

## TOOLS FOR HYDROSTATIC SHAPING OF METAL SHEET

The paper describes a method of hydro-forming sheets. Described the theoretical foundations and the necessary knowledge. The structural design tools are shown. One of the ways unconventional forming is forming in a liquid environment, specifically – sheet metal forming by applying hydrostatic press. For the sphere of production in the engineering area will necessarily need to focus on environmental solutions. Use of water as an essential element of living nature in the manufacturing process is one of the roads leading to this goal.

**Key words:** tool for rotary yields, laboratory, hydrostatic, liquid, environment, knowledge, hydraulic system, metal.

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## ІНСТРУМЕНТИ ДЛЯ ГІДРОСТАТИЧНОГО ФОРМУВАННЯ ЛИСТА З МЕТАЛУ

У статті описується метод гідроформування листів. Описані теоретичні основи і необхідні знання. Показані структурні інструменти дизайну. Одним із нетрадиційних способів є формування в рідкому середовищі, зокрема листове штампування шляхом застосування гідростатичного тиску. Для сфери виробництва в інженерно-технічній галузі, безсумнівно, необхідно зосередитися на екологічних рішеннях. Використання води як важливого елемента живої природи у виробничому процесі є одним з методів, що ведуть до цієї мети.

**Ключові слова:** інструмент для обертального механізму, лабораторія, гідростатичний, рідина, навколишнє середовище, знання, гідравлічні системи, метал.

**Introduction.** The principle of hydrostatic forming consists in an activity of hydrostatic  $p_H$  versatile pressure of fluid in forming tool and punch. Among the methods used for drawing sheet the important place are holding methods which using for this purpose, elastic-plastic environment. In this case it is called loose tool. Against a rigid tool it has many advantages – saving production cost on tool especially for smaller series of moldings with complex shapes. Furthermore, to simplify the process of forming shaping without need of fit of active parts of the tool and also the use of complex retainers [1–5].

Company CINCINATI Milling Machine Co. developed method of deep drawing with liquid – Hydroform method – already in 1951. In this method there is used a universal drawing die formed with container filled with water or oil, which is closed with a rubber membrane. Rigid punch is made of cheap steel. Production costs for the drawing die represent only 25–30% for making classic all-metal tool. In following text, the attention is given to the issue of application of this method in surface forming, using a special made tool for laboratory conditions.

Theoretical knowledge. At constant temperature the volume of liquid changes very little due to pressure, basically it is a phenomenon and the resulting knowledge that liquids are minimum compressible. If the pressure which is exert on the liquid increased, than the volume reduces by a very small value. If the pressure reduced on the original value, than the fluid immediately deliver on the original volume. Liquids are thus perfectly elastic. Compressibility of the fluids is evaluated by known coefficient of compressibility, which is defined by the following formula (1):

$$\gamma = -\frac{1}{V} \frac{dV}{dp} \text{ Pa}^{-1} \quad (1)$$

where: V is the initial volume of liquid and dV is elementary reduction of volume caused by elementary increasing pressure on the value of dp.

The coefficient of compressibility is different for different kinds of liquids and at high pressures it decreases, with increasing temperature it usually increases. Its value for water at 20 °C:  $\gamma = 4,998 \cdot 10^{-10} \text{ (Pa}^{-1}\text{)}$ .

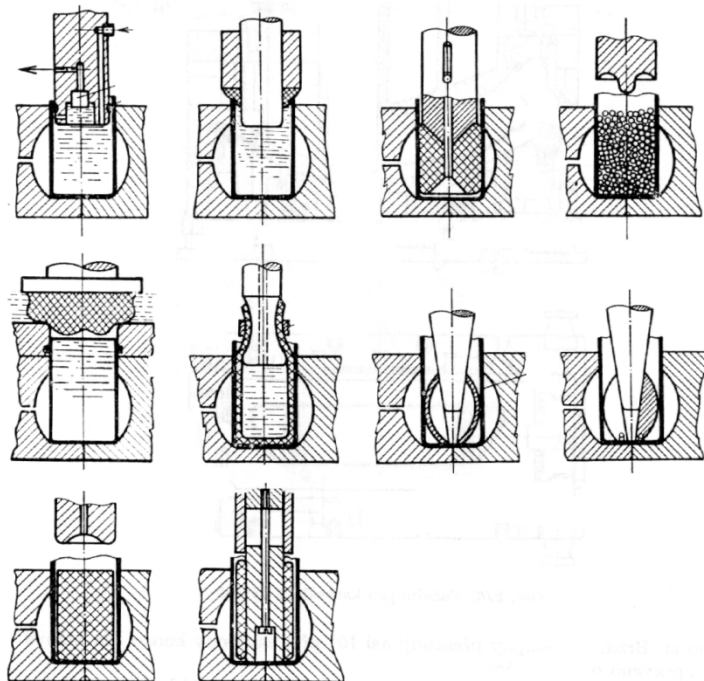


Fig. 1. Principles of forming sheets in the flexible and liquid environment

Forming in the liquid environment is using; respectively there is applied physical knowledge, known as Pascal's Law. According to the figure: there is the vessel filled with incompressible liquid with density  $\rho$ , which is in equilibrium in the gravitational field of the earth [4–6].

