

HYDRAULIC WOOD SPLITTING SYSTEM

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Abstract: *This paper presents a dynamic simulation model of an intelligent wood splitter. The numerical simulation was performed using the Simcenter AMESim simulation environment. Libraries of mechanical, hydraulic and control signal components were used; the time variation of cylinder rod displacement, cylinder rod speed rate, piston force and power used by the whole equipment were determined. The hydraulic fluid model used in numerical simulation is ISO VG46 oil.*

Keywords: *Wood splitting, hydraulic cylinder, hydraulic drive, intelligent hydraulic drive*

1. Introduction

With more than 3.5 million households using stoves and chimneys in the cold season, wood is one of the main sources of home heating in Romania. In rural areas, about 85% of households use wood for heating. [1]

Considering that the need for heating houses starts in October and ends in April, so for 6 months, the consumption of wood for heating homes is very high. With a very large quantity of wood, it is necessary to make the process of supplying wood to households more productive, splitting logs into smaller sizes and splitting them for storage to burn them for heating living spaces. Mainly, in the rural areas of Romania, the cutting of the timber is done with a hand saw and splitting logs is done using an axe. The intelligent mechanization of household activities, including the splitting of firewood, leads to an easier life for Romanian household residents [2].

Splitting consists of driving a wedge into the wood, in the direction of the fibers. The wedge is inserted in the wood and causes it to split. With the increase of the contact surfaces between the wedge and the wood, elastic deformation of the log fibers occurs, followed by the breaking of the connections between them, the parts resulting from the splitting separating from each other [3,4].

The hydraulic cylinder serves to convert the energy of the hydraulic fluid into useful mechanical work. The flow rate generated by the hydraulic pump produces a linear displacement of the piston rod, inside the cylinder bore, with the load on the opposite side of the force imposed by the pressure of the fluid medium [5]. Thus, hydraulic energy is transformed into a controllable force acting in a straight line [6, 7].

Splitters are classified according to several criteria: their mobility, type of construction and the way the wood drive mechanism moves, or the position of the wood during the splitting process. In terms of mobility, splitters can be fixed or mobile. In terms of the design of the drive mechanism, the splitter may have a conveyor chain, a crank mechanism or hydraulic cylinders. In terms of the movement of the drive mechanism, the splitter may perform a rotating motion or a continuous movement. Depending on the type of splitting element, the splitter may be a wedge or a helical cone, the most commonly used being wedge-shaped splitters. In terms of the position of the wood to be split, splitters can be horizontal or vertical [3].

This paper presents, for the process of splitting wood mass, the optimization and development of a fixed horizontal hydraulic system, which performs an alternative rectilinear movement of the cylinder

wedge. To be energy efficient, the system uses a low-power electric motor to drive the hydraulic pump and it is possible to achieve high pressure in the hydraulic cylinder, thus generating the force needed for splitting a log.

2. Material and method

The physical system developed so far is shown in Fig.1, and consists of the metal structure of the system, the hydraulic cylinder, the wedge for splitting the wood mass and 4 elements for supporting the wood mass, another role of which is to position the center of the log at the same level as the tip of the wedge; thus splitting is done correctly; and in the future, the system will be fully functional.

