ISSN 1453 - 7303
"HIDRAULICA" (No. 3-4/2012)
Magazine *of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics*

EXPERIMENTAL RESULTS REGARDING ROTATIONAL SPEED OF THE ALTERNATING FLOW DRIVEN HYDRAULIC MOTORS WITH A STAR INTERCONNECTION OF THE WORKING VOLUMES

Ioan-Lucian MARCU[1], Daniel- Vasile BANYAI[2], Claudia KOZMA[3], Gabriela MATACHE[4]

[1] Technical University of Cluj-Napoca, Lucian.Marcu@termo.utcluj.ro

[2] Daniel.Banyai@termo.utcluj.ro

[3] Claudia.Kozma@termo.utcluj.ro

4 Hydraulics & Pneumatics Research Intsitute, Bucharest – ROMANIA, fluidas@fluidas.ro

Abstract: *The presents aspects regarding the theoretical aproach and experimental results on the the speed of the rotation of an alternating flow driven hydraulic motor having a star interconnection of the working volumes. The mathematical model is developed considering the alternant flows function of the generator driving speed, the constructive parameters of the whole system, considering the elasticity of the phase pipes and the oil column compressibility under pressure. There are presented diagrams between the curves of the obtained theoretical speeds and the curves obtained by experimental results interpretation, which are validating the elaborated mathematical model.*

Keywords*: alternating flow, three-phase hydraulic motor, rotational speed, star interconnection*

1. Introduction

Alternating flow driven systems involves a new approach of the driving systems using pressurized liquids, because we have here, in the entire system, along the pipes, an energy transmissions without volumetric flow transportation between the energy converters, hydraulic generator and hydraulic motor. [1], [2], [3], [4], [5]

Generally, an alternating flow driven hydraulic transmission consists in a alternating flows and pressures generator and a motor, the connection between them being realized with a number of pipes equal with the number of phases, the pipes being filled with fluid at a certain (pre-established) pressure. During the functioning of the system the pressure and the flow within each pipe varies in a sinusoidal way, around an average value.

Within these systems, the active stroke of the hydraulic motor pistons, is produced by the pressurized fluid flow from the generator, while, for the retraction stroke there is necessary a supplementary connection (in a star configuration for example) to a pressure generator, working in opposite phase with respect to the first one.

2. Theoretical approaches regarding the rotational speed of the hydralic motor

Considering the constructive characteristics of the hydraulic generator and motor, and using the medium flow formula, we can calculate the rotational speed of the output shaft of the hydraulic motor as follows. [1], [2]

The medium value of the volumetric flow for a phase of the hydraulic generator, for an active angle $\varphi_g = \varphi_{g2} - \varphi_{g1}$, is defined using the equation:

$$Q_{imed_g} = \frac{1}{\varphi_{g2} - \varphi_{g1}} \cdot \int_{\varphi_{g1}}^{\varphi_{g2}} Q_{ig} \cdot d\varphi_g \qquad 1$$

The instantaneous volumetric flow is defined as:

$$Q_i = \omega_g \cdot \frac{x_g}{2} \cdot S_g \cdot \sin(\omega t + \varphi_0) \qquad 2$$

in which x_g is the generator piston stroke, S_g is the generator piston surface, and ω_g is the angular frequency of the generator.

The effective volumetric flow Q_e is influenced by the capacitive flow Q_{iC}, like figure 1 present:

$$Q_e = Q_i - Q_{iC} \qquad 3$$

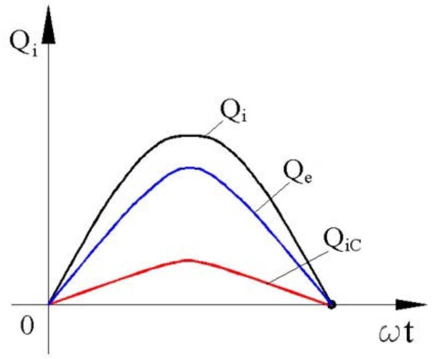

Figure 1. Influence of the capacitive flow on the instantaneous flow [5]

