EXPERIMENTAL TESTING OF A LOW SPEED HYDRAULIC MOTOR WITH AXIAL PISTONS

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Abstract:*In the paper is presented a new design of low speed hydraulic motor with axial pistons. It work stable at low speeds providing high torque. Another important advantagethat brings this new model of stepper motor is the precision of the angular position that can be achieved. Also it is cheaper then electric motors with the same power.The paper presents the results from tests with an experimental model. Analyzing these results can be said that the motor fulfills the requirements on its steady and dynamic behavior.*

Keywords:*Hydraulic motor, axial pistons, low speed.*

1.Design of the new low speed hydraulic motor

The hydrostatic motors have apppeared and been used from the 17th century. Inclined shaft motors, working at high pressure have been developed by Thoma in 1930. In 1950 axial piston motors with tilted disc successfully emerged. Over time there have been researches on hydraulic piston motor, in increasing their performances and accuracy. [2], [3], [4], [7].

Rotary hydraulic motors have to ensure great stability of movement in a wide range of variation of the output values (1 rev/min ... 3000 rev/min) and aratio between active torqueand moment of inertia, grater then electrical drives for the same power. [2], [3], [4].

In case of heavy loads at low speed, we need "slow" running motors that work stable at low speeds and provide high torque. Starting with this premise, it is developed a version of a hydraulic motor with axial pistons that is shown in figure 1. Through this design it was intended to adjust the motor speed without dissipating energy by adjusting the feed rate, but which is able to transmit to the shaft of the motor a greater torque for the entire speed range. [1], [5], [6].

The piston block is attached to the motor housing (8) and secured against rotation. The pistons (4) are arranged in a circle in the block, having the axes parallel to the axis of the piston port block. In line movement is determined by supplying the piston chambers with pressure oil via rotary distributor (6). Turning it is done with a rotary electric motor (stepper motor or DC electric motor (7)).

Pistons of the hydraulic motor (4) under the action of the pressurized fluid perform a reciprocating motion in contact with a tilting drive. The pistons are acting on the disc by means of connecting rods having both ends spheric. Removing the piston rod and the disk is prevented by their crimping pistons, or by means of a retaining plate attached to the disc.

Due to the alternative movement of the pistons, to a full turn of the rotary distributor, the tilted disc performs a swinging movement around its axis. Rotating the distributor allows the pistons to connect to the supply and tank connections through the holes in the block and windows made inside the block.

The rotary distributor must ensure hermetic sealing of cylinder pistons near dead points, areas that allow connecting the cylinders alternatively to the pressure or tank. Through the rotary distributor it separates the high of low pressure zone of the motor.