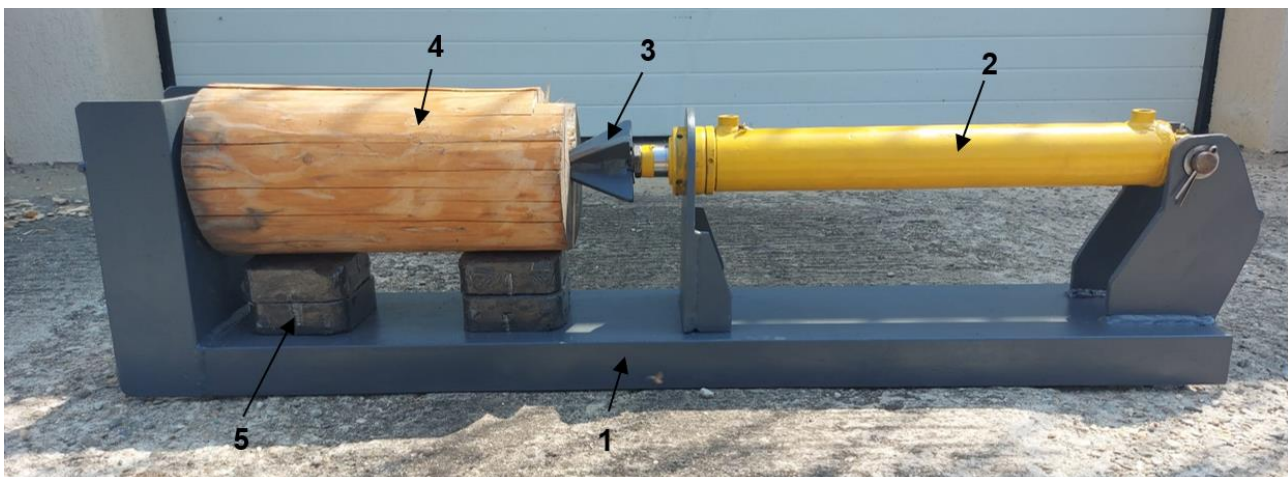


Fig. 1. The hydraulic splitting system

1 - System's metal structure, 2 - Hydraulic cylinder, 3 - Splitting tool (Wedge); 4 - Splitting object (wooden mass, log), 5 - Supporting and positioning elements.

The support on which the log will be positioned to be split will be equipped with two contacts and a spring that indicates the presence of the log in the space intended for its splitting. When the spring is compressed, a contact will send a signal to the hydraulic distributor, indicating the presence of the log.

We have taken some safety measures against possible accidents, namely the introduction of working parameters for the weight of the log. If its weight is in the range of 20-60 kg, the hydraulic cylinder will be activated and the splitting will be performed. If the weight of the log is outside this range, then the control system will not operate the hydraulic directional control valve, and consequently the hydraulic cylinder. This range represents the minimum and maximum weight of the wood mass. The maximum weight of the log was calculated according to its density and volume, and the result is that its maximum weight is 60 kg, because anything over this weight can represent the weight of the handler or other objects that happen to be in the space intended for splitting and could result in injuries or process related accidents. The minimum weight of 20 kg is set because after the entire splitting cycle, fragments of the split wood may remain, and the idle operation of the hydraulic cylinder represents a higher energy consumption. Also, for reduced energy consumption, two contacts will be placed at the end of the stroke of the cylinder rod. The purpose of those contacts is to send command signal to the directional control valve when the cylinder rod has reached 1%, respectively 90% of its maximum stroke.

The system was designed based on the data obtained by the simulation network, being evaluated and optimized virtually first. This was done in the integrated multidisciplinary technical systems simulation platform, namely the AMESim software, through which we combined elements of mechanics, electronics and hydraulics. The result is shown in Fig. 2.

