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# GRAPHICAL MODELLING OF A HYDROMECHANICAL DRAWING DIE

***Abstract:*** *Hydroforming processes have become increasingly popular in recent years, due to the increasing demand for light parts in various fields, such as the automotive, aircraft and aerospace industries. This technology is relatively new compared to other processing procedures, such as lamination, forging or stamping. This paper presents some basic concepts about hydroforming procedures, as well as 3D graphical modeling of a hydro-mechanical drawing die made in the Autodesk Inventor software program.*

***Key words:*** *die, hydroforming, drawing, Autodesk Inventor, graphical modelling.*

## 1. INTRODUCTION

Hydroforming is an unconventional technology based on the influence of high-pressure liquid on the inner or outer part of the semi-manufactured wall. The pressure exerted by the liquid gives the semi-manufactured the shape of the inner active psheet or the outer contour of the punch [1], [2].

This technology is used for deformation in a single operation of parts with complex configuration, but also those of spherical, parabolic, tapered shape, replacing their execution by several operations of ordinary drawing.

Hydroforming is very useful for the production of whole components which would otherwise be made of several stamps merged together. For instance, a typical component of the chassis of a car, which would normally be done by pressing up to six sections of the channel and by welding, can be hydroformed into a single piece [3].

The components of a hydroforming system are shown in Figure 1.

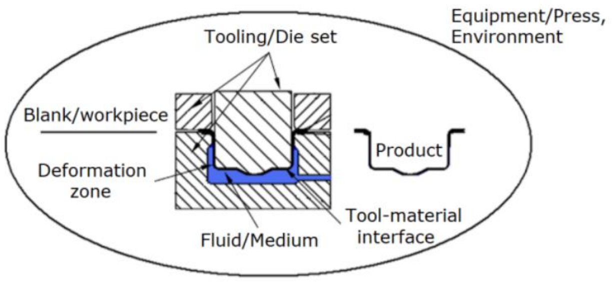



**Figure 1** Hydroforming system elements [4], [5].

The hydroforming system presents a series of advantages [1], [5]:

*a.* the drawing dies are simple, the punch is made of steel only in the case of steel sheet parts, but also when used unheated. For the drawing of parts made of non-ferrous materials, the punch of hydromechanical die-block is made of aluminium-zinc alloys, plastics or hardwood. Only an active element is rigid, so it is no longer necessary to make a precise and uniform drawing game, and processing can be done without using the press.

*b.* the pressure exerted by the liquid on the semi-manufactured is uniform; The high and uniform pressure of the liquid creates a state of tension and deformations more advantageous, allowing to obtain conical, spherical, parabolic, cylindrical, complex and deep parts.

*c.* the accuracy and quality of the drawn parts are better than in the case of the parts obtained by ordinary drawing due to the absence of sliding friction between the semi-manufactured and the active plate. The economic efficiency of the hydraulic drawing process is more evident in processing parts of complex form which are difficult to obtain by the ordinary drawing methods.

*d.* reducing the cost of the die;

*e.* increasing the drawing depth;

As a disadvantage of the process, a relatively low productivity might be pointed out in most situations of use due, in particular, to the working characteristics of hydraulic systems in general.

The degree of deformation in hydraulic drawing is higher than in ordinary drawing. Sealing the space in which the hydrostatic pressure is created is done with elastic membrane, rubber cushion or even by the semi-manufactured (also using a gasket).

The working pressure depends on the dimensions of the part, the degree of deformation and the processed material, with values within 5...30 MPa.

The classification of the hydroforming process is presented in Figure 2.

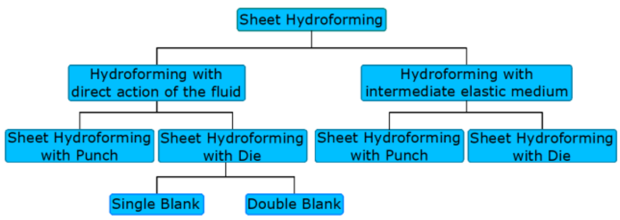



**Figure 2** Sheet hydroforming process classification [5].

Hydroforming may also have other specific names, such as hydromechanical drawing, hydraulic drawing or punch drawing.

