

Simulation Tests of Working Press Loads under Pre-tensioned Body Conditions

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Abstract. The article presents the concept of innovative technology for the production of press bodies, especially hydraulic ones. The manufacturing method is distinguished by the use of pre-tensioning of the press body, which guarantees the required rigidity and relatively low production costs. The SolidWorks Simulation application has been successfully used to assess the strength of the press body in conditions of different press temperatures.

1 Introduction

Pre-tensioned bodies are used in the construction of machinery industry presses, which ensures the necessary rigidity of the body while reducing the weight of material needed for its construction. Various ways of pre-tensioning press bodies are known. Among others, the technology of producing a press with a pre-tensioned frame using a mechanical system is known. A press of this type consists of a cylindrical front and rear head, with links and clamps placed between them. The strings are made of a bundle of sheets surrounded by a rectangular compressed clamp. Pre-tensioning between the clamp faces and the inner faces of the heads is achieved by means of wedges and inserts. The clamps provide guidance for moving press elements. This solution has the disadvantage that additional separate elements in the form of wedges and inserts [1,2] are necessary to achieve pre-tensioning of the press frame.

The bodies in the mechanical engineering department are among the most technologically difficult parts of the machines, hence the need to take special care of the correct solution of their construction and, above all, of their technologically correctness, as it has a decisive influence on the workload and quality of the body. Unfortunately, as it results from the analysis of existing body construction solutions, the problem of technology is usually neglected. Some elements of the body are difficult to manufacture and assemble [1-5].

An important element in the construction of bodies is their compact structure and rigidity. First of all, such a structure is required which limits the possibilities of body deformation and movement of its elements. The problem of deformation of a part of the body is connected with ensuring stability - invariability of the position of elements inside the body: shafts, gears, clutches, etc. The bodies of various devices are exposed to impacts, dynamic

actions, loads and thermal shocks unevenly distributed in the body (and thus causing various deformations), as well as to chemical and corrosive actions of various media (valves, gates) [1,2]. This requires that many different loads are taken into account in the construction of bodies, the shape and thickness of walls and damping partitions. Shaping the outline of the body should ensure that the position of internal elements is constant. In this respect, the material from which the body is made is an important factor. Most of the large bodies in particular are made of various gray or pearlite cast iron.

The body for a hydraulic press should be characterized by a sufficiently high static stiffness, intensity in damping both the vibrations generated during the operation of the machine and the frame's own vibrations and resistance to self-excited vibrations as well as good thermal stability.

The basis for designing press bodies is to create a casing which will be as efficient as possible in terms of operation and economy. Designing and producing such bodies is not an easy task, which is due to the fact that the body is usually an extremely heavy and bulky element, as if it did not represent about 75-80 percent of the total machine weight.

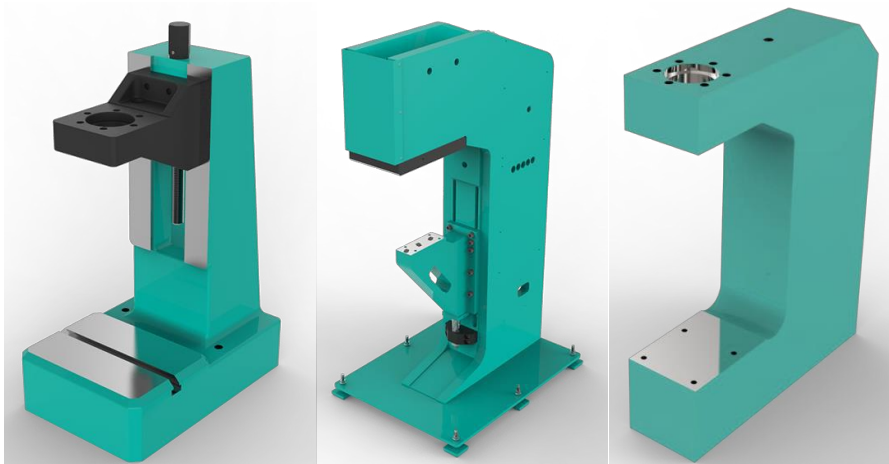


Fig. 1. Series of press bodies from one of the companies [6].

If it is a welded structure, it is relieved, sandblasted and painted. Thanks to the appropriate manufacturing technology, high accuracy of press guidance is achieved, and with it high precision of work, so necessary for accurate technological processes.