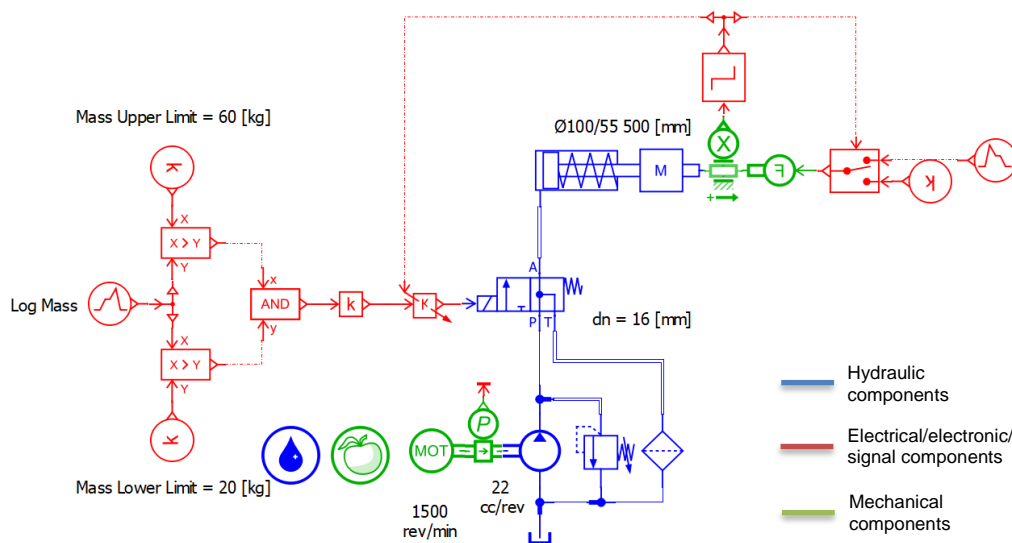


Fig. 2. Numerical simulation network of the hydraulic system for wood splitting

The hydraulic sub-system consists of a hydraulic gear pump with a fixed flow rate of 22 cc/rev. Between the hydrostatic pump and the electric motor there is a power sensor which is used to measure the power consumed by the system. The pressure relief valve, which acts as a safety relief valve, together with the filter are other hydraulic components of the equipment. The nominal diameter of the hydraulic directional control valve chosen is 16 mm. The hydraulic cylinder chosen has a diameter of 100 mm, the cylinder rod is 55 mm in diameter and the maximum stroke is 500 mm. Between the two there are two contacts, mounted at both ends of the cylinder rod, which limit the displacement of the cylinder rod, but also send a feedback signal to the directional valve to retract when the rod reaches its minimum or maximum stroke.

The electronic sub-system consists of an electric motor with a speed of 1500 rpm, a control block made of electrical signals, logic operators and signal amplifiers in the numerical simulation. Physically, this mechanism is composed of a spring and two contacts. It operates according to a simple logic. If the mass of the wood is in the required range, a signal will be sent to the hydraulic directional valve, the hydraulic cylinder will be actuated, and the wood will be split. If the mass of the wood does not fall within this range, then the directional valve remains in the preferred position, so the system will not act in any way. This can also be seen in Fig. 3, which represents the logic behind the whole process.

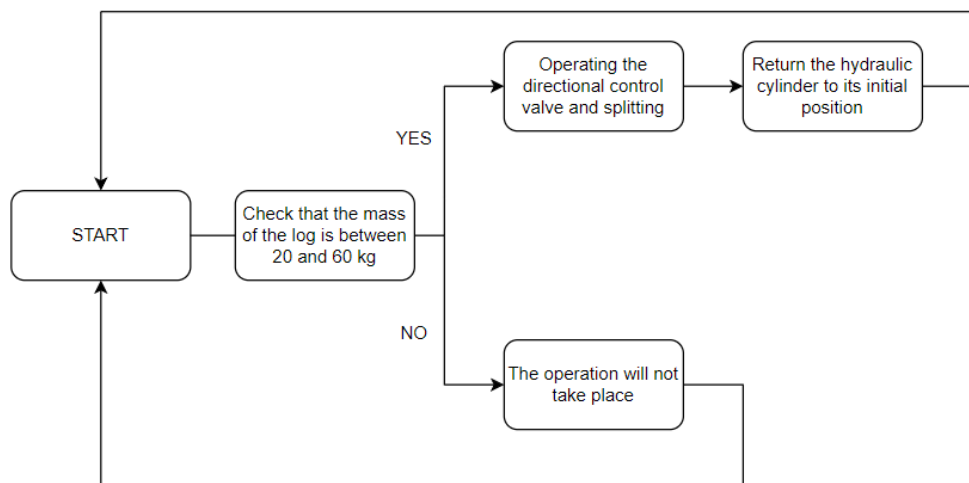


Fig. 3. The ladder diagram of the intelligent command system

3. Results of virtual experimentation

Based on the AMESim simulation network from the previous chapter, the results presented below were obtained:

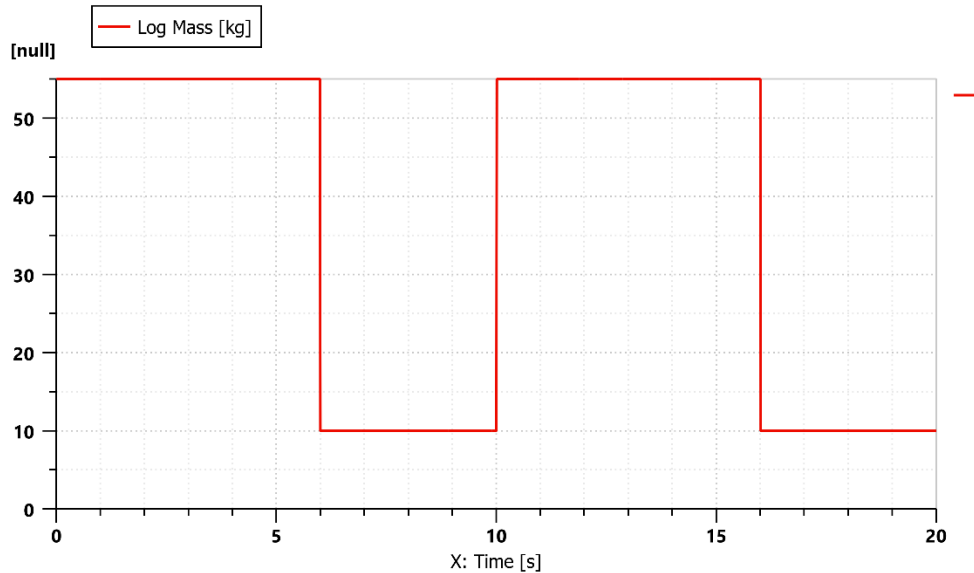


Fig. 4. Time variation in log mass during the splitting process

As one can see in figure 4, after the log is positioned in the splitting space and is included within the weight range - in the figure the weight is 55 kg – one can see how the mass of the log reaches 10 kg after 6 seconds as the wood chipping falls off the support due to the splitting process, the log separating into smaller fragments. It is also observed that the duration of one cycle is 10 s, the splitting time is 6 s and the withdrawal of the cylinder rod takes 4 s.

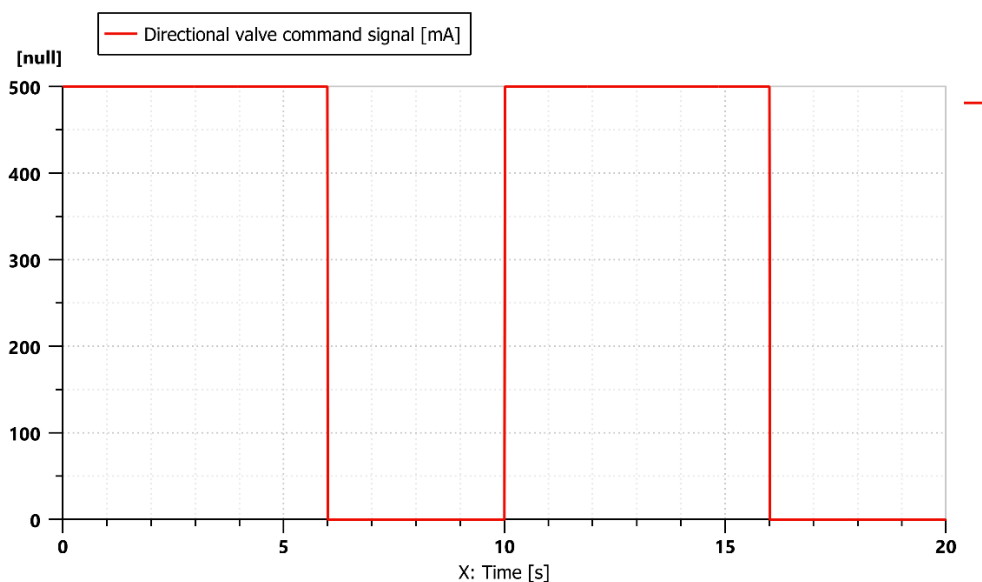


Fig. 5. Time variation in the hydraulic directional valve control signal

As one can see in Fig. 5, the hydraulic directional valve receives a command signal and starts to operate the system for splitting wood. In this graph, the control signal during 6 s, namely during the

splitting process, is 500 mA. When the rod retracts, the control signal reaches zero, after which the cycle starts again.