## 2. GRAPHICAL MODELLING OF A HYDROMECHANICAL DRAWING DIE

In the Autodesk Inventor Part software (*.ipt), each component within the hydromechanical drawing die is modelled, highlighting both 2D drawing commands such as *Line*, *Circle*, *Arc*, 3D controls such as *Extrude, Revolve, Loft, Sweep*, as well as editing commands -

*Fillet*, for connection, *Chamfer*, for bevels, *Mirror*, for making symmetricals, etc. [6], [7], [8], [9], [10].

***Modelling the "upper plate" landmark***

Choose a projection plane, in this case the XZ plane, in the Sketch module, in which the outline of the upper plate is designed, as well as the holes and grip holes associated with it, using the *Line* and *Circle* controls.

The Extrude command, at a height of 25 mm, produces the 3D model of the upper plate. For the graphical representation of the guide pieces, the *Extrude* and *Hole* controls are used, as well as the *Fillet* command, for defining their connection beams, with a value of 8 mm, thus, obtaining the final virtual model of the "*upper plate*" Figure 3.

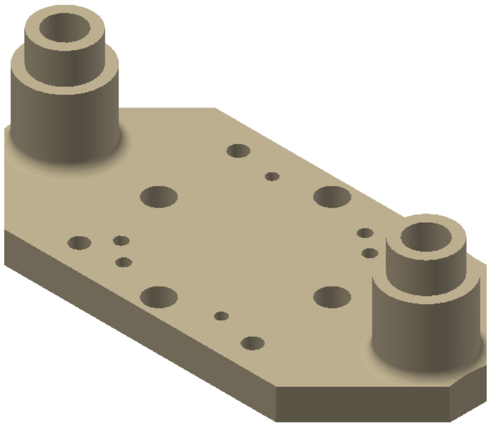


**Figure 3** The virtual model of the "*upper plate*" landmark.

***Modelling the "restraint plate" landmark***

Figure 4 presents the 2D model of the restraint plate, using the *Line* and *Circle* commands with specific dimensions in the *Sketch* module.

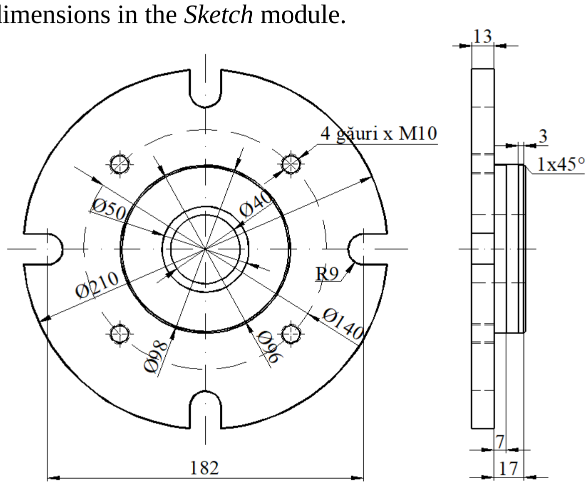



**Figure 4** Sketch of the "*restraint plate*" landmark.

With the help of the *Extrude* control at 13 mm, respectively, 18 mm highs, and *Hole*, with the dimensions shown in Figure 4, the 3D model of the *„restraint plate"* marker is obtained.

Using the *Chamfer* control, the upper part of the restraint plate will be chamfered at dimensions of 1x45o mm 5.

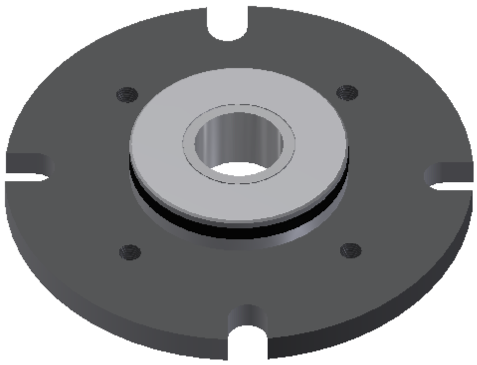


**Figure 5** The virtual model of the "*restraint plate*" landmark.

***Modelling the "cavity retainer plate" landrmark***

For 2D modelling of the "*cavity retainer plate*" landmark, the *Line* and *Circle* drawing commands shall be used, having the corresponding dimensions presented in Figure 6.