The virtual prototyping environment and CAD/CAE applications are often used to assess the design concept of machines and devices. These applications are successfully used to simulate and model large-size machines [7-10], a relatively large group of machines shredding polymer materials [11,12] and organic materials [13,14], including wood chipping [15]. Successful attempts were made to implement applications from the CAD/CAE group in the design of wood chipping machines [16]. The applications are dedicated for use in surface modeling of hardening materials [17], structural strength [18,19], in planning paths of mobile robots within a multilayer system of maps [20,21] and selection of structural features of gears [22]. In terms of material engineering, these applications support the effective selection of components in composites [23]. In recent years, there have been successful attempts to implement artificial intelligence applications in various machine, device and process design [24-26]. One of the well-known CAD/CAE

applications is SolidWorks (Simulation). It allows to examine the model in terms of static strength, frequency testing and model change during the device movement [29,30].

2 The fundamentals of press body design

The basic unit of mechanical presses, which joins all elements together is the body. It contains all press elements such as: table, guides, shaft bearings, drive, electrical installation and others. The body takes over all the forces generated by the machine. The factors determining the construction of the body, its shape and dimensions are the size of the forces transferred, the dimensions of the working space, the materials used and the method of execution. Very often the shape of the body is determined by its rigidity. Depending on the shape, the body can be divided into overhang and frame bodies [1-3]. Particularly advantageous for technical and operational reasons are cantilever bodies, which thanks to their open construction have easier access to the working space. The overhang body shape is much less rigid than the frame body (fig. 2a,b). Additionally, as a result of forces coming from the plastic deformation resistance of the shaped products, the axis of the slider and the press table is "crossed". This is a particularly disadvantageous phenomenon, which leads to accelerated wear of tools and mechanisms of the press and a decrease in the accuracy of manufactured products. That is why the overhang bodies are used in mechanical presses with relatively low pressures, not exceeding 2500 kN. Frame bodies are characterized by a rigid construction (fig. 2c), thanks to which they can carry much higher loads than cantilever bodies [1-3].

Depending on the method of manufacture, the bodies of mechanical presses can be divided into: cast (cast iron) and bodies welded from steel sheets. There are also welded - cast bodies made of steel sheets and steel castings. Cast iron bodies are usually used in presses with relatively low pressures, not exceeding 1000 kN, which are produced in larger series. Cast iron bodies have many advantages, among them: possibility of easy shaping, rational material distribution and greater ability to absorb vibrations. The disadvantage of cast bodies is their higher weight in comparison with welded ones by 20 - 30%, resulting from lower modulus of elasticity of grey cast iron. At present, most bodies with pressures over 1000 kN are formed by welding methods from steel sheets. The decisive factor, apart from the increase of body stiffness with lower weight, is the possibility of more flexible adaptation to customer requirements.

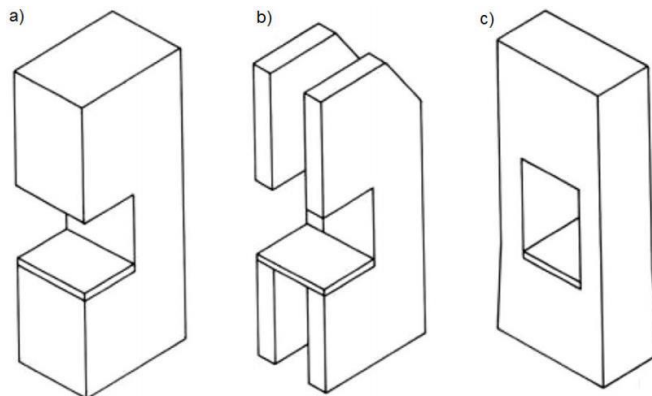


Fig. 2. Shapes of the bodies used in mechanical presses: a) monolithic overhang body, b) overhang body with passage between stands, c) frame body.

Below is a summary of the greatest limitations of classical methods of manufacturing bodies based on cast iron casting and welding:

1. Cast iron bodies
 - very high weight - almost twice the weight of steel bodies,
 - need for stress relief annealing and several months of outdoor seasoning in order to stabilise the shape and dimensions of the cast structure.
2. Welded bodies
 - possibility of changing the mechanical properties of steel as a result of high temperature influence on it during the process of body welding,
 - limitation of the availability of welding technology to selected steel grades - incompatibility of selected steel grades,
 - the welding process introduces stresses into the structure that prevent pre-precision machining - an energy-intensive annealing process through high temperature annealing is necessary,
 - increase in the weight of the bodies due to the possibility of using weldable but medium strength steels for their production,
 - less ability to dampen vibrations,
 - the production of a welded body takes longer and usually such a body is more expensive than a cast iron casting,
 - welded constructions preclude the possibility of constructing bodies of an angled-film shapes.

