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THE INFLUENCE OF WATER COMPRESSIBILITY OF THE EFFICIENCY OF A NEW SOLUTION FOR WATER JET CUTTING MACHINE

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Abstract: *This paper presents a solution for achieving high pressures specific to water jet cutting machines, using theory of sonic. The system consists of a generator which transmits pressure waves to a sonic amplifier that can be mounted directly in the cutting head. Due to high working pressures specific for water jet cutting machine, it was demonstrated that water compressibility has considerable influences on water flow. In order to determine the compressibility of water on the jet it was taken into consideration some simplifying assumptions, which allowed achieving mathematical model for describing the functioning of sonic amplifier.*

Key words: *water jet, sonic generator, amplifier*

1. INTRODUCTION

The researchers conducted in this paper have as basis a new solution for water jet cutting machine patented by [1]. This solution is shown in (fig. 1). The Water jet cutting system (fig.2) comprises a sonic generator (GS) with role of transforming mechanical energy produced by the engine (1) in pressure waves, that are transmitted by means of a hydraulic fluid to cutting head (CT), where it creates water working pressure. Sonic generator (GS) is acted by a motor (1), electric or thermic, which drives a shaft (2) on which are mounted some cams (3). Cams (3) acts by means of some rollers (4), upon some pickers (5) that moves through some connecting members (6) of the arcs (7), pistons (8) mounted in a body (9) of a sonic generator (GS).

Between each of the pistons (8) and the liners (10), we will introduce a low viscosity fluid (oil gas). Thus, it forms a closed hydraulic circuit number, equal to the number of pistons (8). Oil gas, found between sonic generator (GS) and cutting head (CT), is maintained under pressure (20-70 bars), with the aid of compensating valves (SC1) and (SC2). The springs (12) push the pistons (13) and ensures minimum pressure of circuit.

Through their motion, the pistons (8) creates in the pipes (14), pressure waves that acts on pistons receivers (15), causing a synchronic displacement of pistons pairs (8) and (15), located on the same circuit. The pistons (15) are coupled through connecting pieces (16) with small pistons (17) of the high pressure pump (18). In their motion, small pistons (17) change the volume of the chamber (19) of the pump (18) causing suction and pressure side of the pressure water, through direction valves (20) and (21). Cutting burst jet is formed in nozzle (22) of the cutting head. High pressure sealing elements (24) reduce flow losses in high pressure circuit.

Water flow and pressure are proportional to the forming jet stroke pistons (15) and (17). To adjust these parameters, has been provided a feedback loop made up of the pressure transducer (25), the comparator (26) and actuators (27). When between size of control "c" and size of the reaction "r" is an error "ε", caused by the change of size or water pressure in low pressure circuit, or the nozzle wear or sealing elements, actuator (28) make a movement "e" to racks (29), for each piston (8).

Analysing the water jet cutting system shown in figure 1 it was found that the system works with alternating flows. This problem is less studied in the fields of hydraulics, most scientific papers being focused on continuous flows.

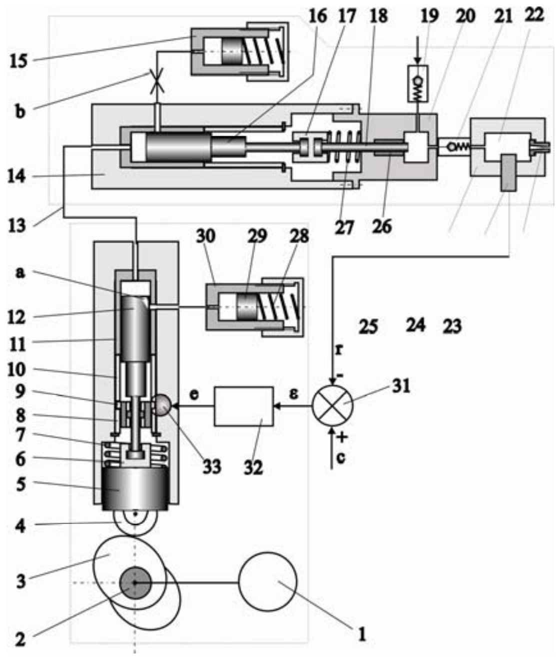

Fig.1. Water jet cutting system

The literature presents numerous aspects regarding sonic actuations. This topic is discussed in many scientific papers, such as [2], [3]. The researched done by [4] are focused on the functional parameters of a sonic generator three-phase motor system. The same author in the paper [5] presents the principles of hydraulic energy converters driven by alternating flow, describing a mathematical model which determines the pressure drop across the pipes, based on the elasticity and the inertia of the fluid.

