EXPERIMENTAL RESULTS AND PROCEDURE FOR THE ANALYSIS OF FLOW IN PROPORTIONAL CONTROL VALVE

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Experimental researche confirm or not theoretical approached hypotheses and studies. The paper present an experimental station buld up for the study of cavitation phenomena which occur in a proportional electro-hydraulic directional valve with sliding cylindrical spool. After the definition of spoon housing ensamble geometry there are establisched the orocedure of experimental study of the flow through valve. Experimental computed aided tests are carried out the base of a given hydraulic circuit scheme and installation using a soft collection written and ruled in the Turbo-Pascal TP 6.

In the second part of the paper are presented the results of the experimental tests, including graphics for six opening of spoon- housing ensamble in the throttled slot and the comparision with theoretical resultas. The tests obtained using a reading method of the pressure repartititon on the spoon shouldes spolting a good concordance between experimental and computed curves. For small rating the superposing of results in very good but as the flow grows the concordance declines.

The use of computing technology in a experimental alow a complex and accurate experimental inspection method but also require high quality reception rule /transmission Interface specific to the area proched. The theoretical and experimental research on the considered model enjoy a high concordance between measured and calculated values in spite of approximation required by the mathematical model and the measurement errors whieh occur in the system.

1. INTRODUCTION

Paper presents a test facility used in the study of hydrodynamic and cavitation phenomena for proportional control valves with cylindrical spool. Figure 1 presents the analyzed control valve. The geometry of the control slit (fig.2) represents a compromise between the qualities required for the device, the imposed flow conditions and the difficulties encountered during manufacturing. The studied prototype has the following characteristics:

- nominal diameter	D_n	10 mm
-spool diameter	D_s	16 mm
-rod diameter	D_t	12 mm
-spool stroke	X_{max}	5 mm
-spool overlap	ε	+2…5%
-nominal pressure	p_n	20 MPa
-nominal flow	Q_n	40 l/min
-cylindrical control slit		

control either with stepping motor or

proportional solenoid

2. Objectives of test facility

The main objectives of the test rig are to put into evidence the pressure distribution in the studied domain, to identify the zones in which cavitation appearance is most probable and to allow comparisons with the theoretical results.

The global running parameters of the facility (pressures, flow capacity, hydraulic losses) are also recorded in order to make some correlation with the local parameters distributed along the hydraulic path.

The experimental investigations show that the main cavitation phenomena which appear in the running of the control valve with cylindrical spool depends on the geometry of the flowing path, the opening and the geometry of the of the slit (fig.1). The extreme working conditions are characterized by great pressure differences and increased velocities in the control slit. At such extreme conditions appear pseudo-cavitation, cavitation and the forces acting on the spool are influenced together with the operating and flow capacity characteristics.

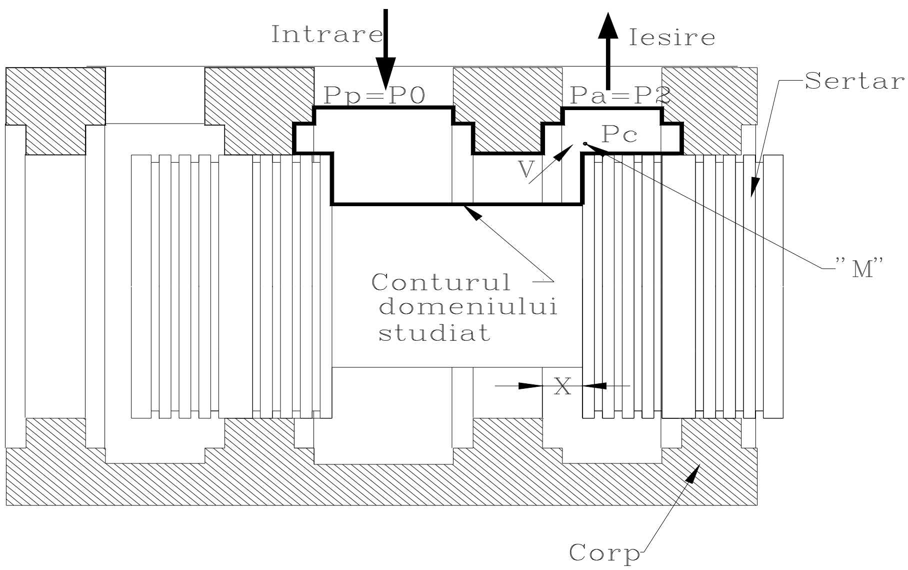

Fig. 1 The geometry of the control valve

3. Test facility

The principal part of the test facility is a model at the scale 5:1 of the Dn10 proportional control valve worked out at HIDROSIB Company (Sibiu-Romania). The model is executed in steel and is working with the hydraulic oil H42As. The general view of the test facility is presented in figure 2 and 3.