Welded steel bodies are much lighter than cast iron bodies. And this is one of their greatest advantages, which includes high rigidity, which prevents the occurrence of deformations resulting from long and intensive use. Unfortunately, welded constructions exclude the possibility of constructing bodies with complicated shapes. A big disadvantage of such bodies is also a lower ability to dampen vibrations. In addition, the production process of such bodies takes longer and is usually more expensive than cast iron. On the other hand, a steel body does not require seasoning [1-3].

3 Concept for implementing innovative press body technology: numerical example

The concept of an innovative technology for the production of pre-stressed press bodies was developed by Hydrapress Sp. z o.o. [27]. AISI 304 steel was proposed for testing. It has a tensile strength of 500 MPa. According to the adopted design [28], the method of producing the body of a pre-stressed press consists in the fact that the body is wrapped in a wire with a temperature higher than the temperature of the body elements, covering all its components with the coil created in this way, then the ends of the coil are joined together and/or the body, and then the temperature of the wire and body elements is equalized. The wire is heated by resistance immediately before it is fed onto the body, moving it through the poles of the electrical circuit. In the body, according to the invention, the heads and side poles have longitudinal cavities on the outside creating a groove in which the stressing wire is placed. The bottom of the cavity in the heads has a half circle shape. Such a solution makes it very easy to obtain initial tension of the press body. The issue in the example is shown in the figure below (fig. 3).

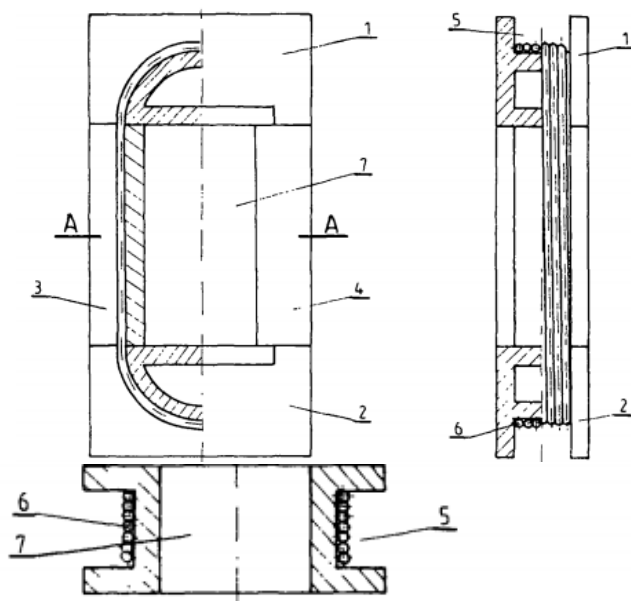


Fig. 3. The body of a pre-tensioned press according to the Hydrapress Sp. z o.o. company concept: upper head - 1, lower head - 2, side posts - 3 and 4, longitudinal cavities forming a groove around the body similar in shape to an oval - 5, steel wire - 6.

The manufacturing of the pre-tensioned body according to Hydrapress Sp. z o.o.'s proposal is as follows. The upper head 1 and the lower head 2 (the bottom of the cavity in the heads is half circle-shaped) are connected to the side posts 3 and 4 by means of screws. The body assembled in such a way is placed on the winder by placing the hole 7 of the body on its spindle. The end of steel wire 6, intended for wrapping, is connected in any way with the body. Then, starting the winding machine, the desired number of coils is wound in groove 5. The moving wire 6 immediately before it is fed to the body passes through two rollers which are the poles of the electrical circuit, closing it. Thanks to the flowing current, the section of wire between the rollers is heated up to a higher temperature by resistance. After winding the required number of coils, wire 6 is cut off and the cut off end is connected to the body in any way. Then the whole thing is cooled down and the temperature of the wire and the body elements is equalised. Coiling coils shrink and compress the body elements, making them stiffer.