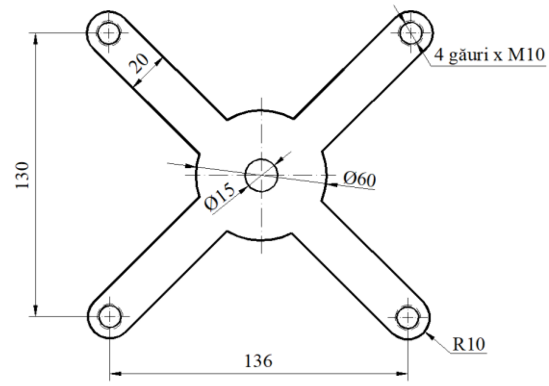



**Figure 6** The virtual model of the *"cavity retainer plate"* landmark.

By using the Extrude command, at a height of 16 mm and the Thread command, in order to generate the threads (in this case, M10), the virtual model of the *"cavity retainer plate "* landmark is obtained, Figure 7.

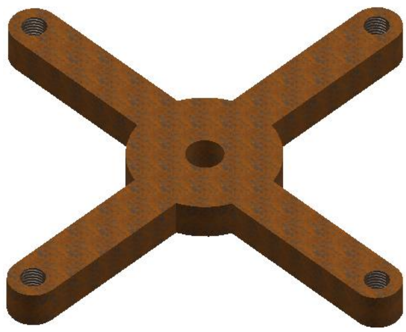


**Figure 7** Virtual model of the *"cavity retainer plate"* landmark.

***Modelling of the "port-punch plate" subassembly***

For the purpose of modelling the punch, the *Revolver* command shall be used, which prints a 360° rotation from the *Z*-axis, resulting in its 3D shape and having the corresponding dimensions in Figure 8.

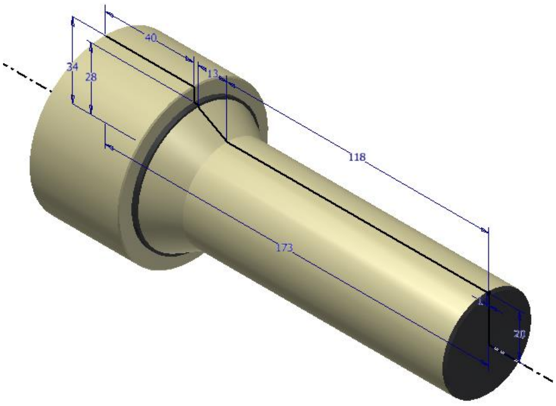



**Figure 8** Virtual model of the punch.

The plate will be modelled using the *Line*, *Circle*, *Circular*, *Pattern* and *Chamfer* - for chamfering, and Fillet controls - for connection, resulting in the virtual model of the "*port-punch plate*" subassembly.

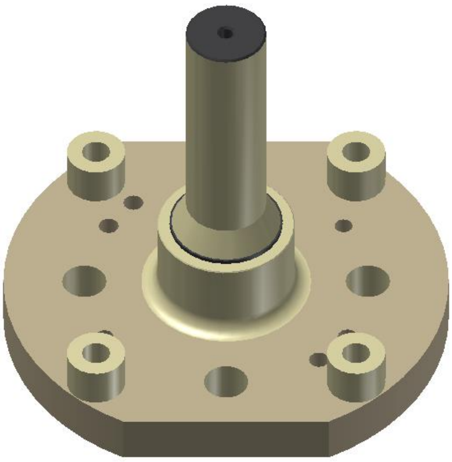
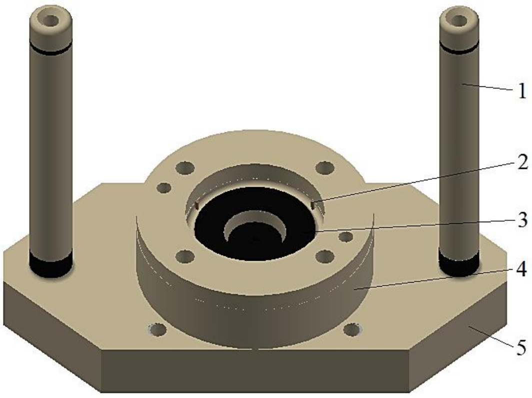


