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DESIGN AND GRAPHIC MODELING OF FIXTURING DEVICES SPECIALIZED FOR MANUFACTURING INDUSTRY

Abstract: *The technological design of devices has a significant share in the industrial field and, therefore, any study that highlights, through concrete examples, the main issues regarding the design of devices used, especially in the machine building industry, is welcome. The paper presents three fixturing devices specialized for the drilling operation of some technical pieces encountered in the field of hydraulic drives - spool valve, fixing clamp and flange support ventilation self-cleaning filter system. Both the pieces and the devices were made with the help of Autodesk Inventor program, a software package that streamlines as concrete and precise as possible the 3D modeling of solids.*

Key words: *fixturing, manufacturing, Autodesk Inventor, devices, graphical modelling.*

1. INTRODUCTION

The phenomenon of machining customization and advances in manufacturing lead to the need to redefine and reconstruct the conceptual of some manufacturing systems. In this context, an important role in a technological system is played by clamping devices, with reflections in increasing labor productivity and processing accuracy of the blanks, according to the specifications prescribed by the designer, with the acquisition of the principles of designing devices, the formation of skills in a specific engineering field and the development of decision-making capacity in order to optimize the technological process [1], [2], [3], [4]. Fixturing devices are thus designed to facilitate both the production of unique pieces or small batches, with multiple clamps, and for the production of large batches. An essential advantage is that there is the possibility of reusing the elements of the devices, which guarantees a flexible and cost-effective application in the manufacturing process. In essence, the essential aspects of device design must be well known and mastered, starting from the definition of technological systems and processing errors, the elaboration and establishment of basic schemes, the presentation of the orientation of the blanks and the calculation of basic errors, types of supports used in the construction of the devices, the construction and exploitation of the supports, with the conditions imposed on them, up to the construction and modeling of the locking and tightening mechanisms, with the highlighting of errors and tightening schemes [5], [6]. It is necessary to define, as broadly as possible, the tightening mechanisms (with wedges, with thread, with eccentric, the centering and tightening mechanisms with prisms, with levers), or the centering and tightening mechanisms with wedges and plungers [7], [8]. In a world with a growing demand for customization and adaptability, correlated with ever-increasing productivity, design and simulation solutions must be found to save time and increase productivity and quality. By combining the facilities offered by CAD software with the possibilities of their simulation, complex devices can be generated quickly, taking into account the constraints imposed by the manufacturing process, but also the performance requirements of the product [9], [10].

2. GRAPHICAL MODELLING OF FIXTURING DEVICES

The modelling of the fixturing devices was made in Autodesk Inventor software program. Each component was modelled in Autodesk Inventor Part software (**.ipt*), using both 2D drawing commands such as *Line*, *Arc*, *Rectangle*, *Circle* and 3D commands such as *Extrude*, *Sweep*, *Loft*, *Mirror*, *Thread*, *Chamfer*, *Revolve* etc.

After modeling all components, the fixturing devices were assembled in Autodesk Inventor Assembly software (**.iam*). In this program, constraints were used for a correct and precise assembly of all the components that form the three fixturing devices specialized for drilling operation of the pieces of the spool valve, fixing clamp and flange support ventilation self-cleaning filter system, such as *Mate* and *Flush*, *Offset Constraint*, *Angle Constraint* etc.

2.1 Modeling of the fixturing device specialized for drilling operation of the spool valve

Among the devices that have the role of distributing the flows of liquid in the hydrostatic installations, in accordance with the orders they receive, directional-control valves with spool occupy the most important place, differing according to a series of criteria such as: the number of channels, distribution scheme and the nature of the switching command.

The role of the directional-control valves is to direct the fluid, to establish or to close one or more flow paths, under the action of different commands (manual, electrical, hydraulic etc.). Each directional-control valve is composed of a fixed part, which constitutes the directional-control valve`s body, and a movable part, representing the distribution mechanism.

The main advantages of these directional-control valves are: simple constructive and technological form; very good pressure balance, in axial and circumferential direction; due to the pressure balancing, they have a high coupling efficiency, respectively actuating force for achieving reduced switching; provides a multitude of control functions [11], [12], [13].

Figure 1 shows the 3D model of the spool valve part, made with the help of Autodesk Inventor software program.