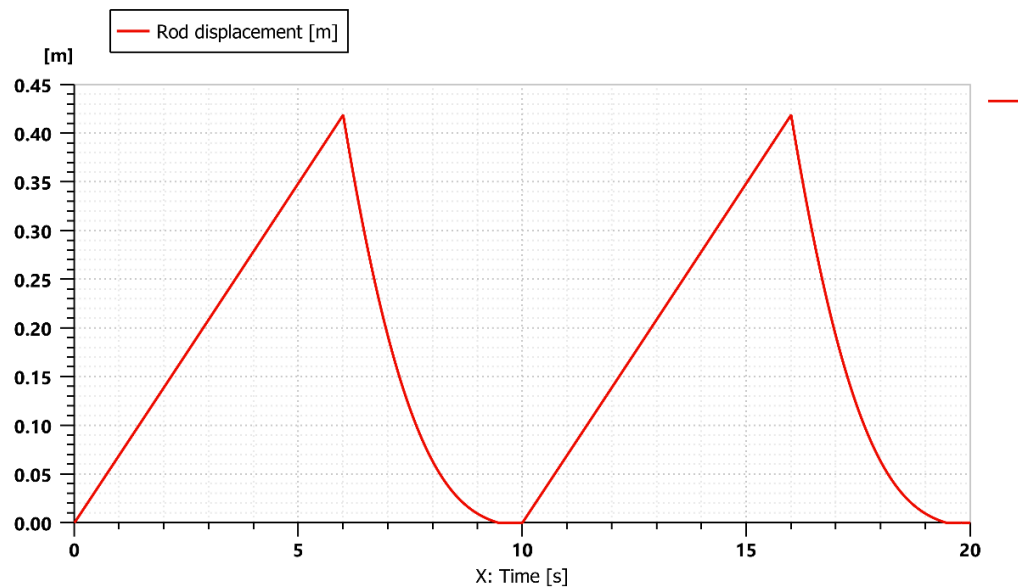


Fig. 6. Time variation in hydraulic cylinder rod displacement

Figure 6 shows the variation over time of the hydraulic cylinder rod displacement, and as one can see, the advance of the cylinder rod into the wood mass to be split is a slower one because the resistance of the log fibers is high. At the same time, the contact located at the end of stroke of the cylinder rod does not make it possible to move it to the end, and in this way, the energy consumed by the whole system is less. Cylinder rod retraction is faster because there are no relevant pressure drops in the system.

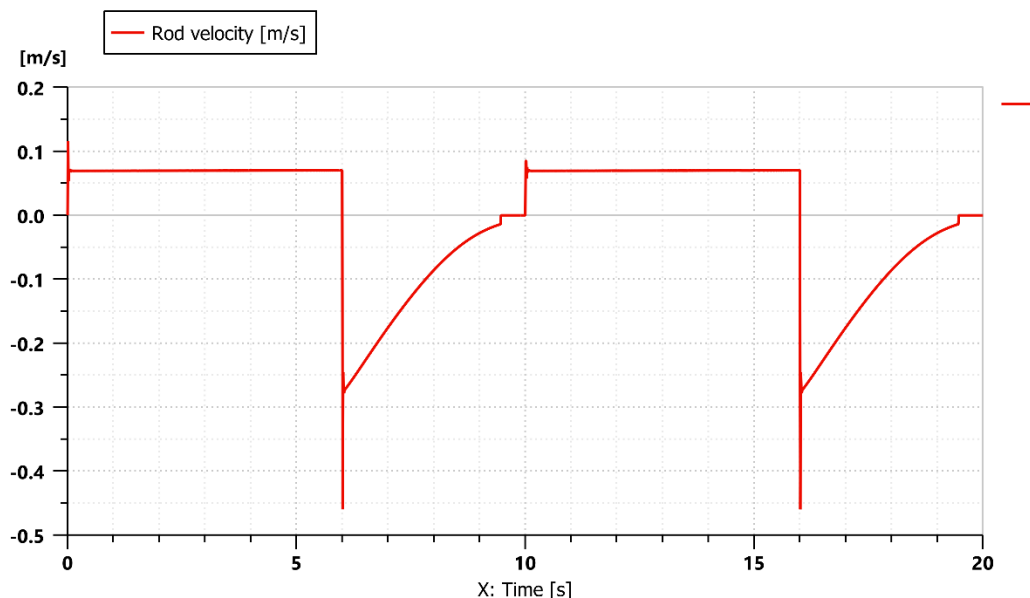


Fig. 7. Time variation in hydraulic piston speed rate

As one can see in the graph in Figure 7, the speed of the hydraulic piston when splitting is constant. It can be noticed that the speed rates achieved by the hydraulic piston are the usual kind, smaller than 0.5 m/s.