There is an element in the depth  $h$  below the surface of the liquid with the volume of an elementary cylinder with base  $S$  and height  $dh$ . At selected elementary volume of liquid there is applied self-gravity (volume force); also pressure forces (surface force) of the rest of the liquid. Pressure forces operated on the upper and lower base of the elementary cylinder have a vertical direction. Pressure forces operated on the shell of the cylinder have horizontal direction. Equilibrium conditions require that the vector sum of all forces had to be zero. Since the gravity of the selected quantity of liquid is:

$$dG = \rho S g dh \quad \text{N} \quad (2)$$

and size of the resultant pressure force of the vertically direction which is oriented upward (lift):

$$df = (p+dp) S - pS = Sdp \quad \text{N} \quad (3)$$

There is equation resulting from the equilibrium conditions:  $\rho S g dh - Sdp = 0$ . (4)

After editing and integrate equation (4) there will be:  $p - \rho gh = const$ . (5)

The potential of the earth's gravitational field at a depth  $h$  below surface of the liquid can be expressed with the equation  $V = - gh$ , (6) and equation (5) goes to the form:  $p + \rho V = const$ . (7) if provided that at the place of liquid surface the potential is equal to zero. Equation (7) has general validity. It could be write: if the incompressible fluid is at peace in any force field, than potential energy is the sum of its unit volume and pressure everywhere in the liquid is the same. If the liquid is under bigger pressure and do not take too much volume, so changes in the potential of the liquid are small than member  $\rho V$  in equation (7) can be practically constant and from equation (7) there can be derive the equation  $p = const$ . (8), what is the expression of Pascal's law which is about evenly spread of pressure in fluids [7–9].

Experimental section. For the experimental work there was design forming tool, in which are applied the relevant knowledge of mechanics of liquids. There are photographs of the tool on Fig. 3 and 4. There was verifying the suitability of hydraulic solution and the convenience of operation of the tool that is at the appropriate level. Found evidences are adequate and it is only a matter of time before the solution will be optimized, respectively there will be add peripheral components which are necessary for convenience of operation and shortening the time which is needed to produce sheet metal part.

**Description of the tool.** Forming tool for hydrodrawing is composed of two basic parts. The lower part is a Plexiglas block. There are M6 screws which are molded into a block to secure the upper part of tool. There is a hole which is lead out on the side for intake and discharge of pressure liquid. The entire lower part is assembled with screws and stands on four legs. There is rubber gasket slid on M6 screws.