„The new principle of switching and control of hydrostatic transmissions" which is based on periodic wave propagation in a so-called resonator" are analysed by [6]. For evaluating the characteristics of the performance resonator, the author [6] used an mathematical model in the form of a damped wave equation.

The system proposed by Scheidl in [6] „turns out to be a pressure converter that controls the output pressure of width pulses for switching between high and low pressure line."

[7] presents some constructive solutions for the impact hydraulic mechanisms, in order to simplify and reduce hydraulic capacities of hydraulic system, in order to achieve adjustable impact frequency.

2. DESCRIPTION OF THE MATHEMATICAL MODEL

Description of the model was based on figure 2 which shows the pressure amplifier itself. The amplifier consists of a piston 1 having the diameters D and d, which oscillates in a metallic housing 2. Pressure waves from the sonic generator acting on the piston diameter D, causing displacement x of piston. This displacement changes the volume of the chamber 3 by aspirating and expelling the water trough valves 4 and 5. Pressure attenuator 6 serves to equalize the flow of the pump pulses.

The study was conducted in the following simplifying assumptions:

- No flow losses through seals or valves
- Valves 4 and 5 is reacted fast without the need for response times
- No loss of pressure valves.

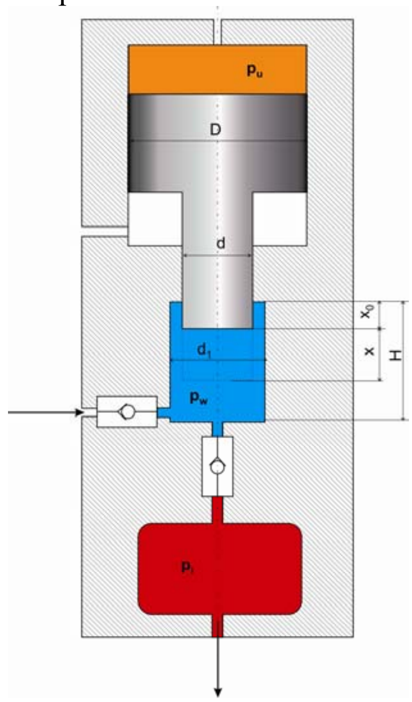

Fig. 2. Simplified diagram of the amplifier

Based on figure 2 it can be written that the compressibility of a fluid k is equal to the decrease relative to the volume dV / V raported to the pressure increase dp:

$$k = -\frac{1}{V}\frac{dV}{dp} \qquad (1)$$

$$dp = -\frac{dV}{V \cdot k} \qquad (2)$$

With the notations of Figure 2 applied to suction phase and discharge of fluid from the chamber 3, it results:

$$p_r = \begin{vmatrix} Pa + \frac{1}{k}\frac{d^2 \cdot x}{H \cdot d_1^2 - d^2 \cdot x_0}, x \in [x_0, x_0 + c] \\ Pl - \frac{1}{k}\frac{d^2 \cdot x}{H \cdot d_1^2 - d^2 \cdot (x_0 + c)}, x \in [x_0 + c, x_0] \end{vmatrix} \qquad (3)$$

Table 1

Constructive values for pressure amplifier

P_l	P_a	d	d_1	D	X_0	c	H
[Bar]		[mm]					
4000	50	20	22	80	2	20	24

Considering constructive values of table 1 and simplifying assumptions, its determined the variation of water pressure by the x piston stroke (Fig. 3).

Figure 4 shows the variation of water pressure by the piston stroke x and the gap j. The gap j = (D1-d) have in particular the following values: j = 0, 1, ..., 5 mm.