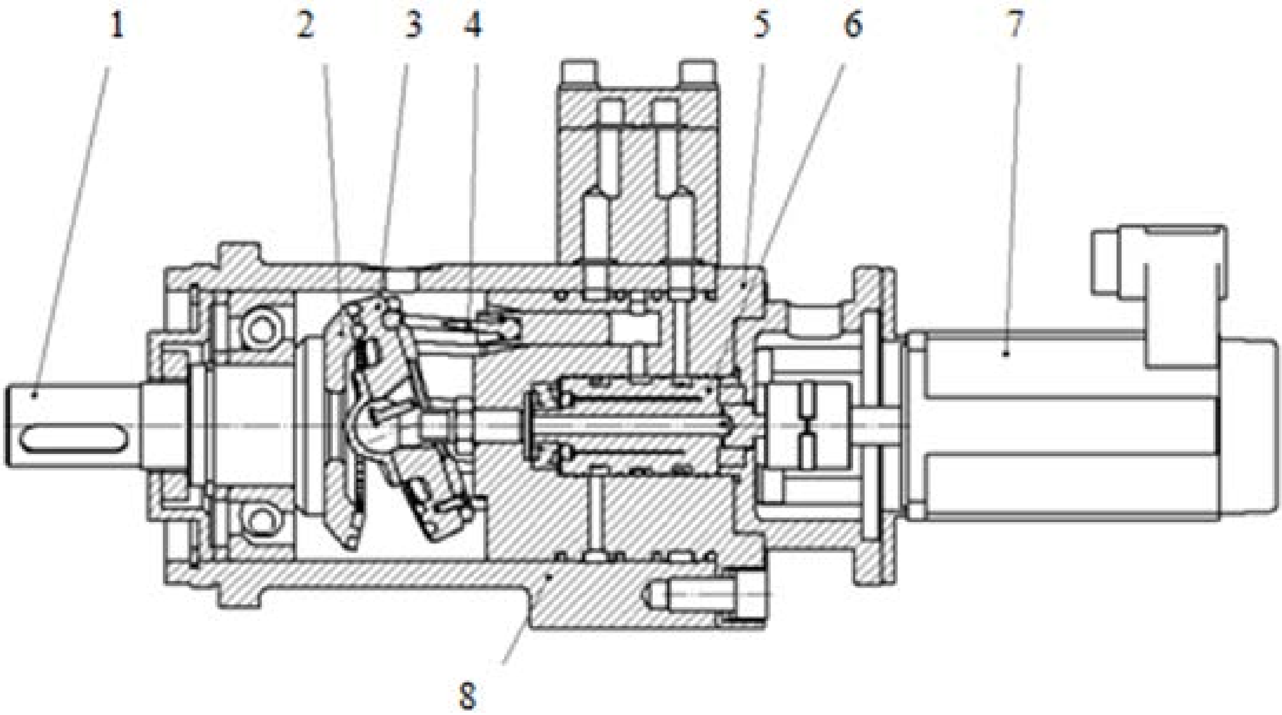

Fig.1. Low speed hydraulic motor: 1 – shaft, 2 – driven gear, 3 – drive gear (tilted disc), 4 – piston,5 – piston block port, 6 – distribuitor, 7 – electric motor, 8 – housing.

2. Description of the experimental stand

Schematic diagram of the testingstand is shown in Figure 2 and the panoramic description of the rig is shown in Figure 3.

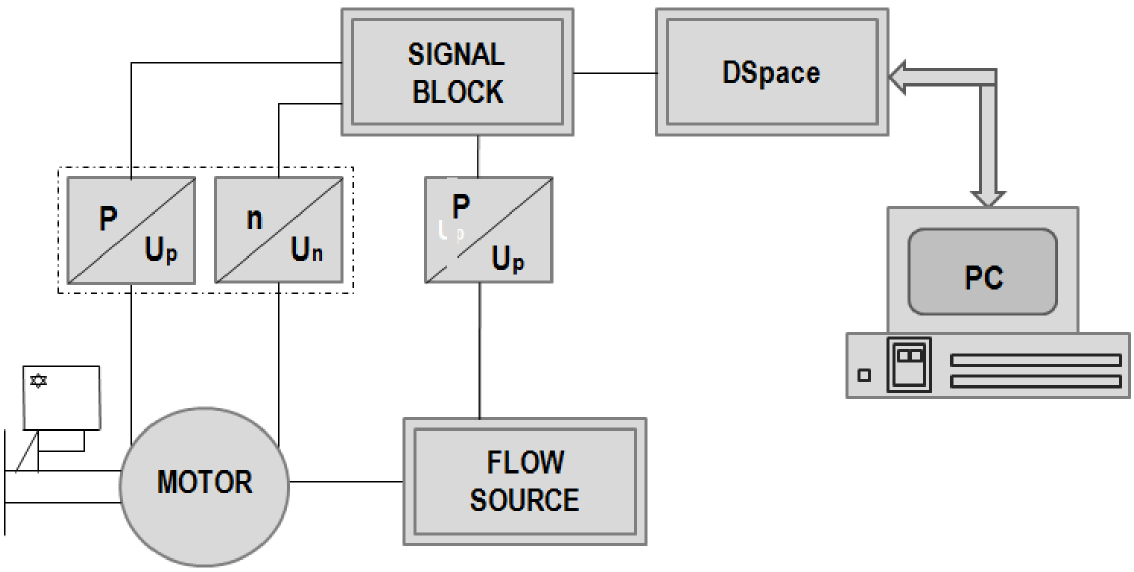

Fig. 2. Scheme of the experimental stand.