If we consider that the capacitive flow is a "negative flow", then the medium value of the volumetric flow which reaches to the hydraulic motor is:

$$Q_{e_{med}} = \frac{1}{\varphi_{g2} - \varphi_{g1}} \cdot \int_{\varphi_{g1}}^{\varphi_{g2}} \left(Q_i - Q_{iC}\right) \cdot d\varphi_g \qquad 4$$

Taking into account the constructive characteristics of the flow driven hydraulic generator and motor, the interconnection pipes, the elasticity of the oil and also of the pipes, the rotational speed n_m of an alternating flow driven three-phase hydraulic motor, with a star interconnections of the working volumes, can be expressed using the formula:

$$n_m = \frac{3\sqrt{3}}{4\pi} \cdot \frac{n_g}{r_m \cdot S_m} \left[x_g \cdot S_g - \frac{d_{c_{int}}^2 \cdot l_c}{4} \cdot \left(\frac{1}{E_{oil}} + \frac{1}{E_{pipe}} \cdot \frac{2{,}5 \cdot \left(\frac{d_{c_{ext}}}{d_{c_{int}}}\right)^2 + 1{,}5}{\left(\frac{d_{c_{ext}}}{d_{c_{int}}}\right)^2 - 1} \right) \cdot p_{a\max} \right] \qquad 5$$

in which n_g is the rotational speed of the hydraulic generator and $p_{a\max}$ is the amplitude of the pressure along the interconnection pipes.

ISSN 1453 - 7303
"HIDRAULICA" (No. 3-4/2012)
Magazine *of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics*

In figure 2 are presented the principles of the star interconnection working volumes for an alternating flow driven three-phase hydraulic motor.

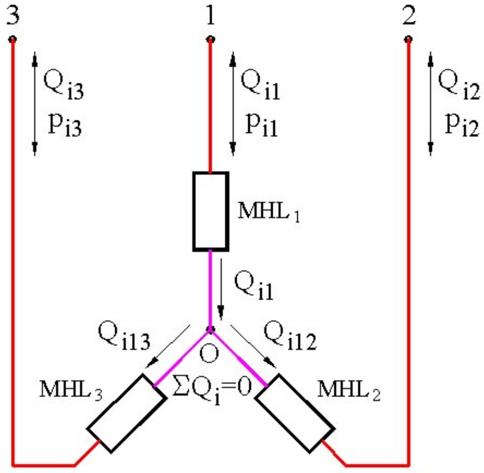

Figure 2. The principles of the star interconnection of the hydraulic motor working volumes.

Schematically the interconnections of the working volumes are presented in figure 2m in which:

- 1, 2, 3 - phase pipes;
- MHL_1, MHL_2, MHL_3 - linear hydraulic motors;
- Q_{i1}, Q_{i2}, Q_{i3} - the instantaneous volumetric flows of the three phases;
- p_{i1}, p_{i2}, p_{i3} - the instantaneous pressures of the three phases.

Each hydraulic linear motor will act individually on the output shaft of the hydraulic motor.

The instantaneous flow of the three-phase hydraulic generator, which provides the active stroke for a linear hydraulic motor is equal with the instantaneous flow generated by the motor pistons movement, and which is provide also the retraction stroke for the next two pistons. So, like the figure 2 shows, we can define the equation:

$$Q_{i1_{star}} = Q_{i1} = Q_{i13} + Q_{i12} \quad 6$$

in which Q_{i13} and Q_{i12} are the volumetric flows providing the retraction strokes of the MHL_2 and MHL_3 hydraulic motors.