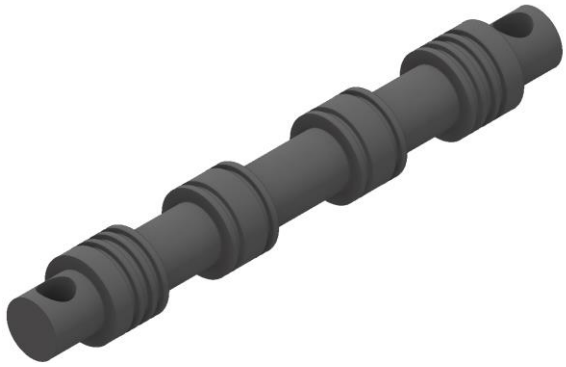

Figure 1 Virtual model of the spool valve.

In order to perform the drilling operation, figure 2, of the spool valve part, a drilling device is used.

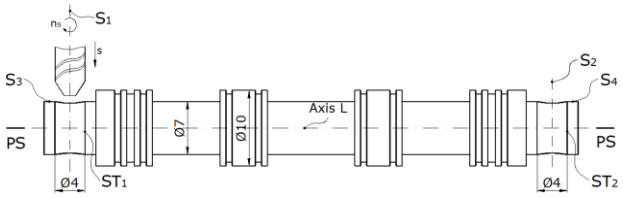

Figure 2 Sketch of the drilling operation.

The geometric and technological conditions imposed are:

1. The axes S_1 and S_2 are in the same plane of symmetry of the piece, *PS*, which contains the longitudinal axis, *L*.
2. The axes S_1 and S_2 are perpendicular to the longitudinal axis, *L*.
3. The processing is done on the length of 7 mm, for the target surfaces ST_1 and ST_2.

By using a device for holding the spool valve, a uniformity of the processing process, a reduction of working times, as well as the safety of the operator are obtained. The orientation elements contain prisms, cylindrical head screws with hexagonal hole and cylindrical pins, supporting pins, corner supports, fixing clamps, plates, bolts, bushes etc.

Figures 3 and 4 show the sketch, respectively the 3D model of the fixturing device specialized in drilling operation of the spool valve part.

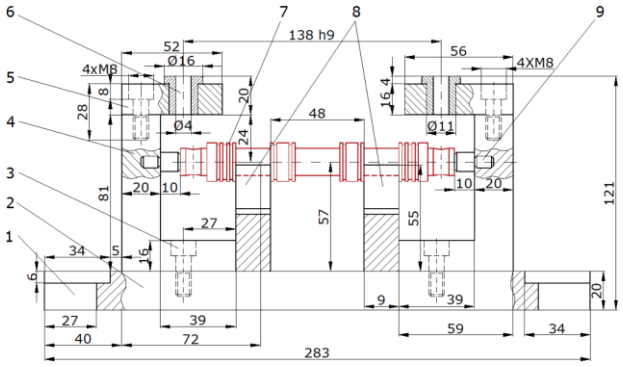

Figure 3 Scheme of the fixturing device for the spool valve: *1 - fixing hangers; 2 - base plate; 3 - screw M8x1; 4 - corner support; 5 - guiding plate for bushes; 6 - guiding bushes; 7 - spool valve; 8 - supporting prisms; 9 - supporting pin with plate cylindrical head.*

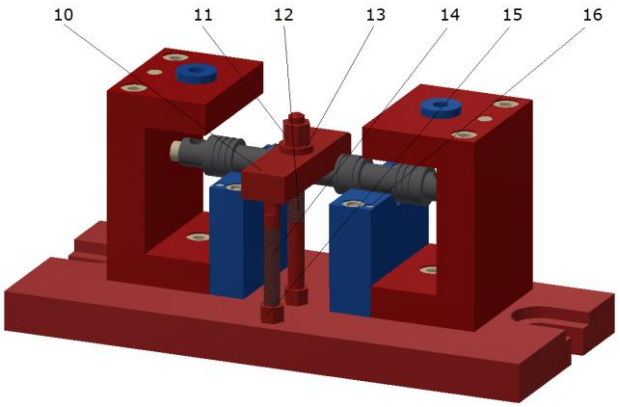

Figure 4 3D model of the fixturing device for the spool valve: *10 - fixing clamp; 11 - hexagon nut with collar; 12 - screwed bolt; 13 - conical hole plate; 14 - variable supporting pin; 15 - thick hexagon nut; 16 - B-type cylindrical pin.*

The spool valve (the blank) *7* is placed in the device with the surface in contact with the two supporting prisms, *8*, mounted on the rectangular base plate, *2*, of the device. Two screws with cylindrical head with hexagonal hole, *3* and two B-type cylindrical pins, *16*, are used to fix the prisms in the base plate.