The maximum working pressure is 3 MPa; this value exceeds the pressure obtained from Pn (nominal pressure of HIDROSIB Dn 10 control valve) by applying the Reynolds similitude law. Besides the control valve model, the test facility is provided also with:

- a linear mechanical scanner
- oil pressure supply;
- drain line;
- transducers;
- measuring and converting devices;
- the computer which controls the test facility and register the data.

The block diagram of the test rig is presented in figure 3.

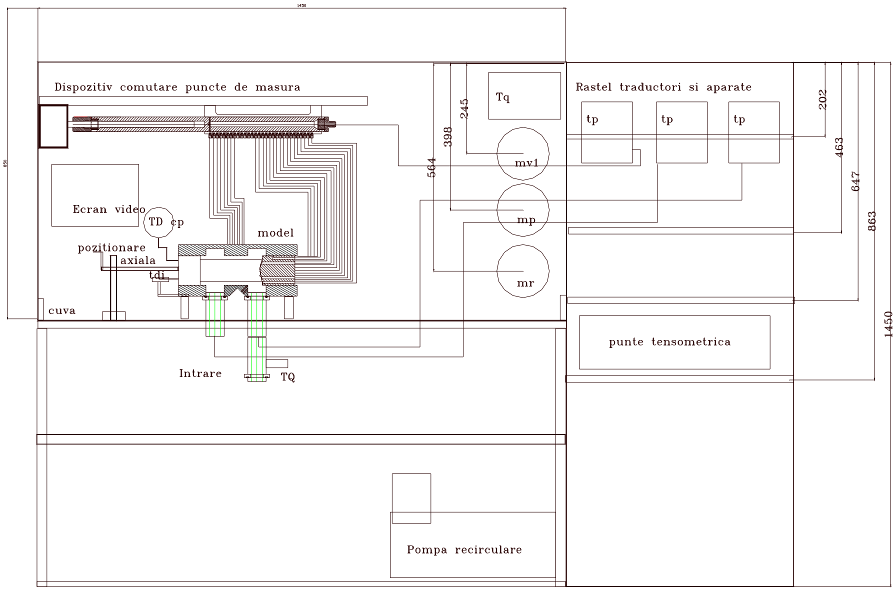

Fig. 2

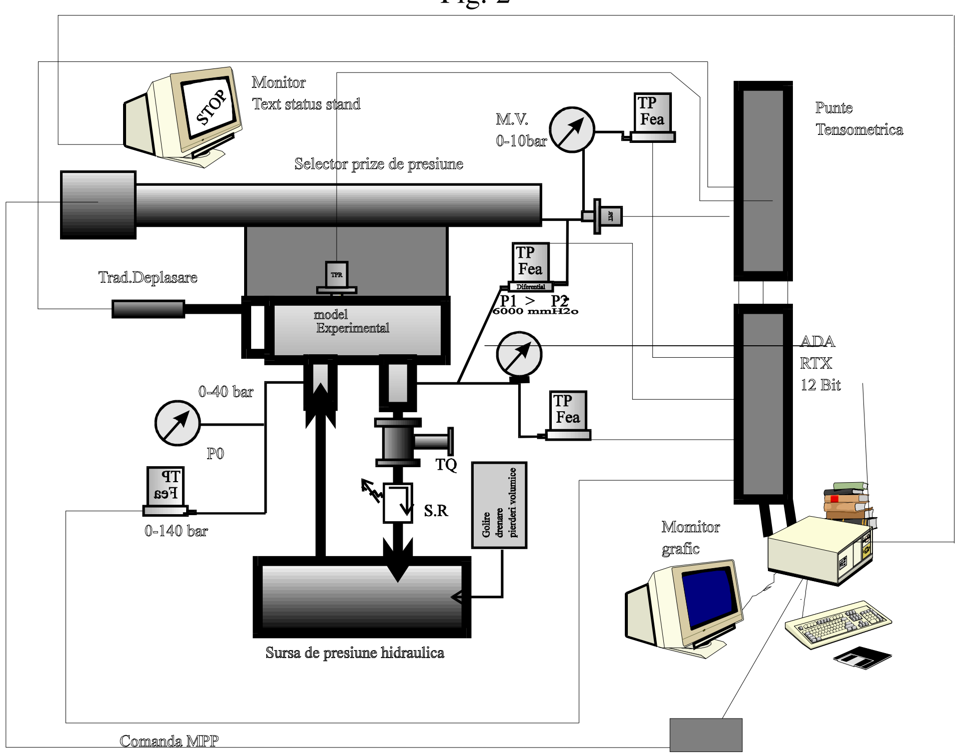

Fig. 3

The pressure measurement connections are accomplished with a mechanical scanner, controlled by a computer through a step function generator. The signals are amplified with the help of electronic devices. The access to the pressure connection points is done sequential, but the scanner can be also commuted to a specific connection point by the test rig command program. One important point during the experimentation consists in the determination of pressure distribution on the frontal side of the spool and in the zone “A” of the control valve using a set of test connection points. Those are placed as a spiral on the frontal surface of the spool so they detect the influence of both angular and axial positions. The placement of the test connection points (and also the operating regimes) were determined by taking into account the velocity field established theoretically.