The elements numbered in Figure 3 are the following:

1. Control panel for electrical motor;
2. Electric stepper motor;
3. Low speed hydraulic motor;
4. Hydraulic brake;
5. Pressure sensor;
6. Hand pump;
7. Device for measuring the pressure;
8. dSpace panel;
9. Computer.

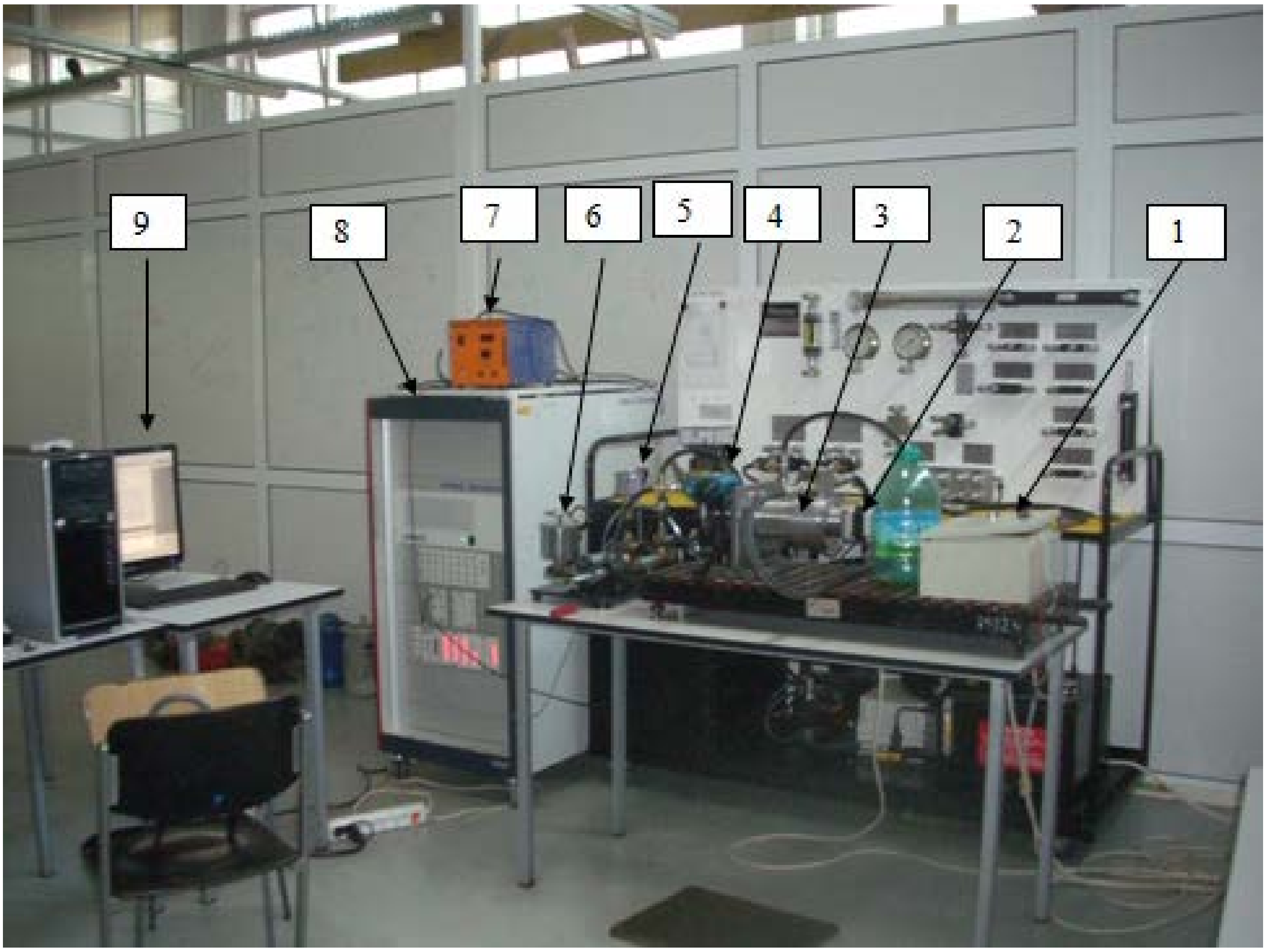

Fig. 3. Experimental rig (overview image).

