

# Study of the clamping force in a pneumatic wedge device

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**Abstract.** The continuous development of computing technology and design and manufacturing software applications have contributed to improving clamping devices used in manufacturing processes, which led to an increase in the quality of cut parts. This paper presents a study on the variation of the clamping force depending on the constructive and exploitation parameters of a pneumatic wedge device.

## 1. Introduction

In the context of companies' competition on the market, continuous improvement of products requires preparation and realization of manufacturing in a short period of time and with minimal expenses. One of the main ways to increase quality, productivity, and reduce expenses is to realize rationally designed and built technological equipment. Compared to the technological equipment used in manufacturing processes, the clamping devices used in manufacturing have the largest share.

Starting from a variant of a manually operated clamping device intended for small series production, an improved variant intended for large series production is presented, in which the action is carried out by a linear pneumatic cylinder with double action. The paper addresses an important topic in clamping device design, namely the study of the variation of the clamping force according to the constructive and operational parameters of the device.

In literature, numerous studies address different aspects in the field of technological devices.

Article [1] presents an algorithm for computer-aided design of a device for parts with freeform surfaces. Based on the algorithm, the minimum number of clamping elements is determined, as to maintain the stability of the part.

Paper [02] presents the design of mechanical clamps with extra-long wedge grips for static and fatigue testing of composite materials in tension and compression.

In thesis [03], the study of a device layout and clamping force for a disk in a numerically controlled vertical lathe were based on factorial experiments and it was established the shape (layout) of the clamping device. By finite element method, the displacements for the range of variation of the clamping force.

By using finite element method for the dynamic analysis of the workpiece clamping system in [04], the clamping force was optimized as to result in the minimal deformation of the workpiece.

Also, by using finite element method, [05] presents the study of a device for "thin-walled curved surface parts" and analyzes the deformation of clamped parts.

In [06], a study on the recent developments on computer-aided device design presents a design solution by using artificial intelligence and proposes to integrate the design steps in order to obtain an effective device.

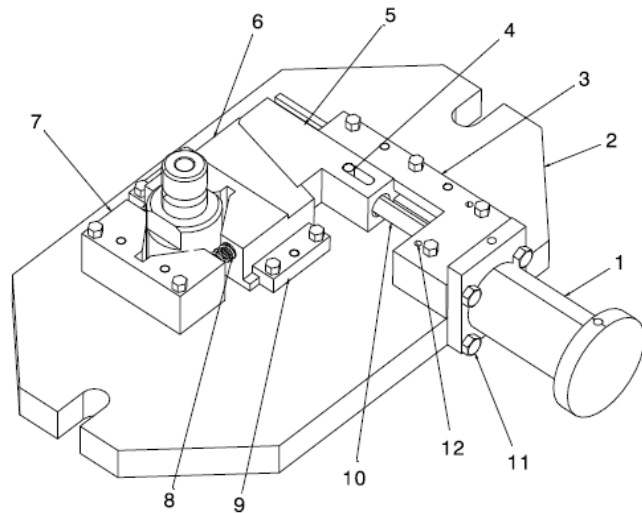
## 2. Fixture design

Wedge clamping mechanisms are characterized by the existence of one or more wedges in their structure, which clamp the workpiece by the action of external forces. The transmission of external forces can be done directly on the blank or indirectly through intermediate elements. The device is intended for clamping cylindrical parts, in order to process the front surface.

The first variant of the manually operated device is shown in figure 1. The clamping force is achieved by rotating the screw (1), which moves the wedge clamp (2) and acts on the mobile clamp (3).

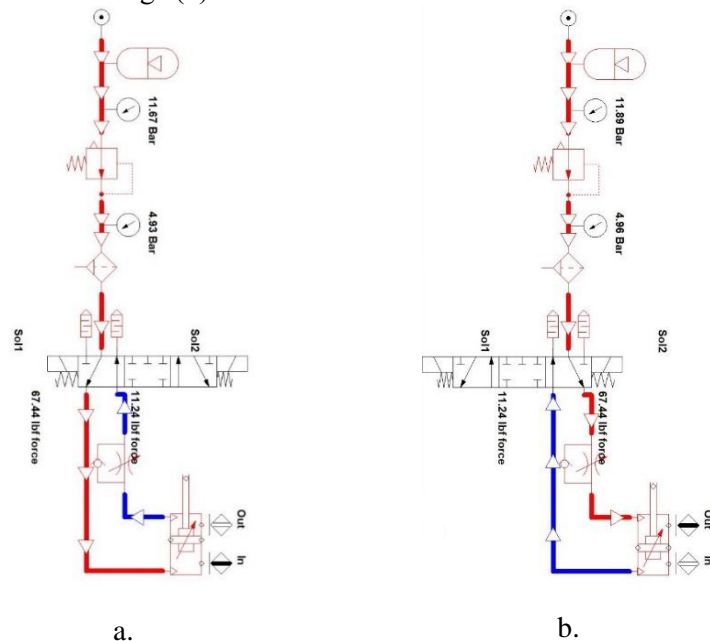


**Figure 1.** Manually operated device.



**Figure 2.** Pneumatic operated device.

For large series production, a variant of pneumatic drive device shown in figure 2 has been proposed. On the device, the acting force of the wedge mechanism is achieved by the double-action pneumatic actuator (1), fixed in horizontal position on the structure of the device base plate, as well as on the guiding system of the mobile wedge (3).