Because the huge number of readings demanded for each running regime, the test rig was equipped with a process computer and with measuring interfaces. The control process is assured with a set of programs written in TURBO PASCAL 6 which cover all the computing necessities and the numerical filtration of data.

The test rig command program commands also the start/stop processes of the system which collects the volumetric losses. The following types of pressure transducers are used:

* manometers and vacuum gauges;
* differential and simple FEA transducers;
* resistive transducers.

4. Measured parameters and measuring devices

During the tests two types of parameters are under surveillance:

a). The model measured ***global parameters***, which are:

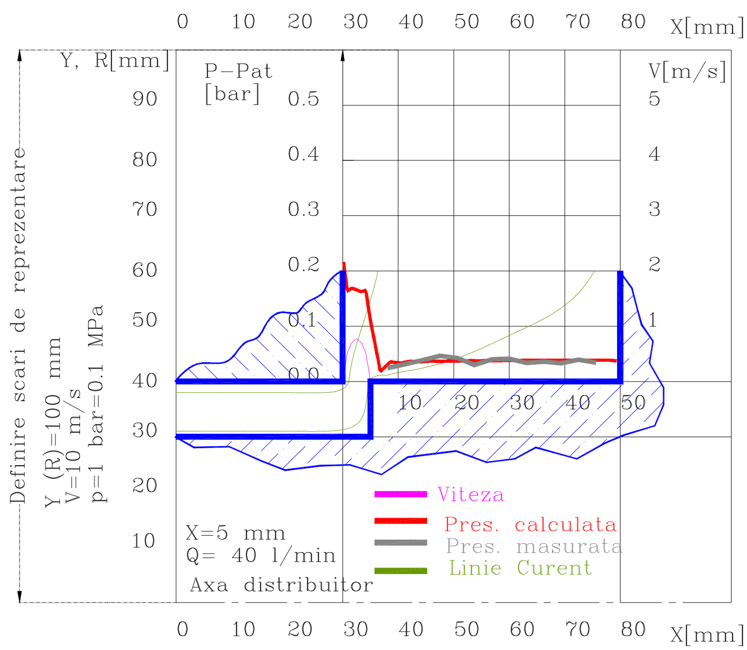

Fig.4.

- the opening x of the control slit (x = 0…50 mm) is measured with a position inductive transducer, the notice rod of which is interdependent with the control valve spool;

- the model inlet pressure -p_0 is simultaneously red by two electrical sensors and confirmed by a manometer (precision class 0.6) calibrated in the LMH laboratory;

- the model outlet pressure -p_2 is measured with a FEA transducer and confirmed by a manometer (precision class 0.6);

-the flow rate of model - Q is measured with a turbine flow meter (type TurboQuant) with frequency range between 150 and 1500 Hz, with 1…2 % maximum deviation. The frequency reading is done with a frequency meter and converted in flow rate units with the help of an integrating converter provided by the manufacturer. There is given also a voltage equivalent with the flow rate. Before each measurement the turbine flow meter was calibrated with the method of the calibrated vessel.