The two supporting pins, *9*, are mounted on the base plate, *4*, in order to be oriented in a horizontal position.

The pins are mounted in the device body by pressing with with tight fit. Fixing the corner in the base plate is done with the help of 2 M8 screws and two cylindrical pins. The fixing of the corner support on the base plate is made by 2 M8 screws and two cylindrical pins.

The blank is fixed for processing using a fixing clamp, *10*. The clamp is fixed with screwed bolt *12* and hexagon nut with collar *11* supported by the conical hole plate *13* and variable supporting pin *14*.

Both supporting pin and screwed bolt are mounted on the base plate of the device with the thick hexagon nut *15*. In order to mount the device on the cutting machine table, the fixing hangers *1* are used.

The guiding bushes of the cutting tools *6* are mounted on the guiding plate *5* for processing the holes of the blank.

After processing, the final part is removed from the device.

2.2 Modeling of the fixturing device specialized for drilling operation of the fixing clamp

In general, for the processing of unique parts, the drilling operation is performed on special devices. By using a device it achieves a uniformity of the processing process, a reduction of working times, as well as the safety of the operator.

In the drilling process of the ”clamp” part, a fixturing device is used, for the design of which the orientation and fixing schemes of the part must be specified, as well as its orientation elements. The fixing clamps are built on the principle of levers of degree I, II, III. They are easy to handle, which is important in terms of the operator's effort and the time of the grip and release.

Figure 5 shows the virtual model of the clamp part, made in Autodesk Inventor program.

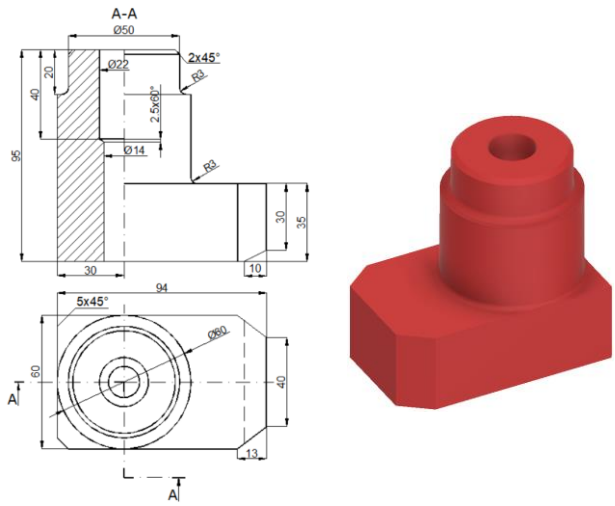

Figure 5 Virtual model of the fixing clamp.

In order to perform the drilling operation of the clamp part, a drilling device, figures 6 and 7, is used.

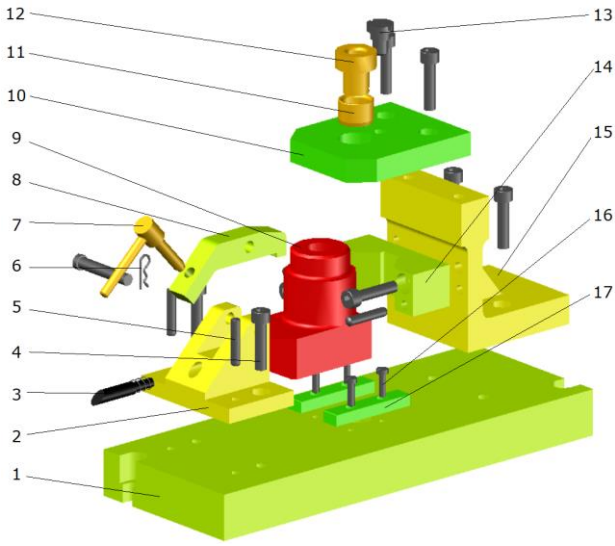

Figure 6 Fixturing device components:
1 - base plate; 2 - clamp support; 3 - mobile pin with spring; 4 - screw M10x50; 5 - cylindrical pin; 6 - bolt with head and splint; 7 - screw with fixed handle and pin; 8 - fixing clamp; 9 - clamp part; 10 - plate for bushes; 11 - fixed bush; 12 - removable bush; 13 - fixing screw for bushes M10; 14 - supporting prism; 15 - support; 16 - screw M6x20; 17 - support plate.