Figure 4represents the application made in MathLab Simulink software, performed for command and data acquisition of the experimental stand.[9]

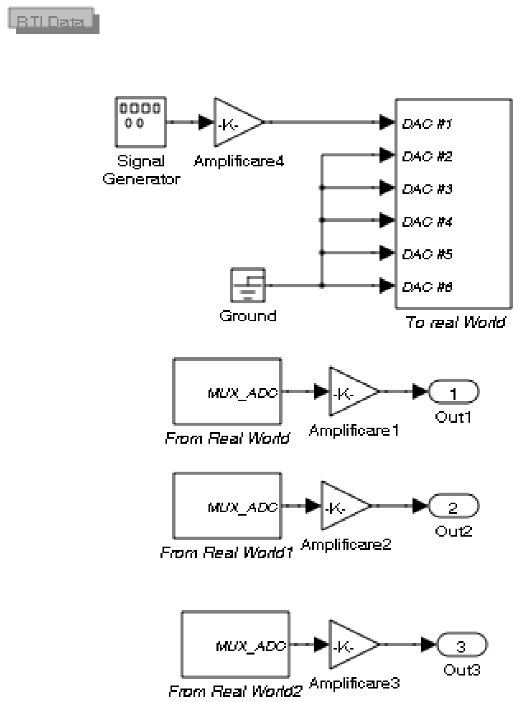

Fig. 4. Control and data acquisition application

Graphic blocks marked "From Real World" and "To Real World" correspond to functions for accessing hardware resources dSpace system. Amplification blocks serve to scale physical quantities in the interval [-1,1]. Block "Signal Generator" transmits the frequency that control the electric stepper motor which drives the distributor.

With the Control Desk software was made a GUI for controlling and viewing the parameters. According to figure 5, this interface contains a block for entering numerical frequency for electrical stepper motor, two display windows for pressures. Speed of the hydraulic motor and distributor are plotted in two separate windows. [8]

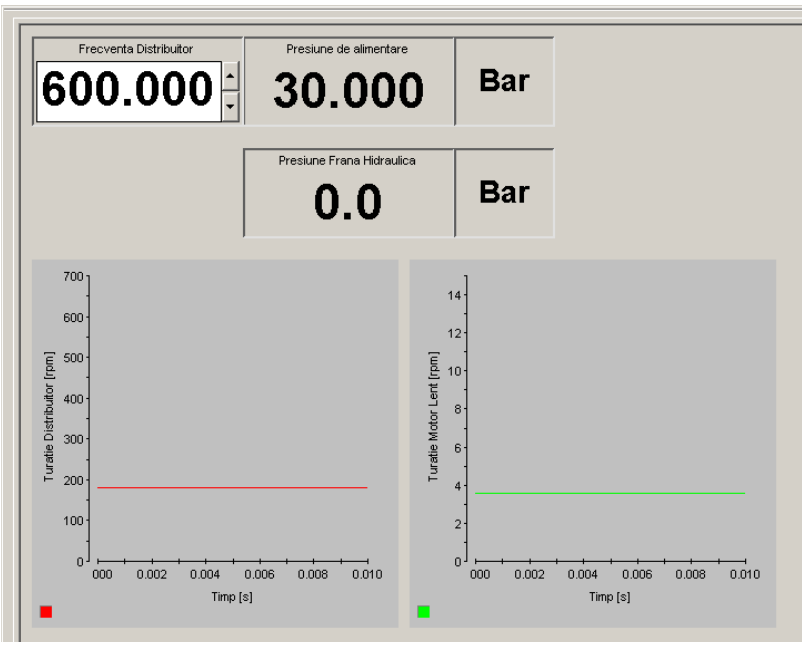

Fig. 5. GUI for data acquisition and control

3. Conducting experiments

There has been two series of experiments. In a first series, no load was considered, for different supply pressures. For each value of the supply pressure were ordered seven different speeds, introducing at the keyboard interface feed rate values corresponding to the stepper motor.

