force of the pressure plate with die-cutting knives will depend on this parameter. As a result, the end result is the quality of the cut contours in the cardboard scan.

Determine the air pressure in the final position of the technological course of the piston:

$$p_s = p_a + \frac{c \cdot s + P}{F}. \quad (6)$$

Calculation formula for determining the pressure at the beginning of the piston stroke (for the initial position):

$$p_{x_1} = p_a + \frac{c \cdot x_1 + P}{F}. \quad (7)$$

Required pressure when cutting the contours of the cardboard scan:

$$p_{x_2} = p_a + \frac{c \cdot x_2 + P}{F}. \quad (8)$$

Figure 3 shows a graph of changes in temperature t and air density ρ in the chamber of the pneumatic module. From the given graph it is seen that with increasing temperature t the air density ρ decreases.

The pressure at the beginning of the piston stroke is the smallest and increases as it moves to the maximum upper coordinate. Accordingly, the pressure force is corrected in proportion to the increase in piston stroke. Since the resistance of the compressed air generated in the grooves of the desktop of the upper pneumatic chamber must be equivalent to the die-cutting force, it must also be adjusted to the specified design values.

The air temperature in the pneumatic module can be an important

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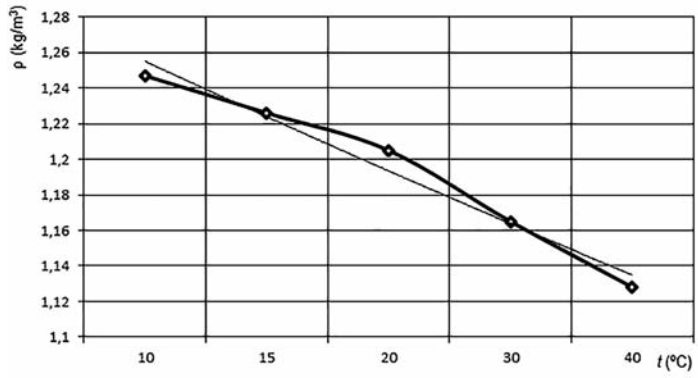

Fig. 3. Change of temperature t and air density ρ in the chamber of the pneumatic module

parameter in its operation. Technological pressure losses in the pneumatic chamber can depend on temperature (fig. 4). The presented dependence of pressure losses P_{mod} on temperature t in the chamber of the pneumatic module shows that with increasing temperature the pressure losses decrease. This is due to the air density ρ in the pneumatic chamber. However, as we can see, the losses are not large and will not have a significant impact on the operation of the module.

In the process of moving the piston, the air is compacted, resulting in an increase in pressure and temperature. From the given graphs we can conclude that with increasing temperature t the air density ρ decreases. As a result, pressure losses are reduced.

Physical and technical characteristics of paper and cardboard (internal structure, location of fibers, ratio of cellulose, fillers, ink additives, sheet thickness, degree of calendering, etc.) will have a great influence on the final result of high-quality cutting of contours.

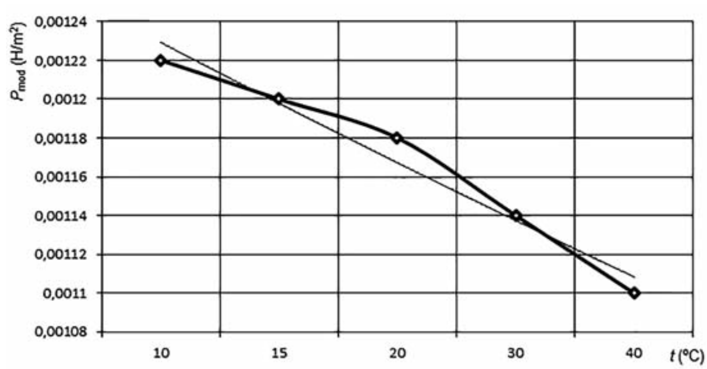

Fig. 4. Dependence of pressure losses P_{mod} on temperature t in the chamber of the pneumatic module

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Conclusions

Creation of resistance by compressed air will allow providing cutting the contours in cardboard scan without using cheek. The mechanics of the technological process of cutting contours helps to reduce the complexity of manufacturing a semi-finished product without adding additional supporting elements like counter knives and cheeks. And as a conclusion reduction of necessary total power of a power source and elimination of the accelerated blunt of cutting knives.

The two-chamber pneumatic module with contour grooves creates equable resistance in the working zone of cutting the contours by the prepared compressed air. This will increase the wear resistance and durability of the cutting knives. It should also be noted that the formation of the contours of the cardboard scan will be performed much better. Reducing the number of additional technological operations for the preparation of the semi-finished product will increase the productivity of the machine.

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В статті запропоновано новий спосіб прорізування контурів у картонних розгортках та пристрій для його реалізації.

Ключові слова: картонна розгортка; висікальний ніж; ежекторна подушка; стиснене повітря; перфораційний паз; пневматична камера.

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