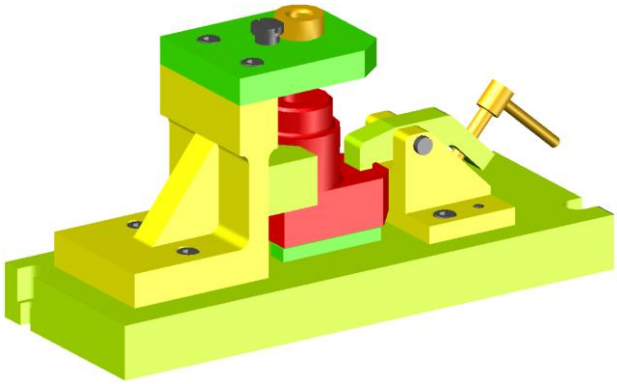

Figure 7 3D model of the fixturing device for the fixing clamp.

The clamp (the blank), *9*, is placed on the support plates *17*, with the contact surface towards the supporting prism *14*, which is fixed to the support *15* with hexagon head screws, *13* and pins, *5*.

The support plates *17*, the support *2* and *15* are fixed to the base plate *1* with hexagon head screws and pins. The mobile pin with spring, *3*, is mounted inside the support *2* and is driven by the screw with fixed handle *7*. The screw with fixed handle is screwed on the two-direction fixing clamp, *8*, until the contact moment with the mobile pin. The fixing clamp is mounted on the support *2* by means of the bolt with head and splint, *6*.

The plate for bushes *10* is fixed on the support *15* with the screws *13*. On this plate are mounted the fixed bush *11*, for performing the enlargement operation and the removable bush *12*, for for performing the drilling operation. After processing, the final piece is removed from the device.

2.3 Modeling of the fixturing device specialized for drilling operation of the flange support ventilation self-cleaning filter system

For the design of a fixturing device specialized for drilling operation of the ”Flange support ventilation system self-cleaning filter” part it is necessary to follow the steps: defining the geometric and technological structure of the part - making the execution drawing and axonometric sketch of the part; surface identification and coding; defining the technological operations plan; designing the orientation mechanism; calculation / choosing of / the orientation elements; fixing mechanism design; defining the geometric and functional structure of the device - making the sketch of the fixturing device and the assembly design of the device.

The piece from figure 8 is a flange of a ventilation support from a self-cleaning system of a filter from a marine ballast water treatment installation, made in Autodesk Inventor program.

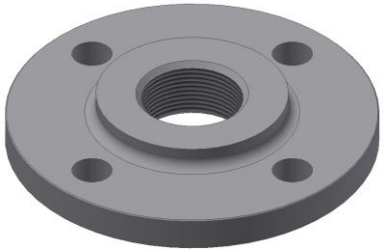

Figure 8 Virtual model of the flange.

The flange is mechanically operated and is an element of a combined air valve, which has the characteristics of both an air release valve and an air / vacuum valve. The air release component is designed to automatically release small air gaps into the atmosphere as it accumulates along a pipe or duct system when it is full and operating under pressure.

This valve will open to relieve negative pressures whenever water column separation occurs. The working pressure range varies between 0.2÷16 bar. A special clamping device has been designed for a helical drill with a diameter of Ø16 mm, in order to perform the drilling operation for the flange part.

In order to design the device, the geometric and technological structure of the part was taken into account, a calculation was made for the established processing operation and the sketches of the orientation mechanism of the device were designed, as well as the corresponding orientation elements, these being made with the AutoCAD and Autodesk Inventor software package, figures 9÷12.

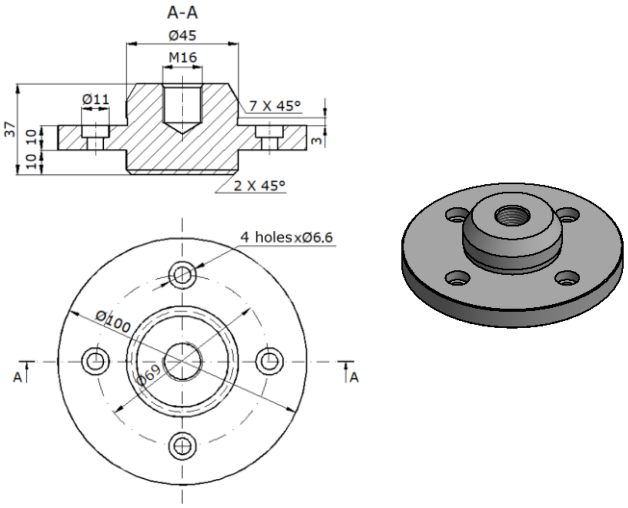

Figure 9 Seating plate with cylindrical bolt for centering.