Similarly the relations defining the flows for the next two phases, when those are actives, can be written as::

$$Q_{i2_{star}} = Q_{i2} = Q_{i21} + Q_{i23} \quad 7$$

$$Q_{i3_{star}} = Q_{i3} = Q_{i31} + Q_{i32} \quad 8$$

This type of interconnection of the hydraulic motor working volumes is characterized by a null sum of the instantaneous three-phase volumetric flow in the connection point:

$$\sum_{1}^{3} Q_i = 0 \quad 9$$

ISSN 1453 - 7303
"HIDRAULICA" (No. 3-4/2012)
Magazine *of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics*

In figure 3 is presented the alternating flow driven hydraulic motor with a star interconnection working volumes.

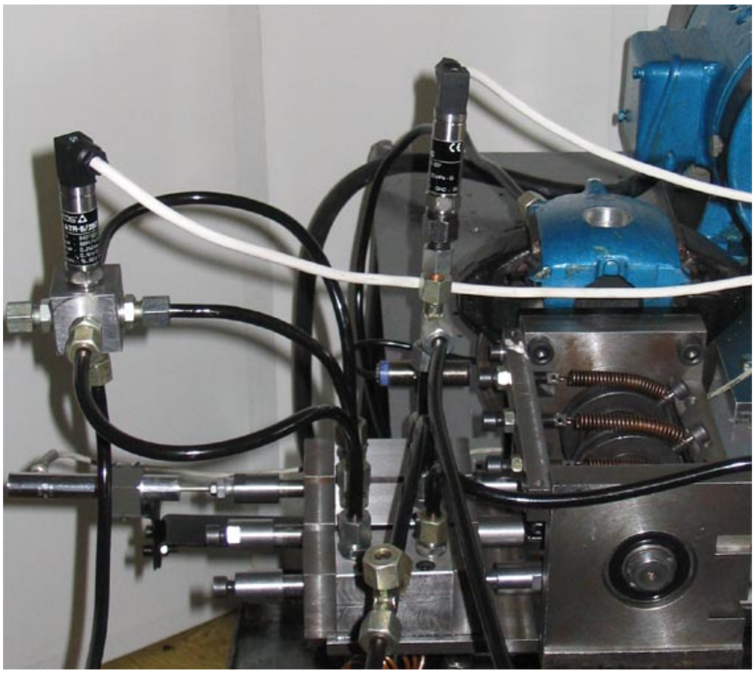

Figure 3. The star interconnection of the hydraulic motor working volumes. [1]

3. Experimental results

The designed version of the three-phase alternating flow driven hydraulic motor included in the experimental strand is schematically presented in figure 4.