**Figure 9** Virtual model of the *”port-punch plate*”.

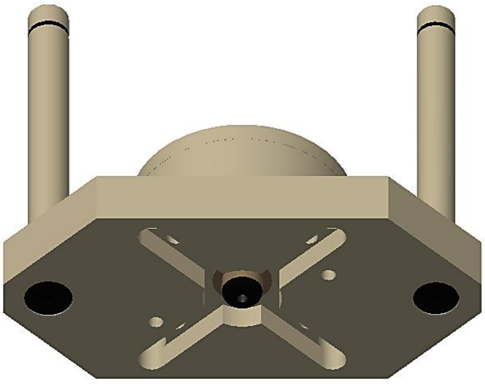
### *Modelling the ”drawing plate” subassembly*

The *3D* model of the "*drawing plate*" subassembly is presented in Figure 10, obtained through the *Extrude*, *Revolve*, *Hole* and *Mirror* commands. Using the *Fillet* and *Chamfer* controls, the connections and the bevels of the subassembly are obtained.




**a.**

**Figure 10** Virtual model of the *”drawing plate*”:



**b.**

**Figure 10** Virtual model of the *”drawing plate*”:
*a. top projection: 1 - guide columns; 2 - centering studs; 3 - active drawing plate; 4 - clamping plate; 5 - motherboard; b - the bottom projection.*

### *Modelling the „support plate” landmark*

The "support plate" landmark has the same dimensions as the top plate and the base plate.

Therefore, in the 3D design environment, with the help of the *Extrude* command, at a height of 35 mm, the virtual model of the part is obtained, Figure 11.

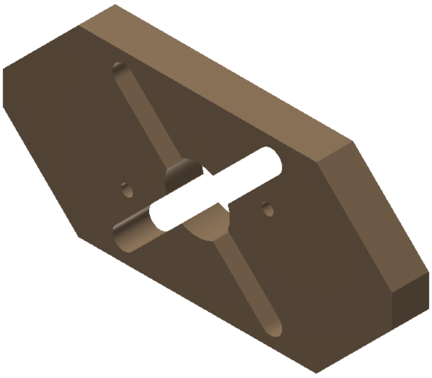


**Figure 11** Virtual model of the *”counter punch”* landmark.

### *Modelling of the "manometer" landmark*

The virtual model of the manometer is shown in Figure 12. The *YZ* projection plane is chosen, in the *Sketch* module, where a sketch is made, generating the manometer, using the *Circle* command.

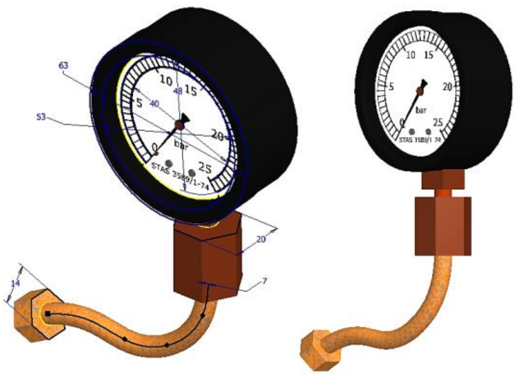


**Figure 12** The *”manometer*” landmark.

The *3D* module uses the *Extrude* commands to design the solid, and the *Shell* command to remove the inside of the generated body.

The scale is done using the *Text* command. In the *Sketch* module, using the *Spline* and *Circle* commands, the trajectory and the diameter of the manometer hose are traced, and are designed in the *3D* environment by the *Sweep* command. The *Polygon* command is used for nut modelling, and the final manometer model is obtained using the *Extrude* and *Hole* commands.

**Modelling the *”tiller”* subassembly**

The components of the *”tiller”* subassembly are presented in Figure 13.