**Figure 3.** Pneumatic diagram designed for device operation.  
a. for locking; b. for unlocking

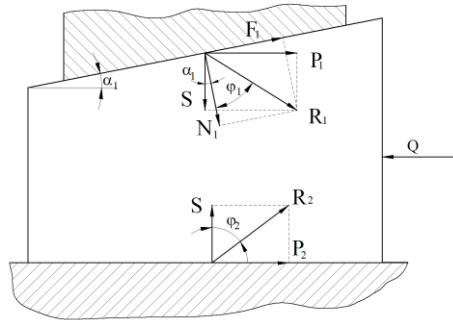
The pneumatic cylinder rod ensures that through the cylindrical bolt action (4), the connection between the movable wedge (5), which acts on the movable prism (6) is realized, and which clamps the part by moving the wedge.

The pneumatic diagram designed for device operation is shown in figure. 3.a, b, the electromagnetically controlled position of the type 5/3 pneumatic distributor at the clamping of the blank in the device, indicates the compressed air circuit, which determines a pushing force on the wedge which by linear motion actuates the fixing system.

According to the pneumatic diagram shown in figure 3.a, it can be observed that the wedge motion (5) is done at lower speed, which is achieved by pushing a linear stroke, which determines the motion of prism (6) from right to left, achieving blank clamping and orientation. The track drosel restricts the compressed air flow through the sense valve, thus achieving a lower travel speed. In the pneumatic scheme shown in figure 3, b it can be seen that when the blank is unscrewed from the device, the motion of the mobile wedge is made in reverse with higher speed by pulling. In this case, the track drosel does not restrict the compressed air flow through the sense valve, thus achieving a higher retraction speed, favoring a hydraulic shock, so that it does not remain stuck.

### 3. Clamping force

The clamping forces are calculated by considering the wedge in Figure 4., on which the outer force  $Q$  acts in the wedging direction. Due to the action of external force  $Q$  on the inclined and horizontal plane, the normal force reactions  $N_1$  and  $N_2$ , respectively the friction forces  $F_1$  and  $F_2$  result. By combining these forces, the resultant forces  $R_1$  and  $R_2$  appear, which are decomposed by horizontal and vertical directions, so forces  $P$  and  $S$  are obtained.



**Figure 4.** Sketch for calculating the clamping forces.

Knowing the acting force  $Q$ , the clamping force "S" can be determined using the diagram in figure.4.

$$Q = P_1 + P_2 \quad (1)$$

$$P_1 = S \cdot \operatorname{tg}(\alpha_1 + \varphi_1) \quad (2)$$

$$P_2 = S \cdot \operatorname{tg}(\varphi_2) \quad (3)$$

$\alpha_1$  –the wedge angle

$\varphi_1$  și  $\varphi_2$  – are the friction angles on the two sides of the wedge

$$\varphi_1 = \operatorname{arctg} \mu_1 ; \quad \varphi_2 = \operatorname{arctg} \mu_2 \quad (4)$$

$\mu_1$  și  $\mu_2$  are the friction coefficients on the two sides of the wedge

After replacement results:

$$S = \frac{Q}{\operatorname{tg}(\alpha + \varphi_1) + \operatorname{tg} \varphi_2} \quad (5)$$

The clamping mechanisms must comply with the self-braking condition in order to keep the blank in the device after the external force ceases to act,

The self-braking condition involves the determination of the  $\alpha$  angle, so that it will not self-operate when the drive  $Q$  equals 0.