4 Simulation research

Simulation tests carried out in SolidWorks application with active Simulation additive were aimed at determining the range of static loads generated in a 1 m² beam at 1000 kNload. The following figure shows how the loads were generated.

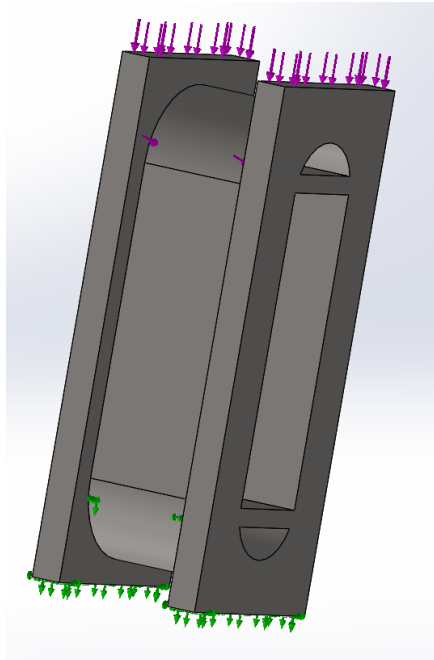


Fig. 4. Press model with accepted load pattern.

The stress range in the beam is between 5 and 30 MPa and slightly more, as shown in the figure below (fig.5).

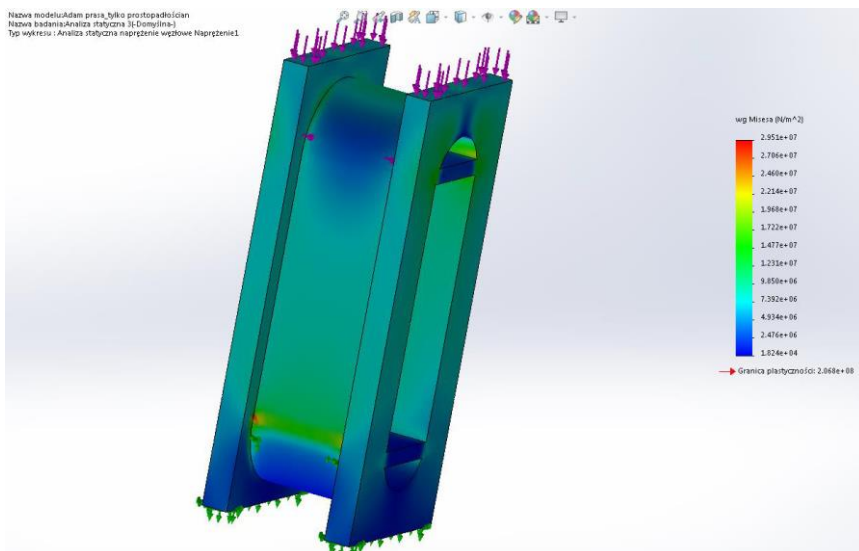


Fig. 5. Specified stress range in the press frame.

In order to verify the assumptions of the notification, a simulation was carried out for the case of winding one layer of 10 mm diameter wire (60 coils), which is schematically shown in the figure below (Fig. 6).

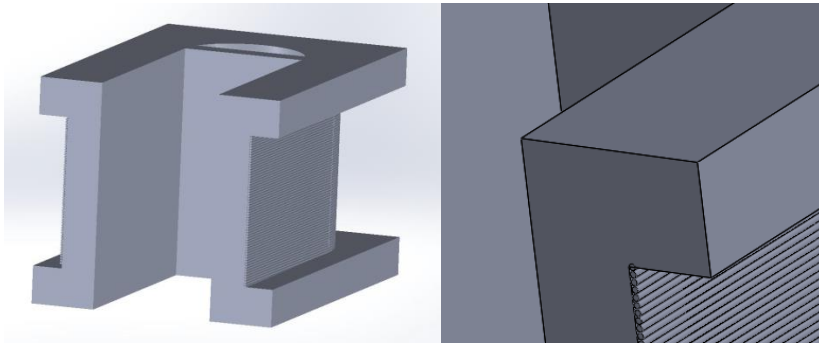


Fig. 6. Simulation of the state of wire winding on a press frame.

For thermal analysis, the SolidWorks application with the active addition of Simulation (Advanced Simulation-thermal studies) was used (Figure 7).