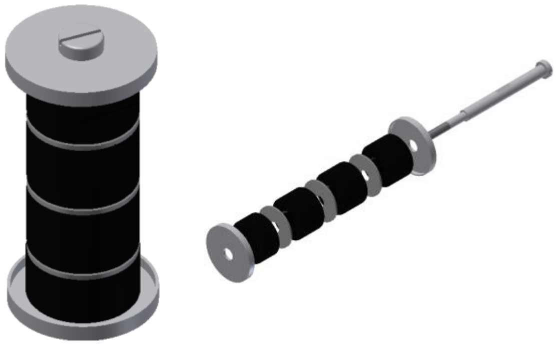
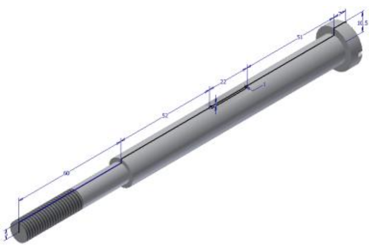
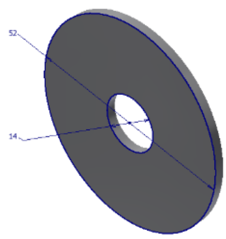


**Figure 13** Virtual model of the ”*tiller*” subassembly.

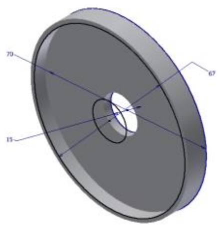
The Revolve command shall be used for rod shaping, having the appropriate dimensions in Figure 14. The other components of the *"tiller"* subassembly were made using the *Circle* and *Extrude* commands.



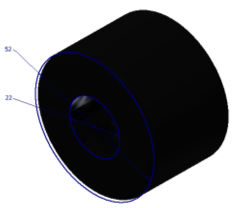
**a.**



**b.**



**c.**



**d.**

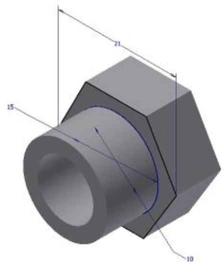
**Figure 14** Virtual model of the elements of the ”*tiller*” subassembly: *a – tiller rod*; *b -middle plate*; *c – end plate*; *d – rubber pad*.

***Modelling the fastening-fixing elements***

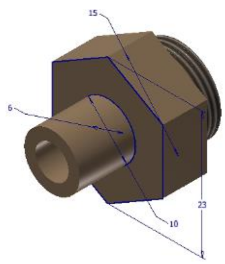
Nuts, screws and rods that play a role in fixing and maintaining the stability of the hydromechanical drawing dies are numerous and diversified.

Therefore, only a part of them is presented, and they are executed using *2D* drawing commands - *Line, Circle,* as well as 3D drawing commands - *Extrude, Revolve, Hole,* respectively, editing commands - *Chamfer* and *Fillet.*

The threads of the fastening-fixing elements are made using the *Thread* command, Figure 15.



**a.**



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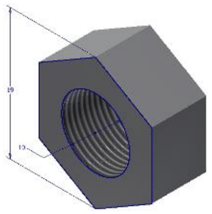
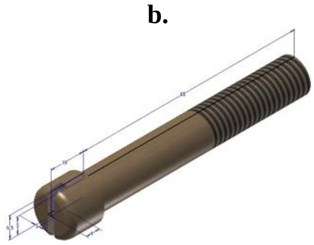
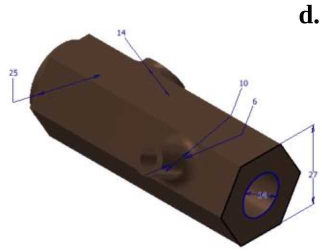


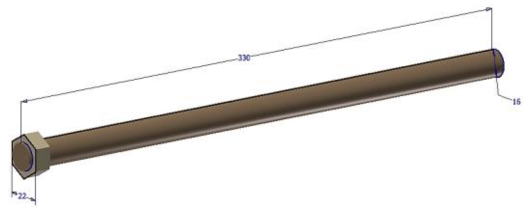
**c.**



**d.**



**e.**



**f.**

**Figure 15** Modelling the fastening-fixing elements: *a - mantle corbel*; *b - oil funnel*; *c - nut*; *d - M10 screw*; *e - clack*; *f - adjuster*.

***Graphical modelling of the hydromechanical drawing die***

The assembly of the hydromechanical drawing die is carried out in the Autodesk Inventor Assembly *(*.iam)* software program, in which the following constraints are used: *Mate* and *Flush* (surface constraints), *Offset Constraint* (remote constraints), *Angle Constraint* (constraints for setting angles between two surfaces), *Grounded* (constraints for fixing the main element against other components) etc..