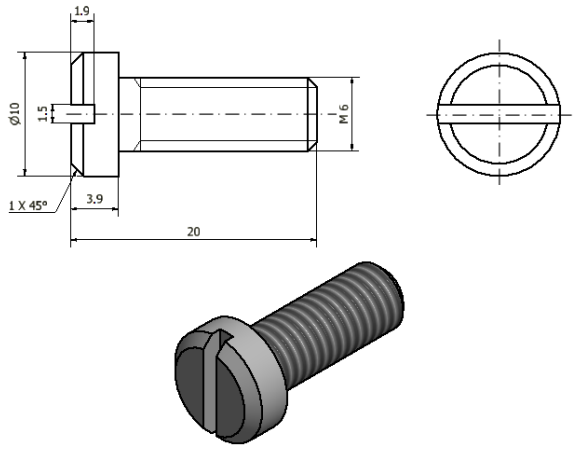

Figure 10 M6 screw with notched cylindrical head.

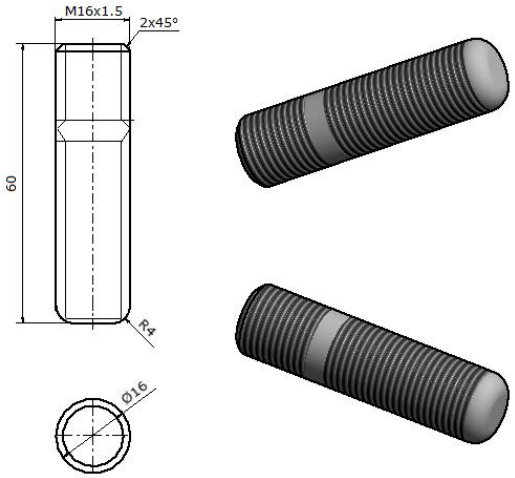

Figure 11 Screwed bolt.

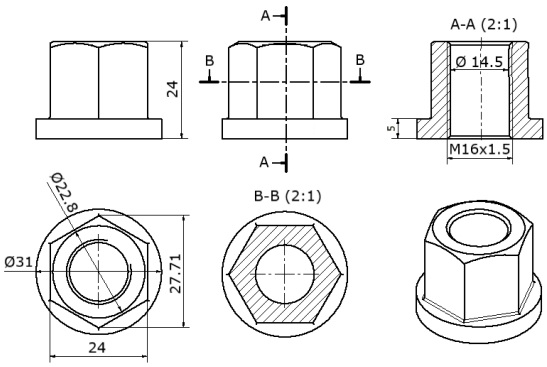

Figure 12 Flat detachable plate.

The components of the drilling device are shown in figure 13.

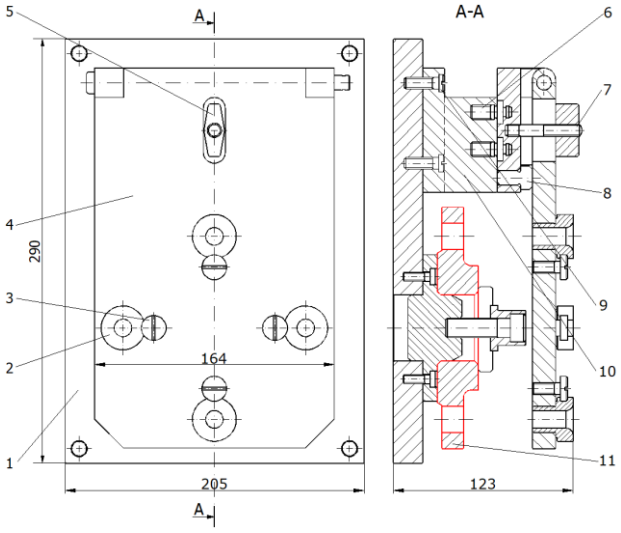

Figure 13 Fixturing device components of the flange: *1 - base plate; 2 - guiding bush; 3 - screw M6x1; 4 - folding plate; 5 - removable plate nut; 6 - centering bolt; 7 - bolt; 8 - supporting pin with cylindrical head; 9 - screw M8x1; 10 - hinge plate support; 11 - flange support ventilation self-cleaning filter system.*

Figure 14 shows the 3D model of the drilling device specialized for the drilling operation of the flange support ventilation self-cleaning filter system part.