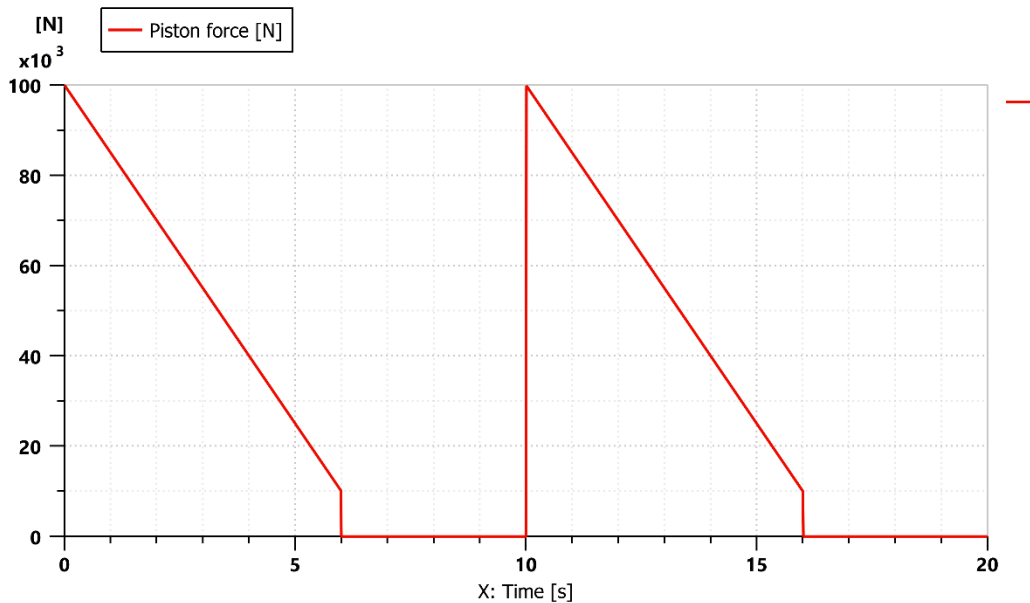


Fig. 8. Time variation in piston force

Figure 8 shows that at the moment of splitting, namely when the tip of the wedge is tangent to the wood mass, the force of the hydraulic piston is maximum, because the fibers resisting the splitting are resistant. When the splitting is complete, the force of the piston gradually decreases to 0 as the log is split; after 6 seconds it's split completely; the piston starts retracting and is waiting to receive a signal from the electronic control block, after which, if another log to be split is within the parameters, the cycle resumes.