By approximating  $\varphi_1 = \varphi_2 = \varphi$ , after calculations, the relationship (5) becomes:

$$\operatorname{tg}(\varphi - \alpha) + \operatorname{tg} \varphi = 0 \quad (6)$$

in order to have self-braking, must

$$\alpha < 2\varphi$$

Considering that the surfaces of the feathers are small roughness, the friction coefficients  $\mu = 0,1 \dots 0,15$ , respectively  $\varphi = 5^{\circ}43'$ , where we get

$$\alpha < 10^{\circ} \dots 12^{\circ} \text{ if } \mu = 0,1, \text{ and } \alpha < 16^{\circ} \dots 18^{\circ} \text{ if } \mu = 0,15$$

#### 4. Numerical study

The purpose is to determine the variation of the clamping force depending on the working pressure and the angle of inclination of the wedge and the diameter of the piston. The pressure parameters and the angle of inclination considered have a continuous variation between the following limits:

$$p : 0,4 \dots 0,8 \text{ MPa}; \alpha : 8^{\circ} \dots 18^{\circ}; D : 10, 12, 16, 20, 25, 32 \text{ mm}$$

From figure 5 result in how the three parameters influences the clamping force. It can be seen that the clamping force varies in proportion to the pressure and the diameter of the pneumatic actuator and inversely proportional to the angle of the wedge.

In figure 6 is shown the 3D variation of the clamping force depending on the air pressure and the wedge angle.

Parallel Plot Representation offers a better understanding of dependencies between variables, constraints, and system response. Each variable and system response is represented on a vertical axis and has its own representation scale. The combinations between variables and system response are represented as a series of lines connected to each axis. Using the parallel plot representation, one can determine the parameters that can produce a particular clamping force. For example, the parameters that produce a clamping force contained in the interval 600-700 N are those connected with the blue lines in figure. 7.

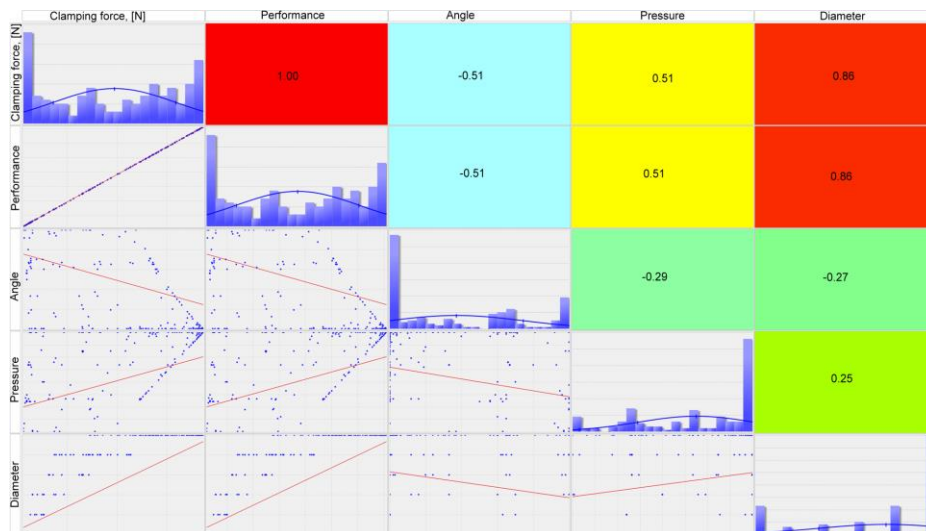
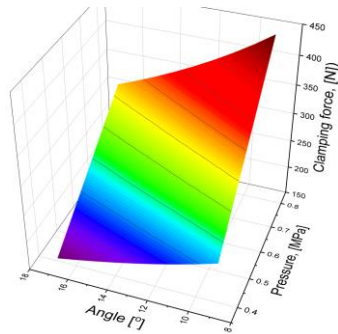
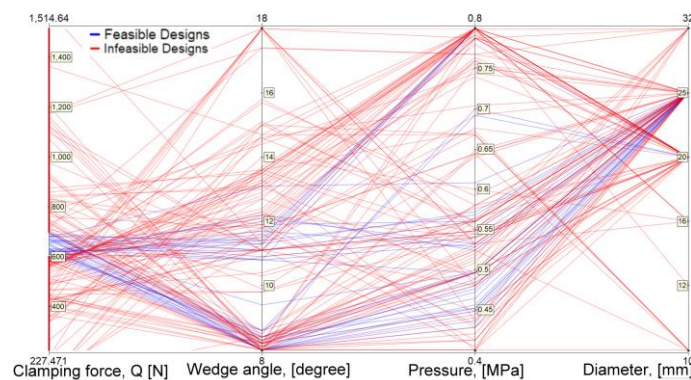


Figure 5. Correlation plot.



**Figure 6.** Clamping force vs. air pressure and wedge angle.



**Figure 7.** The parallel plot.

## 5. Conclusions

A quick-acting wedge device driven by an actuator has been designed to reduce the clamping time. According to these parameters, it was determined the relationship of calculation of the clamping force according to the constructive parameters and the air pressure at the compressed air network,

Numerical research was carried out on the variation of the clamping force., and it was shown that the clamping force increases when increasing the pressure and diameter of the pneumatic cylinder and when decreasing the angle of the drive wedge.

## References

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