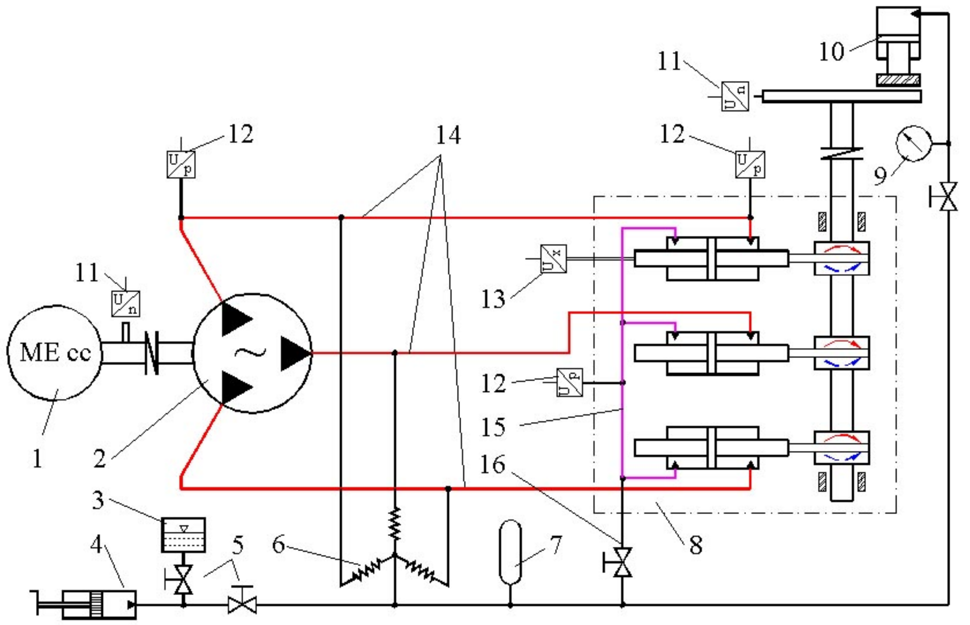

Figure 4. The schematic representation of the experimental stand, having a star interconnection for the motor working volumes. [1]

The components of the hydraulic system presented in figure 4 are:

1 - continuous current electric motor;
2 - axial pistons flow generator;
3 - auxiliary oil tank;
4 - manual screw pump;
5 - vanes;
6 - capillary hydraulic resistances;
7 - hydraulic accumulator;
8 - alternating flow drive hydraulic motor;
9 - manometer;
10 - braking device;
11 - proximity sensors;
12 - pressure sensors;
13 - displacement sensor;
14 - phase pipes;
15 - interconnection pipes;
16 - secondary hydraulic ramification

In order to acquire the experimental data during the testing process we had to precisely control the mechanical and hydraulic parameters using proximity sensors mounted on the rotation shafts, pressure sensors mounted on the representative points of the hydraulic pipes and displacement sensors mounted on the motor cylinder pistons, figure 4.

The monitoring protocol of the entire system was established using an input/output parameters diagram. The preliminary experimental data, representing the functional parameters, were obtained considering the monitoring protocol, the sensors disposition and using a data acquisition board. The large amount of information was reviewed and processed afterwards, taking into consideration each particularly mechanical configuration and input adjustments.

In figure 5 and figure 6 are presented some comparative diagrams obtained using the experimental data and the numerical simulation application developed by using the mathematical model.

The mathematical model was developed considering the two energy converters, hydraulic generator and hydraulic motor, the compressibility of the oil column and also the elasticity of the connections pipes. Another condition was that the volumetric flow provided by the generator is totally used by the hydraulic motor

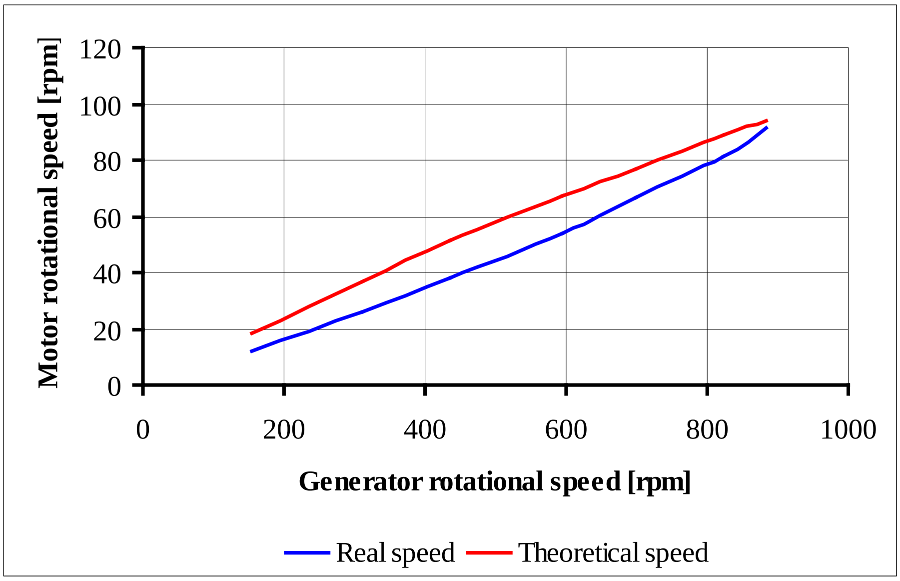

Figure 5. Motor rotational speed evolution: star interconnection schema, generator piston stroke 8 mm and initial static pressure 25 bar.