In this case the power supply of the motor was determined by the relationship:

$$P_{source} = \frac{Q \cdot p}{600}[kW] \quad (1)$$

Where:

Q- flow [l/min];

p- pressure [bar].

The measured values from the experimetal research, are shown in Table 1.

Tab. 1. Testing without load

Nr. crt.	Supply pressure [bar]	Speed at stepper motor [rot/min]	Speed at hydraulic motor [rot/min]	Pressure hydraulic brake [bar]	Braking torque [Nm]	Power source [kW]	Power hydraulic motor [kW]
1	30	100	2	0	-	0,675	-
2		150	3				
3		200	4				
4		250	5				
5		300	6				
6		400	8				
7		500	10				
8	45	100	2	0	-	1,01	-
9		150	3				
10		200	4				
11		250	5				
12		300	6				
13		400	8				
14		500	10				
15	60	100	2	0	-	1,351	-
16		150	3				
17		200	4				

18		250	5				
19		300	6				
20		400	8				
21		500	10				

A second series of experiments was performed by placing a load torque on the motor, again for different supply pressures and the drive speed of the distributor.

For the test conditions, the values of the power supply has been calculated with the equation (1), the braking torque determined with (2) and the motor power with (3):

$$M_{fr} = \frac{d_{med}}{2} \cdot \mu \cdot F_{p\,fr}[Nm] \quad (2)$$

$$P_{motor} = \omega \cdot M[kW] \quad (3)$$

Where:

d_{med}- the mean diameter of the braking disc [mm];

μ- friction coefficient;

$F_{p\,fr}$- braking force [N];

ω- angular velocity [rot/min];

M- torque [Nm].

The parameter values for this series of measurements are presented in Tables 2, 3, 4, for maximun pressure of 30, 45, 60 bar.

The values for the measurements at the supply pressure of 30 bar is given Table 2.

Tab. 2. Testing at 30 bar

Nr. crt.	Speed at stepper motor [rot/min]	Speed at hydraulic motor [rot/min]	Pressure hydraulic brake [bar]	Braking torque [Nm]	Power source [kW]	Power hydraulic motor [kW]
1	100	2	3,6	19,94		0,268
2	150	3	3,2	17,72		0,278
3	200	4	2,7	14,95	0,675	0,313
4	250	5	1,8	9,97		0,261
5	300	6	1,2	6,64		0,208

6	400	8	0,8	4,43		0,185
7	500	10	0,4	2,21		0,116

Data from measurements made at a pressure of 45 bar can be seen in Table 3.

Tab. 3. Testing at 45 bar

Nr. crt.	Speed at stepper motor [rot/min]	Speed at hydraulic motor [rot/min]	Pressure hydraulic brake [bar]	Braking torque [Nm]	Power source [kW]	Power hydraulic motor [kW]
1	100	2	5,9	32,68		0,342
2	150	3	5,5	30,47		0,478
3	200	4	4,8	26,59		0,556
4	250	5	4,1	22,71	1,01	0,594
5	300	6	1,8	9,97		0,313
6	400	8	1,2	6,64		0,278
7	500	10	0,6	3,32		0,173

Table 4 displays the experimental data from testing at 60 bar.

Tab. 4. Testing at 60 bar

Nr. crt.	Speed at stepper motor [rot/min]	Speed at hydraulic motor [rot/min]	Pressure hydraulic brake [bar]	Braking torque [Nm]	Power source [kW]	Power hydraulic motor [kW]
1	100	2	6,9	38,22		0,400
2	150	3	6,6	36,56	1,35	0,573
3	200	4	6,3	34,90		0,730

4	250	5	6	33,24		0,869
5	300	6	5,3	29,36		0,922
6	400	8	3,8	21,05		0,881
7	500	10	2,7	14,95		0,782

4. Experimental results

For experiments without load at the motor shaft, there has been done the following actions:

- It was fix the supply pressure of the low speed hydraulic motor at 60 bar;
- The values for the speeds of the rotary distributor (100, 150, 200, 250, 300, 400, 500 rot / min);
- For each value of speed were drawn response diagrams depending of the slow speed hydraulic motor (Figure 6).