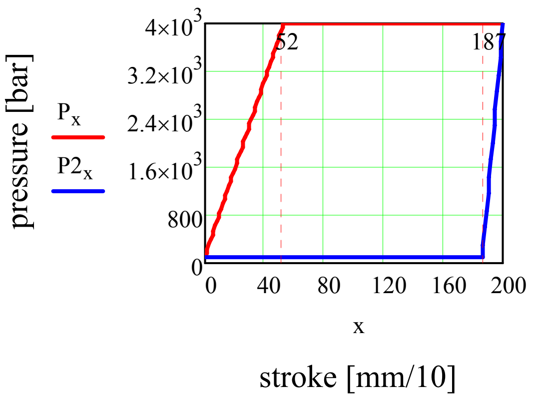

Fig.3. The variation of water pressure by the x piston stroke

The racks (29) rotates pistons (8) through gears (30), changing the slot position "a" of each piston against the valve orifice communicating with compensation valve (SC1). Angular position of the piston slot (12) has a direct influence on the amplitude of the pressure waves created by sonic generator. This changes the piston stroke receivers (15) and adjusts the flow, respective, pressure in the high pressure circuit.

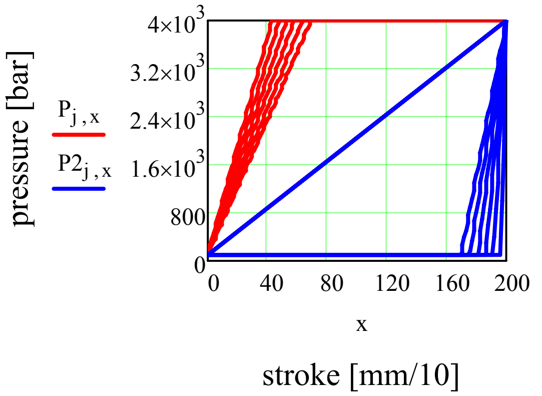

Fig. 4. The variation of water pressure by the piston stroke x and the gap j

Compensation valve (SC2) is used to offset fluid losses through leaks, to mitigate reflected waves the pistons, and bleed receivers in the initial phase. Hydraulic resistance "b" located on pipe compensation valve (SC2), serves to direct wave action pressure on receiver pistons.

Based on scheme showed in figure 2, the authors made an experimental model (Fig.3). With the experimental model, the authors studied the obtained pressure in high pressure floor. This was done by measuring the carrying capacities deformation on focusing nozzle. It was concluded that the pressure created by the high pressure floor is between 2500 and 3000 daN/cm^2.

3. CONCLUSION

Based on the researches done by the authors of the present paper, the following conclusions can be formulated:

The solution adopted by transmitting energy in the form of pressure waves, from sonic generator to cutting head, allows mounting the pressure amplifier into the cutting head. This offered the advantages of water transport through flexible pipelines, with Kevlar insertions.

The water working pressure obtained at the output of amplifier is reduced to the pressure for which the installation was developed (75%). In the proposed solution, the amplifier has a very low reliability (app.10 hours).

In order to improve the performances, by increasing the operating pressure and reliability, the following changes were proposed:

- increasing the pressure wave amplitude of sonic generator (GS);
- increasing the amplification ratio of the cutting head;
- developing a mathematical model to optimize installation parameters.

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Influența compresibilității apei asupra eficienței unei noi soluții de prelucrare cu jet de apă

Rezumat: Lucrarea prezintă o soluție constructive pentru realizarea de presiuni ridicate specifice maşinilor de tăiere cu jet de apă, folosind teoria sonicității. Sistemul constă dintr-un generator care transmite undele de presiune la un amplificator sonic, care poate fi montat direct în capul de tăiere. Datorita presiunilor mari de lucru cu jetul de apă, s-au constatat influențele semnificative de compresibilitate ale debitului. Pentru a determina influența compresibilității apei asupra jetului s-a ținut seama de ipoteze simplificatoare, care au permis realizarea modelului matematic pentru descrierea modului de funcționare al amplificatorului sonic.

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