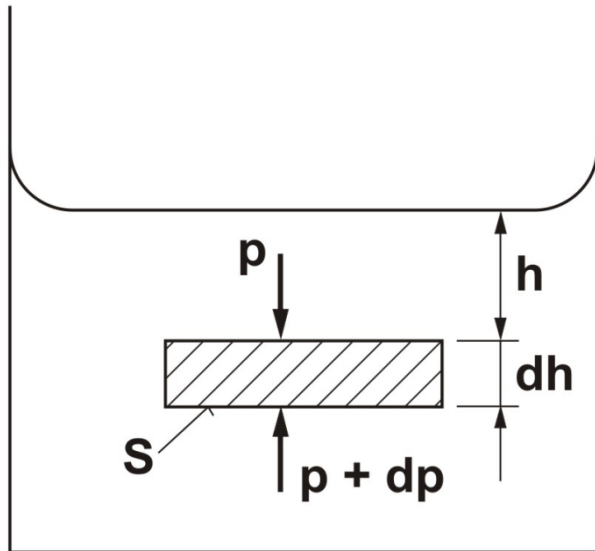


Fig. 2. Used for derive the relations



Fig. 3. Photograph of assembled tool

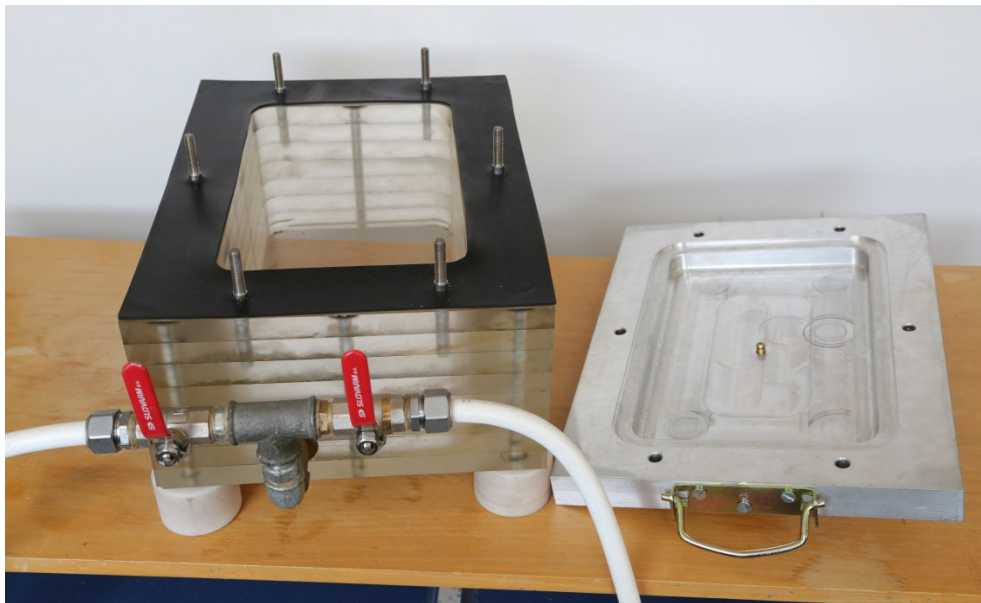


Fig. 4. Photograph of disassembled tool

The upper part is a plate which is made of dural, in which is milled the required shape of the drawn part. The cavity cannot have sharp edges and transitions must be rounded. Part is drilled with the bottom and is plugged on the M6 screws which are screwed in the tank.

There is pressure liquid supplied to the tool and because of her influence the blanking layout sheet is evenly squeezed into a selection on top part of the tool. In Figure 5 is a diagram of insertion of the tool into the hydraulic system.

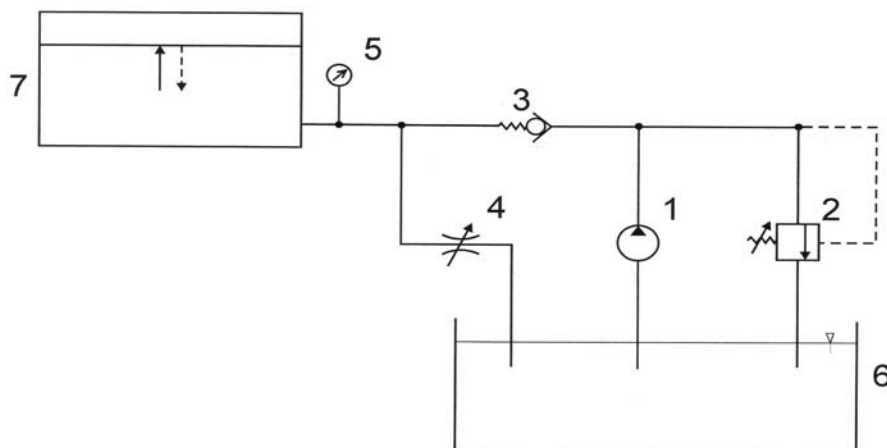


Fig. 5. Diagram of insertion of tool for hydrodrawing into the hydraulic system  
1 - gear pump, 2 - SV - safety valve, 3 - RV- return valve, 4 - TV - throttle valve,  
5 - gauge, 6 - tank, 7 - tool - forming chamber

#### Technological process for working in the tool

- insert blanking layout sheet on top part of the tool,
- plug the top part on the M6 screws,
- screw M6 nuts,
- turn on the pump, check the pressure of liquid, forming drawn part,
- turn off the pump, remove the liquid from the tank,
- remove the top part, postpone,
- take out stamping and visually check out surface of the drawn part,
- postpone part to pallet.

When using water as a medium, although it is relative the most accessible, there is a risk of corroded surface of drawn part. Its advantage is that it does not load the ecological environment. Oil is the most optimal in terms of tribological characteristics for the job. Proper viscosity of oil should be tested. The oil has a clear priority over another media. Disadvantage – after crash escape into the environment and the worker must have gloves. Figure 6 and 7 are details tool for rotary yields.



Fig. 6. Photograph of assembled tool for rotary yields



Fig. 7. Photograph of disassembled tool for rotary yields

Conclusion. Presented tool is useful in the laboratory conditions at the Faculty of Mechanical Engineering University of Žilina. It is a good complement to the teaching of forming. Experimental work confirmed the suitability of this type of forming especially for the piece production and application of the tool is expanding the sphere of physical knowledge which are used in sheet metal forming. Experimental works were carried out in laboratory of forming techniques on Department of Engineering Technology, Faculty of Mechanical Engineering of the University of Žilina.

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Рецензія/Peer review : 8.11.2015 р.

Надрукована/Printed :5.12.2015 р.  
Рецензент: д.т.н., проф. Шалапко Ю.І.