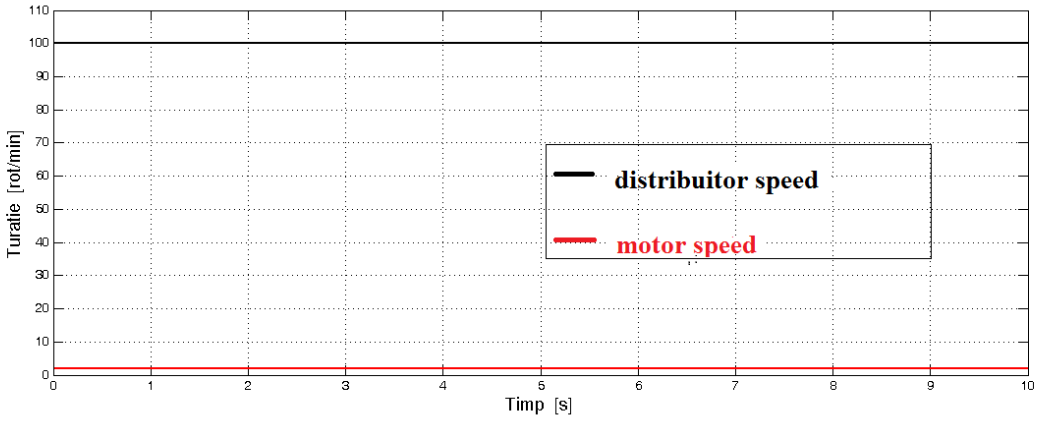

Fig. 6. Diagram of speed at 100 rot/min value.

For the other speeds distributor diagram is still linear, with values from Table 1.

For sets of measurements with load:

- Three values for supply pressure were successively set (30, 45, 60 bar);
- For each value for maximum pressure, the values for the speeds of the rotary distributor (100, 150, 200, 250, 300, 400, 500 rot / min);
- For each value for maximum pressure,was increased the load until the motor speed was zero;
- For each set of measurements diagrams were drawn (Fig. 7, Fig. 8,Fig. 9).

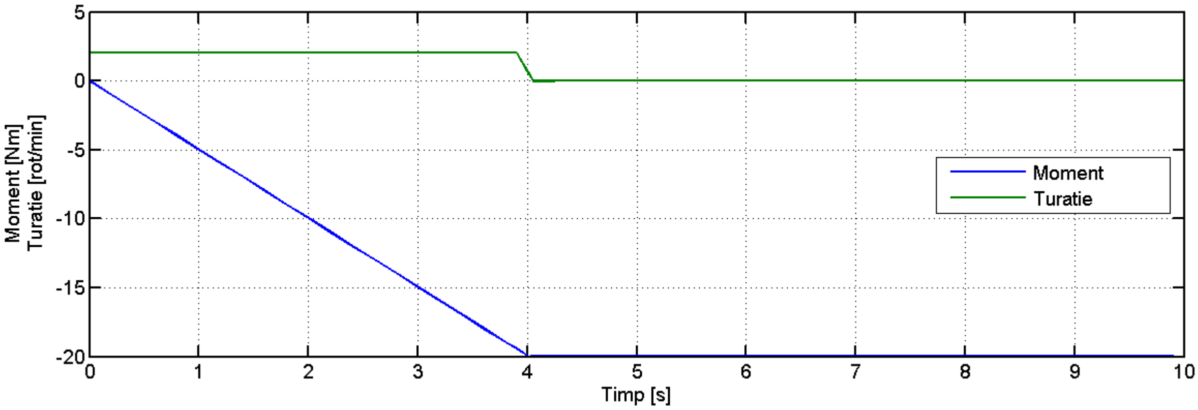

Fig. 7. Supply pressure 30 bar, speed distribuitor 100 rot/min.

For other speeds of the distributor, the diagrams look the same except that the values given in Table 2.