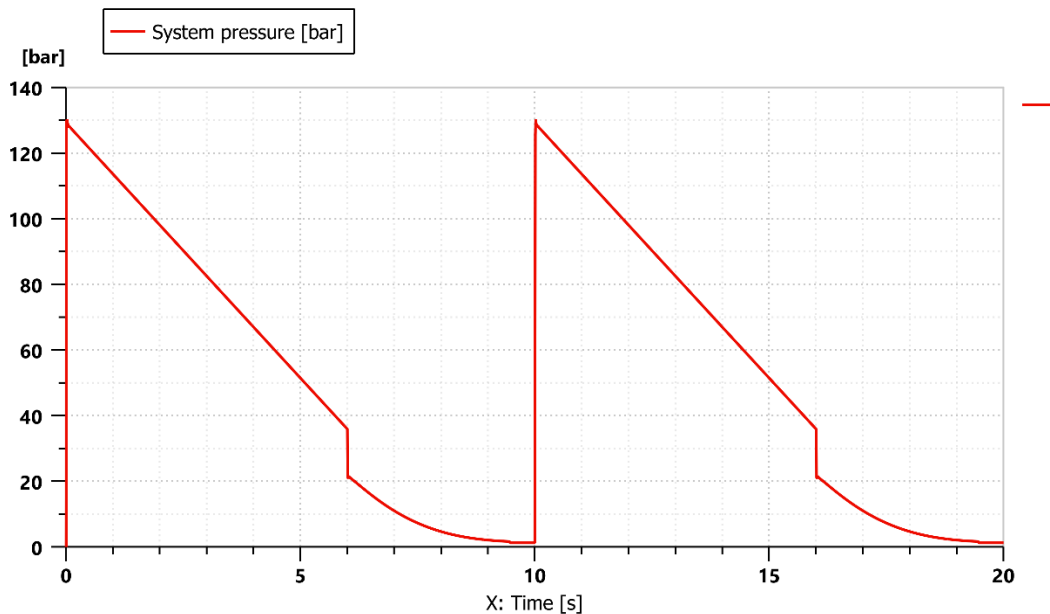


Fig. 9. Time variation in system pressure

Figure 9 shows the variation in system pressure over time. When there is no wood for splitting in the splitting proximity, the system pressure is 0. When the log is positioned and is to be split, the system pressure decreases throughout the splitting process, and when the hydraulic piston is no longer compressed, the system pressure gradually decreases.

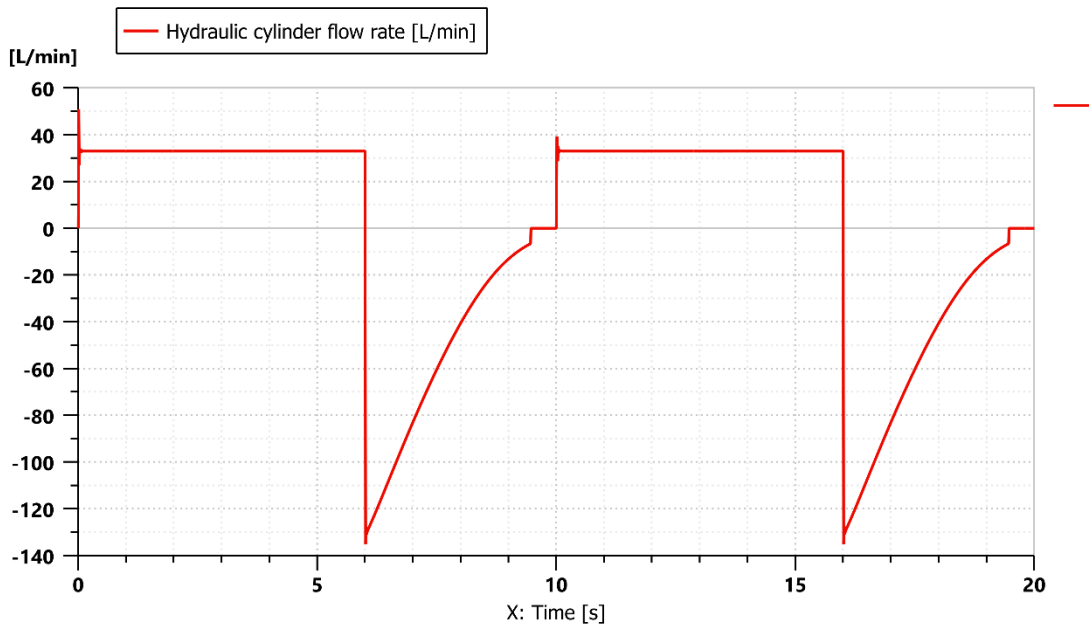


Fig. 10. Time variation in hydraulic cylinder flow rate

As one can see in the graph in Figure 10, the hydraulic cylinder flow rate remains constant during the splitting process because the whole system is optimized to operate under the correct conditions. When there is no more wood mass for splitting, the oil flow rate is redirected to the tank, which is necessary to retract the cylinder rod to its initial position, after which the cycle is resumed.