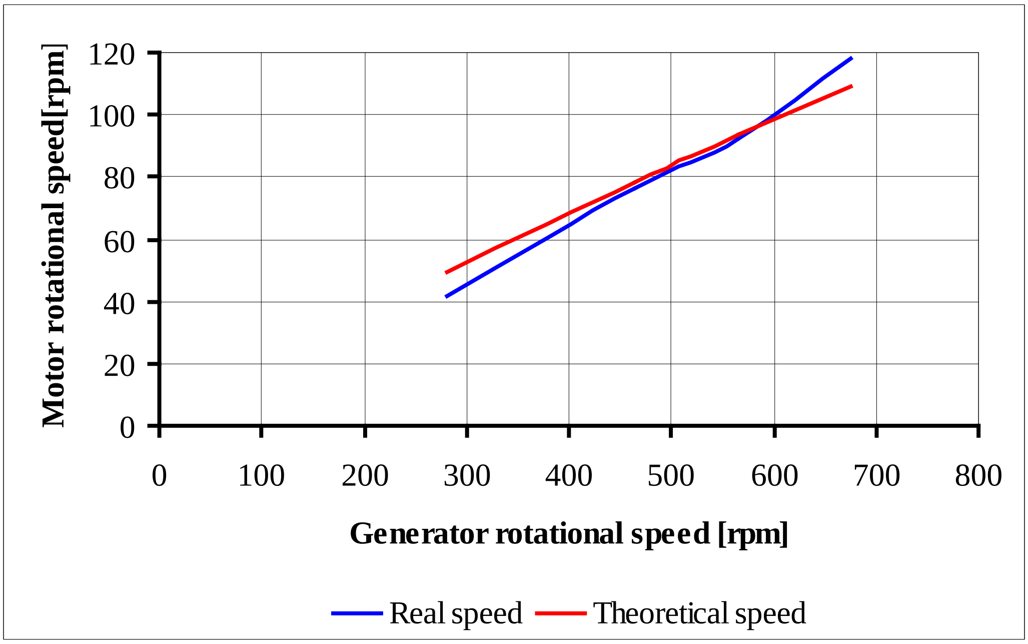

Figure 6. Motor rotational speed evolution: star interconnection schema, generator piston stroke 12 mm and initial static pressure 25 bar.

4. Conclusions

The objective of this research was a new approach of the hydraulic drives, in which the pressure and flow is not continuously transmitted between the energy converters (pumps and motors). The paper describes the constructive principles of the alternating flow driven hydraulic systems, and also its main components.

The experimental results, combined with the developed mathematical model of this system, demonstrates the possibility to adjust, during the functioning, several input parameters (like the initial static pressure and the generator angular speed), in order to obtain the anticipated output values of some parameters, or if the system load is modifying.

REFERENCES

[1] Marcu, I. L., "Researches and contributions regarding the functional improvements of the alternating flow driven hydraulic systems", PhD Thesis, Technical University of Cluj-Napoca, 2004.
[2] Marcu, I.L., Pop, I. "Interconnection possibilities for the working volumes of the alternating hydraulic motors" Proc. of the 6th International Conference on Hydraulic Machinery and Hydrodynamics - HMH2004 in Trans. of Mechanics, Tom 49 (63), Timisoara, October 2004, ISSN 1224-6077, pp. 365-370.
[3] Pop, I., Marcu, I.L., Khader, M., Denes Pop, I., "Conventional Hydraulics", Ed. U.T.PRES, Cluj-Napoca, 1999.
[4] Pop, I., "Sonic Theory Treatise", Ed. Performantica, Iasi, 2006.
[5] Pop, I. et al, "Sonics Applications. Experimental Results", Ed. Performantica, Iasi, 2007.