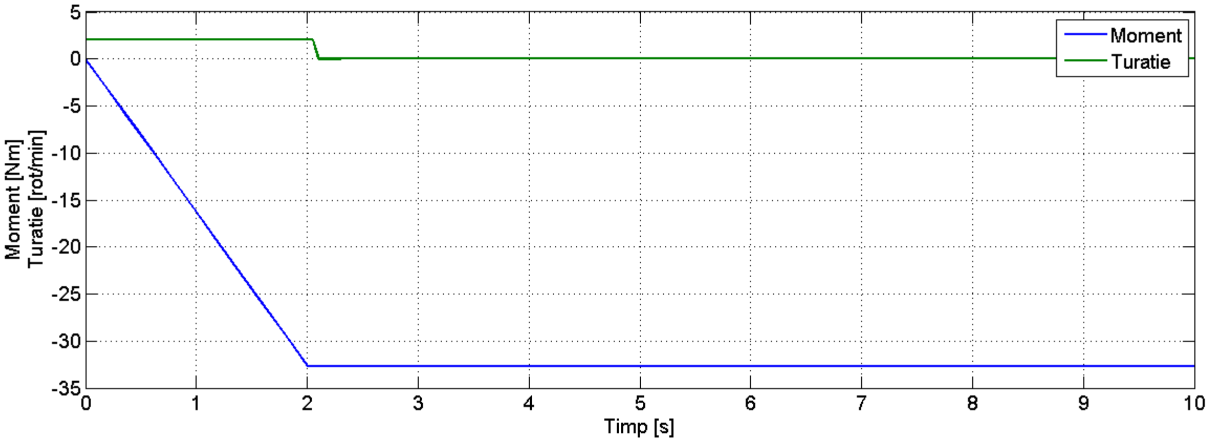

Fig. 8. Supply pressure 45 bar, speed distribuitor 100 rot/min.

The other diagrams are the same, only the values, shown in Table 3.

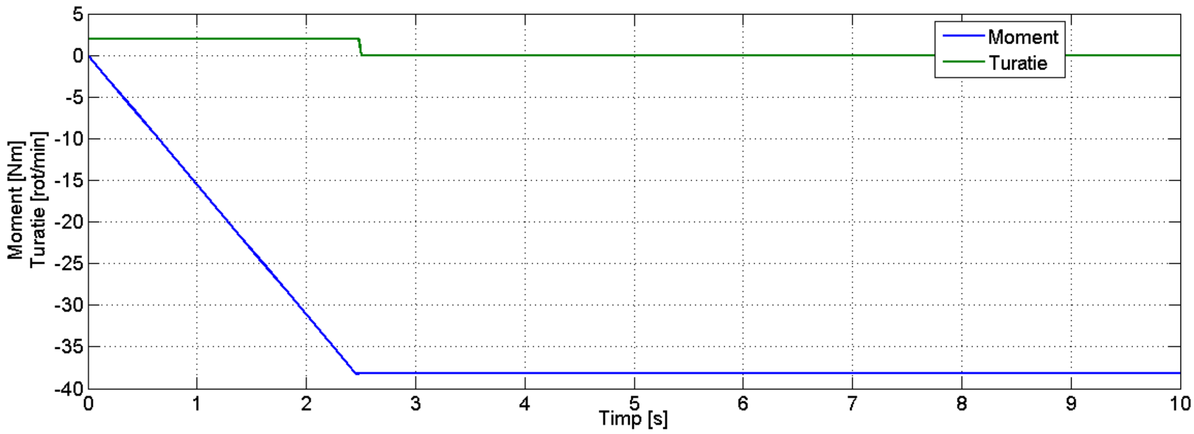

Fig. 9. Supply pressure 60 bar, speed distribuitor 100 rot/min.

For other values of speed, diagrams have a similar shape, the values are presented in Table 4.

5. Conclusions

Were clarified the parameters which strongly influences the behavior of the low speed motor, leading thus to find ways to improve their performance.

The trend of increasing the pressures is limited for these motors because the pressure in thepistons chambers made forces acting on the gear teeth so the materials used require special measures.

Finally we can say that the new hydraulic motor behaves as a dynamic system very stable at real operating conditions. Compared to equivalent electrical systems, they are robust, reliable and have a small size, also can achieve very small angular displacements and high torques.

6. REFERENCES

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