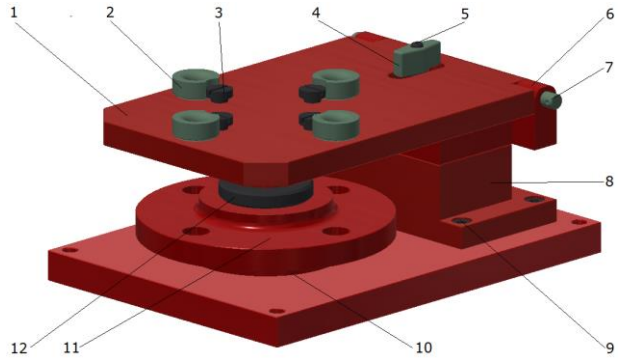

Figure 14 3D model of the fixturing device for the flange: *1 - folding plate; 2 - removable bush; 3 - screw M8x1; 4 - removable plate nut; 5 - bolt; 6 - hinge plate; 7 - hinge bolt; 8 - hinge plate support; 9 - screw M6x1; 10 - seat-support plate; 11 - flange support ventilation self-cleaning filter system; 12 - base plate; 13 - flat detachable plate.*

Therefore, the drilling device with the base plate is fixed on the table surface of the drilling machine. The plate *1* is folded in an upright position. The seating plate *10* is fixed on the base plate *13*, with the help of the tightening screws. The drilling flange *11* is fixed, the bolt *5* is fixed in the seating plate and the removable plate nut *4* is tightens. Then, the plate 1 is folded in a horizontal position. To perform the drilling and enlargement operations of the holes of the "flange" part, the mounting of the exchangeable bushes on the folding plate will be used. The "removable bush" guide element is used as the main guide element for drilling operation.

The removable bushes *2* will be fixed in the fixed bushes, the blocking being done with the M8 fixing screws with notched head for removable bushes, *3*. The folding plate will be fixed on the supporting pin with the help of the bolt and the tightening nut. The Ø16 mm drilling operation is performed and for the enlargement operation, the removable bushes will be extracted from the space of the fixed bushes.

After processing, the final piece is released from the device.

3. DESIGN OF THE FIXING MECHANISM OF THE DRILLING DEVICE SPECIALIZED FOR DRILLING OPERATION OF THE FLANGE PART

Figure 15 shows the application scheme of the cutting-fixing-operating forces for the flange support ventilation self-cleaning filter system.

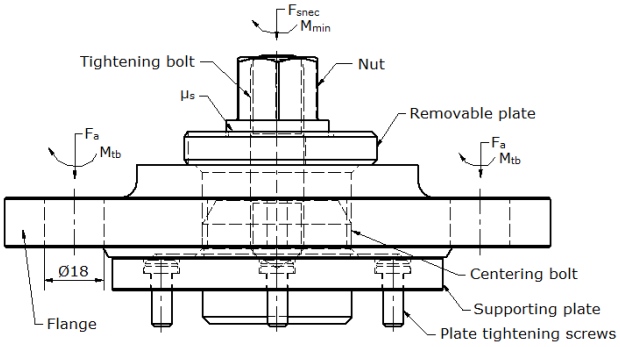

Figure 15 Application scheme of the cutting-fixing-operating forces.

Figure 16 shows the virtual model of the assembly support ventilation self-cleaning filter system.

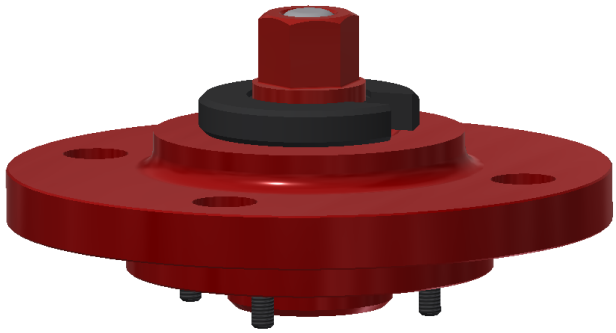

Figure 16 Virtual model of the assembly support ventilation self-cleaning filter system.