-the temperature of the working liquid-t_u being a global parameter was maintained constant with devices included in the hydraulic power supply unit and verified with a quicksilver thermometer;

-the environment temperature and pressure-p_{at}, t_{at}, the first is recorded with a precision manometer, the second with a quicksilver manometer and the humidity is obtained with the method of the wet thread.

b). The model measured ***local parameters*** are:

-the pressure distribution on the 30 test connection points placed on the control valve body and on the control valve spool. There were measured the absolute pressures and the pressure differences with regard to the inlet (with a differential pressure transducer). The measurements are done electrically with the help of a pressure transducer with strain gauge and a FEA transducer. The pressure difference p_0-p_x is measured with a FEA transducer.

5. Experimental researches and obtained results

The occurrence and development of cavitation phenomena in the hydrodynamic flux of control valves with cylindrical spool was put into evidence by a great number of authors those of Martin and Wiggert [1], [2] being a classical reference. The general purpose of this research is to compare the experimental results obtained by testing a model control valve with cylindrical spool (magnified five times) with those obtained theoretically by modeling the flow with FEM maintaining the same global conditions as for the experiment. The results have been compared for 7 openings and 2 values of flow rate.

As a result of the tests it was obtained a set of files which contain the measurements directly converted in physical parameters by the calibration functions. The pressure distributions can be displayed on the computer screen as tables or diagrams, without auxiliary processing, by the means of a PASCAL program. The pressure values p_x determined on the pressure test connecting points placed on the control valve body and spool are relative values. For each measurement the inlet pressure values is obtained by the two transducers p_{0Tr} and p_{0FEA}.

In figures 4…9 the experimentally obtained results are graphically presented and compared with the computed ones.

Figure 4 presents the comparisons for an opening of the cylindrical control slit x = 5mm. For small openings the number of test connection points on the frontal part (11 points) are sufficiently. From the theoretical distribution it can be seen that that the pressure presents a sharp decrease immediately after the spool edge. This decrease was confirmed by the experimental pressure distribution.

Figure 5 presents the same results for an opening x = 10 mm. Because the passing area is greater, the pressure decrease and the velocity increase are smaller. Simultaneously it can be seen a remove of the jet from the body wall. By modifying the opening at x = 15 mm all the described phenomena are increased and the possibility of cavitation occurrence is diminished. For the maximum opening and a the flow rate Q = 40 l/min, both from the computed and measured distribution it can be remarked a flattening of all characteristics including the pressure distribution. On the other part the jet is oriented strongly towards the frontal part of the spool, but is not attached to it.

For a flow rate Q = 120 l/min the behaviour is to some extent similar to those described for Q = 40 l/min, but with pronounced differences between the measured values and those obtained experimentally. Because the flow rate is greater the absolute values of velocity is greater. The pressure and velocity variations are greater and with pointed peaks. The minimum pressure values are in the proximity of the edges as it can be seen in figure 9.

6. Conclusions

6.1. The experimental results obtained by reading the pressure distribution on the frontal surface of the spool put into evidence a good agreement between the shape of the measured and computed curves. For small values of the flow rate (Q=40 l/min) the correspondence between the two types of curves is very good while with the increase of the flow capacity this quality decreases.