Therefore, by selecting the *Place* button, the components necessary for the assembly of the hydromechanical drawing die are inserted, the command being made for each component.

The assembly between the *counter punch* (having already applied the *Grounded constraint*) and the cavity retainer plate is carried out by the constraints of coincidence and contact between the surfaces of the two plates, for which it is established that the distance between them is zero, Figure 16.

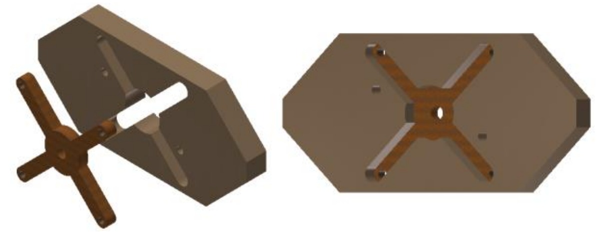


**Figure 16** Assembly between the counter punch and the cavity retainer plate.

Similarily, the components of the die are assambled by applying the constraints, Figures 17-22.

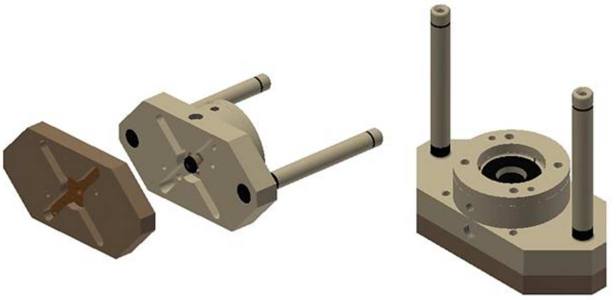


**Figure 17** The assembly of the drawing plates.

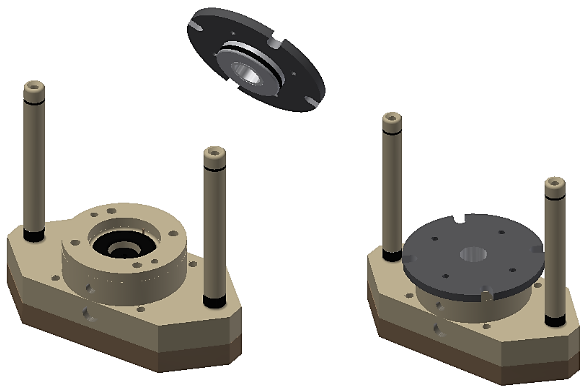


**Figure 18** The assembly of the restraint plate.

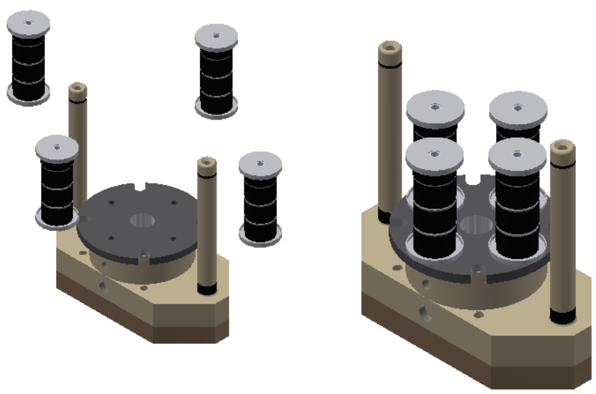


**Figure 19** The assembly of the tillers.

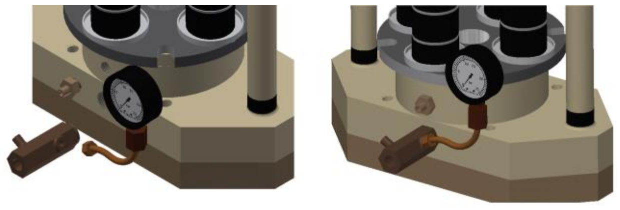


**Figure 20** The assembly of the stud, the clack and the manometer.

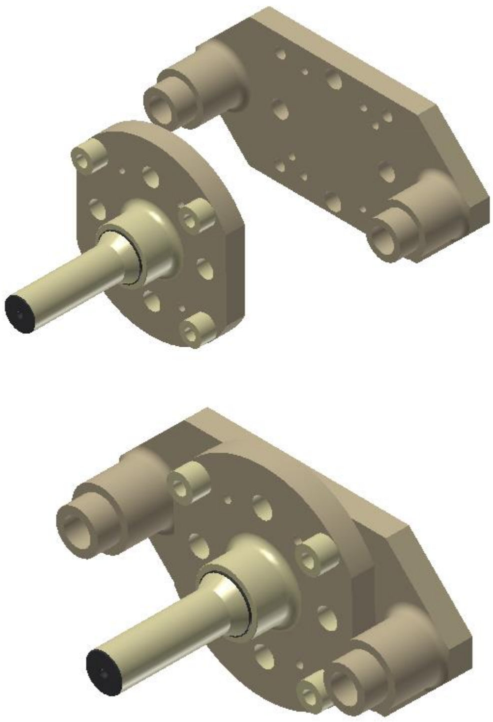


**Figure 21** The assembly between the superior plate and the port-punch plate.

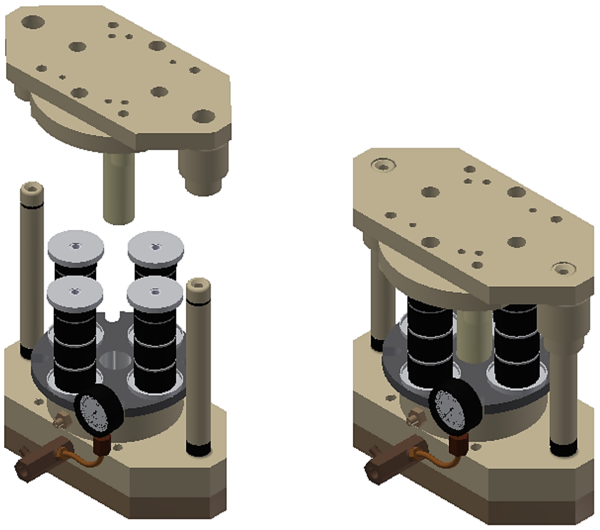


**Figure 22** The assembly between the inferior and the superior plates.

Finally, after assembling the rods, studs and screws, using the surface constraints *Mate* and *Flush*, the virtual model of the hydromechanical drawing matrix is obtained and presented in Figure 23.