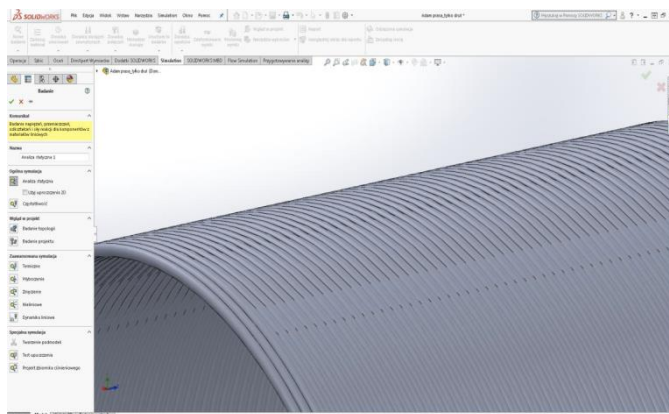


Fig. 7. The simulation of the state of winding of wire coils on the frame.

The temperature setting of the winding wire was recorded at 250 °C. Then the temperature of 20 °C was set and the range of generated stresses in the winding wire during cooling was analysed. Fig. 8 shows the division of the body with a grid of divisions into finite elements and the direction of generated loads (fig. 8).

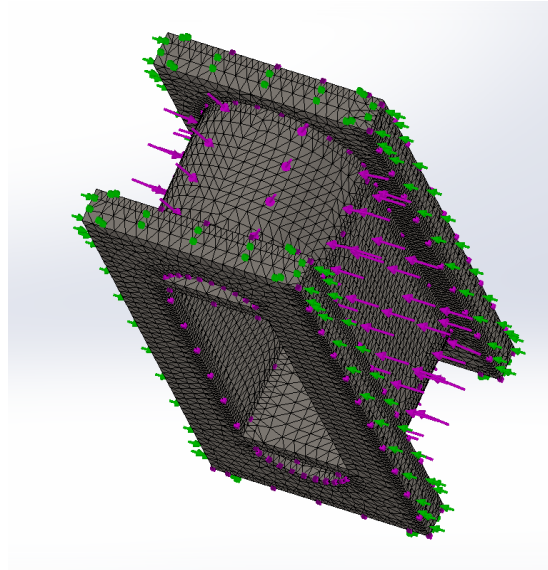


Fig. 8. Subdivision of the press body with a grid of divisions into finite elements and direction of generated loads.

On the basis of the reworked analysis it was shown that for one layer of winding wire the range of generated stresses is at the level of max. approx. 1.5 MPa (fig.9). From the point of view of expected values, this range is far too low.

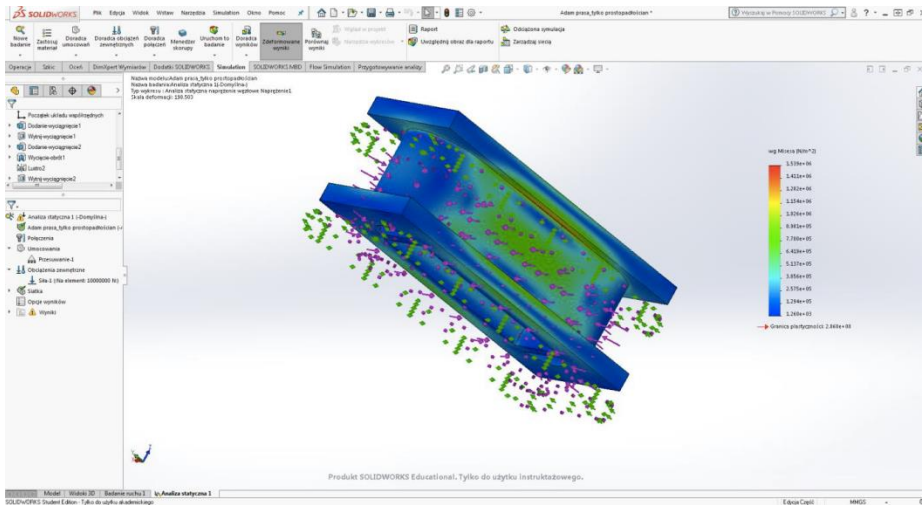


Fig. 9. Stress state for one layer of winding wire - the range of generated stresses is max. approx. 1.5 MPa.

For this reason an attempt was made to increase the number of layers of winding wire to 12 (fig. 10).