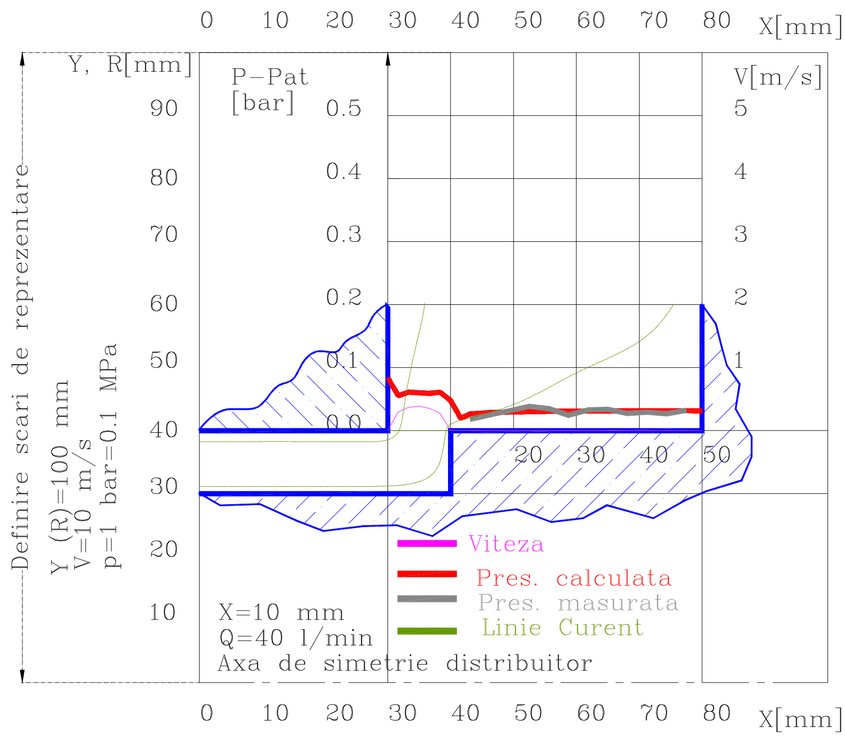

Fig. 5

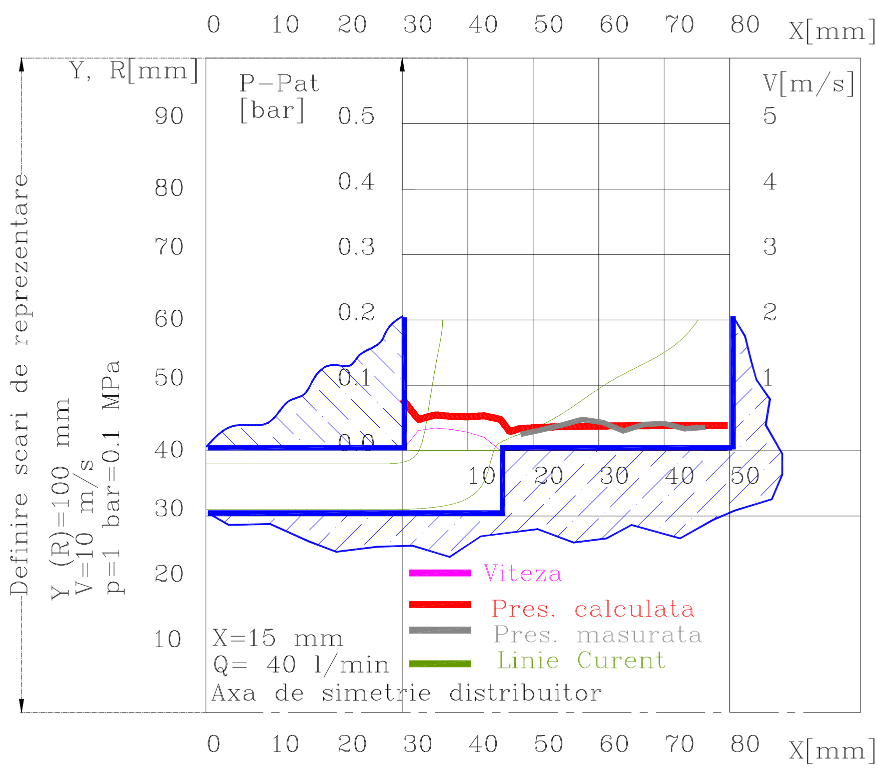

Fig. 6

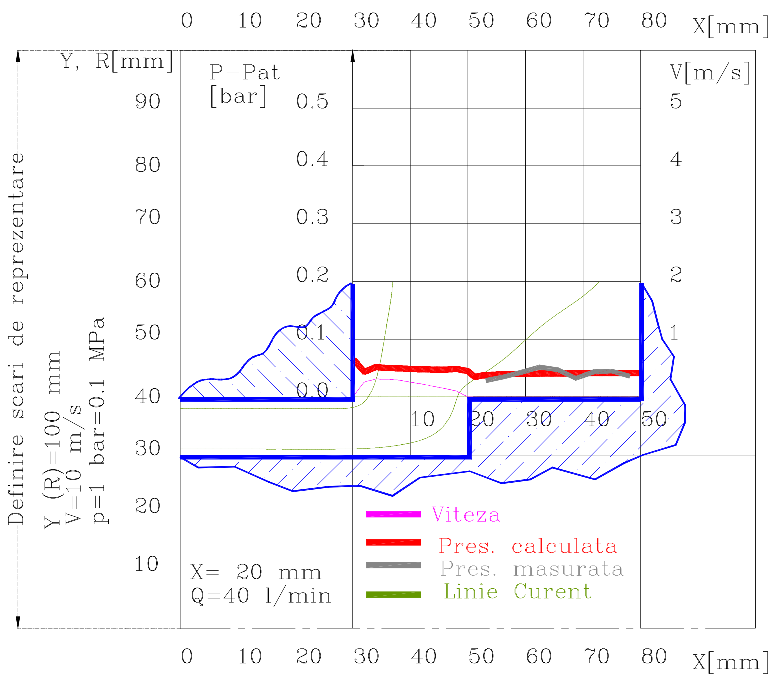

Fig. 7

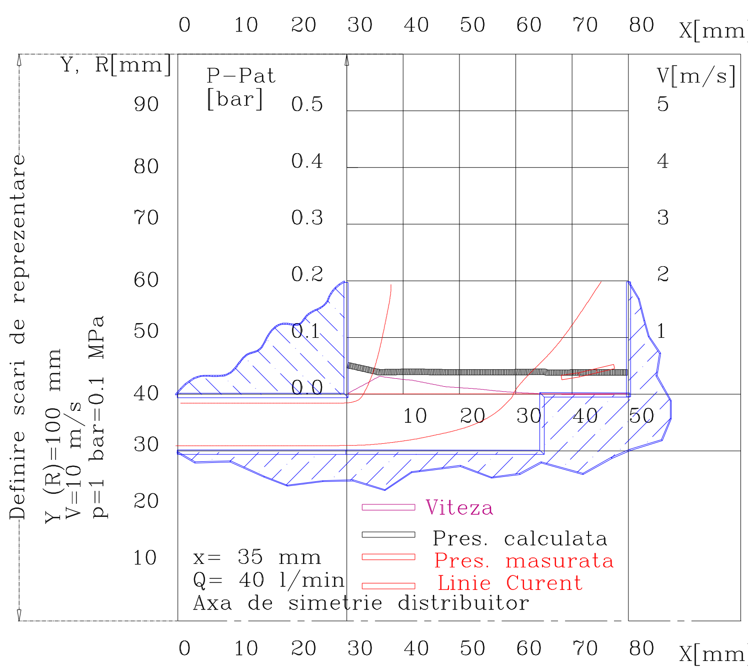

Fig. 8

6.2. For the both measurement sets (40 and 120 l/min) it was put into evidence a decrease of pressure in the immediate proximity and downstream of the control slit, reflected in the values measured with the test connection point 1 which is very close to the control edge. Although the measured decrease in pressure is relatively pronounced in comparison with those upstream of the control slit, they do not reach the values necessary for cavitation inception. We must note that as a result of the measuring procedure there