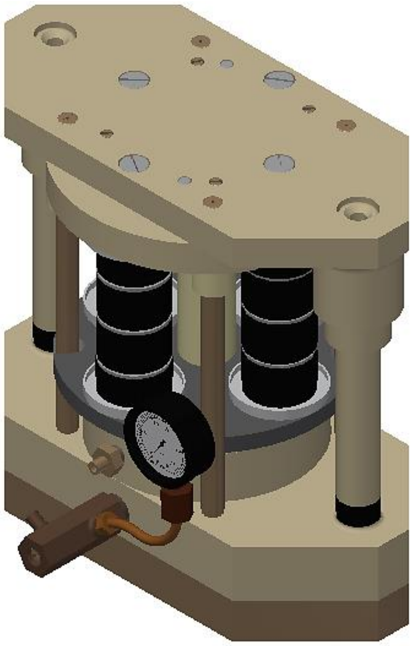


**Figure 23** Virtual model of the hydromechanical drawing die.

The hydromechanical drawing matrix, as presented in Figure 23, has the following principle of operation:
- hydraulic pressure occurs when the punch is lowered;
- through a discharge valve, the excess fluid is removed, while maintaining a constant working pressure in the enclosure;
- after deformation, the drawing depth of the material is increased, without the danger of breakage.

## 3. CONCLUSIONS

Hydromechanical drawing is used for deformation in a single operation of parts with complex configuration, but also those of spherical, parabolic, tapered shape, replacing their execution by several operations of ordinary drawing.

Engineering graphics has been and will remain a fundamental field of engineering knowledge. The *Autodesk Inventor* software includes all the basics for *3D* graphic modeling, as well as extensive capabilities for designing complex assemblies.

The hydromechanical drawing matrix has been graphically modelled with the *Autodesk Inventor* software package, its physical model being existing in the Department of Manufacturing Engineering, Faculty of Engineering, "Dunărea de Jos" University of Galați.

## ACKNOWLEDGEMENT

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