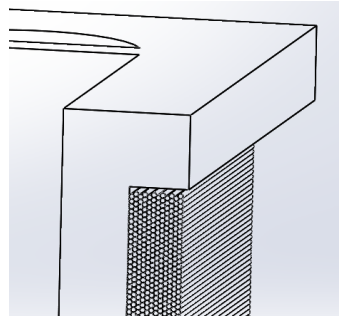


Fig. 10. Stress state for 12 layers of winding wire.

The temperature setting of the winding wire was recorded at 250 °C. Then the temperature of 20 °C was set and the range of generated stresses in the winding wire during cooling was analysed. Fig. 11 shows the division of the body with a grid of divisions into finite elements and the direction of generated loads.

Again (for 12 layers of wire) the temperature settings of the winding wire were recorded at 250 °C. Then the temperature of 20 °C was set and the range of generated stresses in the winding wire during cooling was analysed. The approximate stress range obtained with the introduction of necessary simplifications indicates a significant increase in the stress range occurring in the punch to the level of max. approx. 20 MPa (fig. 11).

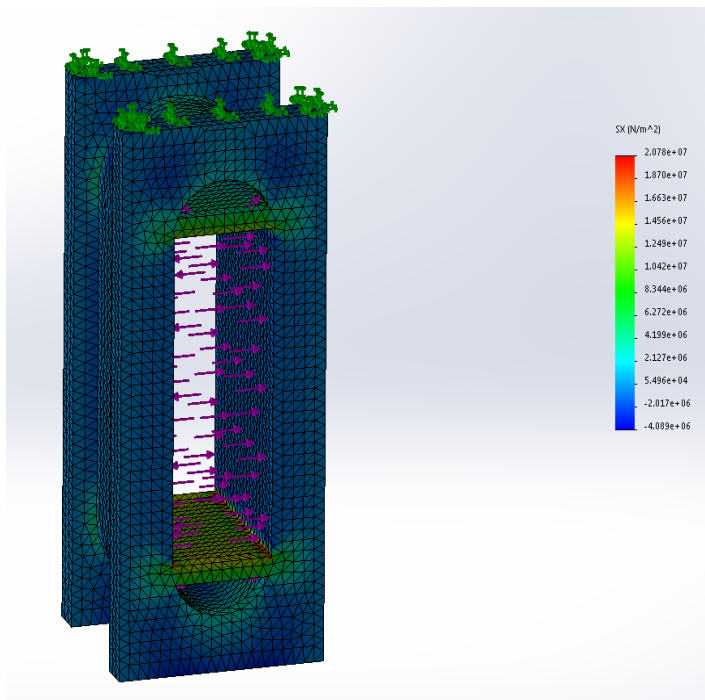


Fig. 11. Stress range of the punch during the temperature rise of the winding wire at 250 °C.

5 Summary and conclusions

The optimisation process carried out [28] made it possible to introduce changes to the design form, especially after taking into account the results of the MES analysis. The application of optimization in SolidWorks allows to check many alternative solutions, which led to the best possible design of the tested body model.

It is assumed that the implementation of the new technology will allow for a significant increase in productivity in relation to alternative solutions - consisting of body welding. The innovative process of manufacturing the bodies for hydraulic presses according to the new technology will be 66.3% more efficient, due to significant shortening and even eliminating the process connected with welding. Pre-tensioned bodies will be connected by wrapping with hot steel wire. This process will be carried out with established parameters of temperature and wire winding speed - which in total will guarantee the production of 1 body in 29 hours. In the process of producing a pre-tensioned press body, electricity will be saved in welding and machining processes and the process of thermal annealing will be eliminated. It is worth noting that the new technology enables the production of more universal pre-tensioned press bodies in a shorter time, but also reduces material consumption.

The results obtained prove that it is possible to control the stress range by increasing the number of wire coils subjected to the process of heating and then cooling. The range of obtained stresses indicates the possibility of compensating the stresses resulting from the pressures during the operation of the press punch.

The simulation fully confirms the assumptions presented in the patent application no. P.431205 entitled "Stress compensation". "Method of making the press body with pre-stress" of 19.09.2019. of Hydrapress Sp. z o.o. The production of the pre-tensioned body according to the invention [27], reduces the thickness of the body walls, and by pre-tensioning the produced body, increases the strength and stiffness of the entire structure, which reduces its weight by the possibility of using extremely durable construction materials. The solution according to the invention significantly reduces the welding processes in the production of bodies, which reduces energy and labour intensity in their production.

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