were obtained only time mediate pressures which are higher than the real ones. 6.3. Both from experiments and FEM numerical computations it results that the parameters which have most influence on cavitation occurrence are the pressure differences between the inlet and outlet side (p_0-p_A) of the control valve and the slit opening (x).

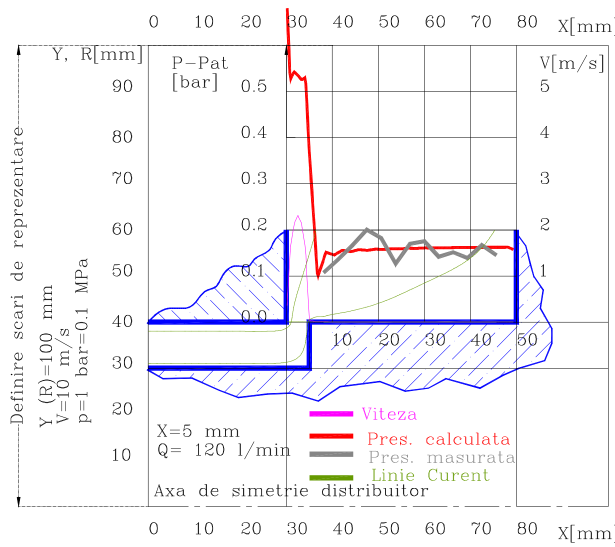

Fig.9

6.4. Comparing the experimental and the analytical results there has been obtained a qualitative concordance between the measured and computed values, in spite of the approximations imposed by the mathematical model used on the one hand and the measuring errors on the other hand.

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