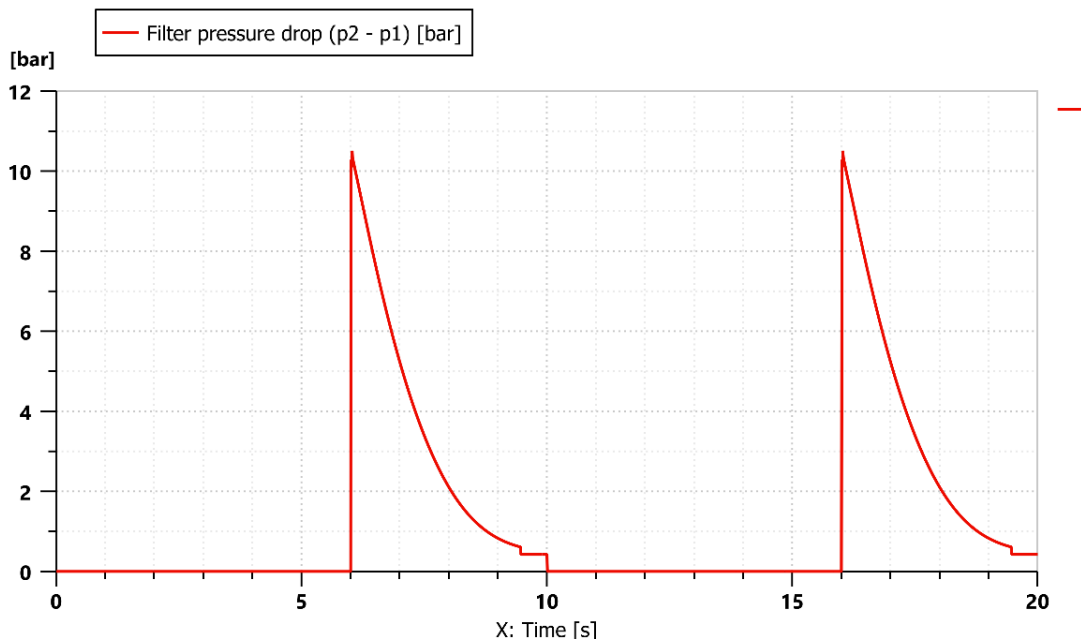


Fig. 11. Time variation in the pressure drop on the hydraulic system filter

As one can see in the graph above, the pressure drop on the system is quite small and there are no significant losses in the system that would prevent the whole system from functioning properly. The graph in Figure 11 shows that at the moment of splitting, the whole system needs a lot of power to operate the cylinder rod. The higher the resisting forces, the higher power transmitted by the hydraulic pump is needed for the splitting process to take place properly.

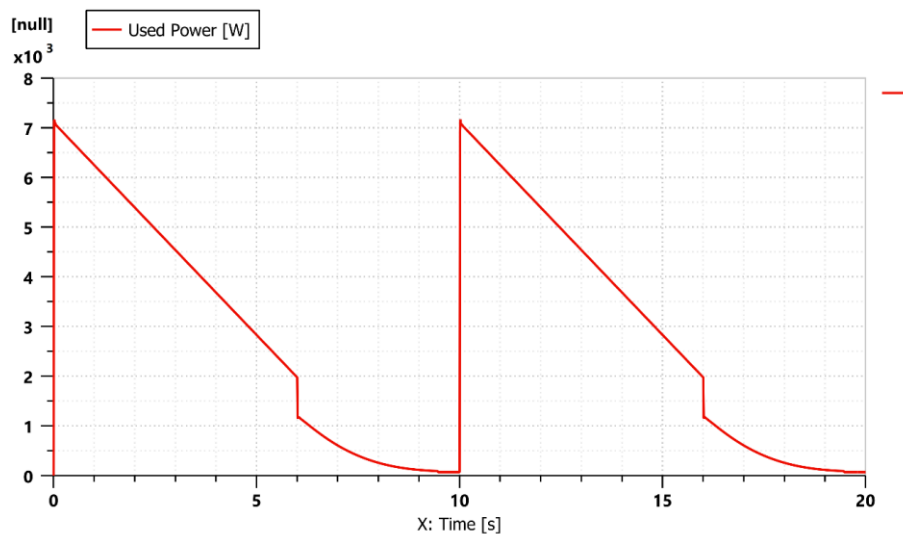


Fig. 11. Time variation in the power used by the hydraulic pump

4. Conclusions

- One of the most important results of this paper is the analysis and development of a system that mainly increases productivity due to the automation of a simple process, which previously required intensive labor, done in most households. More splits can be achieved with this intelligent hydraulic system in less time than with mechanical devices.
- The system was designed to offer the performance required for the process of wood splitting, without fancy components; the simple hardware used results in a lower purchase price if the system was placed on the market. In addition, energy consumption is kept as low as possible resulting in high reliability that is needed for household uses, the main targeted purchaser being country people from rural areas, where income is low.

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