Calculation of the fixing and operating forces

The fixing condition is:

$$F_s \geq \frac{K_s \cdot M_t}{\frac{D_{AG}}{2} \cdot \mu_s} = F_{snec}\,[\mathrm{N}], \tag{1}$$

where:
- F_s represents the fixing force;
- F_{snec} - minimum tightening (fixing) force;
- μ_s - friction coefficient; μ_s=0.15;
- M_t - torsion moment of the cutting process; M_t=16 N·m;
- D_{AG} - circle diameter of the holes centers of Ø18 mm of the flange; D_{AG}=125 mm;
- K_s - safety coefficient of fixing the blank in the device:

$$K_s = K_1 \cdot K_2 \cdot K_3 \cdot K_4, \tag{2}$$

where:
- K_1 is the coefficient related to the non-uniformity of the processing addition; K_1=1.8;
- K_2 - influence coefficient of the supporting surface size; K_2=1;
- K_3 - coefficient that takes into account the continuity of the cutting process; K_3=1;
- K_4 - coefficient that takes into account the increase of external forces due to the wear of the cutting tools; K_4=1.15.

$$K_s = 1.8 \cdot 1 \cdot 1 \cdot 1.15 = 2.07.$$

Replacing in relation (1) is obtained:

$$F_{snec} = \frac{K_s \cdot M_t}{\frac{D_{AG}}{2} \cdot \mu_s} = \frac{2.07 \cdot 16}{\frac{125}{2} \cdot 0.15} = 3.53\ \mathrm{N}.$$

The tightening moment M of the medium manual operation force, F_m, is calculated with the relation:

$$M = F_m \cdot L_m \cdot 10^{-3}\ [\mathrm{N \cdot m}], \tag{3}$$

where:
- F_m=100÷150 N; it has been chosen F_m=150 N, and:
- L_m=250 mm - the length of the operating lever (fixed wrench).

$$M = 150 \cdot 230 \cdot 10^{-3} = 34.50\ \mathrm{N \cdot m}.$$

The fixing force, F_s, is calculated with the relation:

$$F_s = \frac{F_m \cdot L_m}{\frac{d_f}{2} \cdot tg(\alpha + \varphi) + \frac{\mu_s}{3} \cdot \left(\frac{D^3 - d^3}{D^2 - d^2}\right)}, \tag{4}$$

where:
- d_f is the diameter of the tightening bolt; d_f=16 mm;
- D - outer diameter of the plate; D=60 mm;
- d - inner diameter of the plate; d=17 mm;
- α - angle of the thread screw calculated with relation:

$$\alpha = arctg\left(\frac{p_f}{\pi \cdot d_f}\right)[^{\circ}], \tag{5}$$

where p_f is the thread pitch; p_f=1.5 mm;

$$\alpha = arctg\left(\frac{1.5}{\pi \cdot 16}\right) = 1.71^{o}.$$

- φ - the friction angle between the thread whirls, calculated with the relation:

$$\varphi = arctg\mu_f \left[^{o}\right]. \quad (6)$$

where μ_f is the the coefficient of wet friction from the thread; μ_f = 0.12;

$$\varphi = arctg\,0.12 = 6.84^{o}.$$

Replacing in relation (4) is obtained:

$$F_s = \frac{150 \cdot 250}{\frac{16}{2} \cdot tg\left(1.71 + 6.84\right) + \frac{0.15}{3} \cdot \left(\frac{60^3 - 17^3}{60^2 - 17^2}\right)} = 3.61 \text{ N}.$$

Verification of the mechanism:

$$\left.\begin{array}{l} F_s \geq F_{snec}; \\ 3.61 \text{ N} \geq 3.53 \text{ N} \end{array}\right\} \Rightarrow \text{ the condition is accomplished.}$$

4. CONCLUSIONS

The advantages of using devices in the manufacturing process are multiple, from supporting and stabilizing the blanks or pieces during the clamping process, to the exact positioning on the basic elements or to processing several workpieces in a single processing cycle.

The paper provides those interested in the directly productive sphere, information related to the practical design of three devices, but highlights and leaves open many other approach directions of which can be as many suggestions for other important developments in the field of devices design.

ACKNOWLEDGEMENT

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