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Contributions to the modernization of fluid power field by integration of intelligent equipment

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Słowa kluczowe: cyfryzacja, digitalizacja, hub, inteligentna hydraulika, inteligentne stojaki hydrauliczne, Przemysł 4.0

Abstract:

The article refers to some directions of modernization in the field of hydraulics focusing on digitalization and the transition to intelligent hydraulic equipment and systems. Before exposing the achievements, the authors try to remove some confusion related to digitization and digitalization. The article presents two intelligent equipment designed by IHP, a proportional directional valve and a digital actuator and two intelligent stands, one of servo-valves and one of digital hydraulic cylinders, existing in operation in laboratory and which by the endowment and working procedures represent solutions in the field of intelligent hydraulics.

Streszczenie:

W artykule odniesiono się do wybranych kierunków modernizacji hydrauliki, koncentrując się na cyfryzacji i przejściu na inteligentne urządzenia oraz systemy hydrauliczne. Przed przedstawieniem osiągnięć autorzy artykułu starają się usunąć zamieszanie związane z pojęciami cyfryzacji i digitalizacji. W artykule przedstawiono dwa inteligentne urządzenia zaprojektowane przez IHP, rozdzielacz proporcjonalny i siłownik cyfrowy oraz dwa inteligentne stanowiska, jeden z serwozaworów oraz jeden z cyfrowych siłowników hydraulicznych, stosowane w laboratorium, które ze względu na wyposażenie i procedury robocze są rozwiązaniami inteligentnej hydrauliki.

1. Introduction

Hydraulic drive has become extremely useful and is used very intensively due to the fact that in addition to the power transmission load, it also lubricates the system and dissipates generated heat.

In recent years there has been a technological development that, within Industry 4.0, leads to a radical change in industrial production, with the main support of digitalization and smart equipment.

Intelligent hydraulic equipment and systems are a combination of hydraulics, which brings traditional power, with the intelligence of electronics, to which sensors and informatics are added [1, 2, 3, 4]. This combination serves both the process of monitoring the parameters and the predictive maintenance activity, or modernized variants of it. It is also important that all the information retrieved is processed, transferred, used to establish commands, permanently using Internet technology (Ethernet).

2. Digitalization of hydraulics

In recent years, technique and technology have undergone essential changes [5, 6], and all this falls into several priority directions, such as: Industry 4.0, digitalization, renewable energy resources or the circular economy [7, 8]. With the development of a powerful Internet infrastructure, things in the technological fields have become a field of progress, difficult to anticipate 50 years ago. The problem is that there has also been a confusion of terms, due to the superficiality of some, who without understanding the correct meaning of these novelties, permanently misuse the term with purpose, but especially without purpose.

One of the big confusions is the incorrect use of the terms digitization and digitalization.

Digitization, as a general idea, is the process of switching from analog data, or collecting all available and accessible information, in digital formats. Digitization takes place in two stages: discretization and quantization. The discretization realizes the division in time (frequency) of the signal, and the quantization represents the phase of discretization in amplitude of the signals, which in practice is usually realized simultaneously [9]. Objects, images, sounds, texts and other forms of information are finally converted from analog signal to binary signal.

Digitalization is a process making intense use of digital technologies to generate, process and exchange information, or according to some specialists is the use of technologies supported by the Internet in actions of storage, processing, search and use of information. A rather dangerous idea is that digitization is easily solved by acquiring computer technology. Digitalization is a later phase of digitization, through which binary information is used in centralization, automatization and command, but this requires the industry software, which will develop continuously in the coming years. Along with the Internet, the role of tablets and phones will increase, which will increase their importance in taking over the processing and storing data, reducing from the basic function of the phone to ensure only phone calls. One of the interesting consequences, pronounced during this period, is the development of the working from home variant, or how a lot of people express outsourcing to their own home. In the field of hydraulics there have been digital activities for a long time, such as those in transferring data from one company to another, in the field of testing, when data are taken from sensors, stored, processed and prepare the system for new orders, or in the field of maintenance. The institute investigates new applications that take digitized data and use digitalization methods to modernize the field. Unfortunately, hydraulics is only at the beginning of digitization, digitalization and digital transformation, the essential element being in our opinion the precariousness of specific knowledge of design and manufacturing workers.

Without a management with digital experience, without understanding that production also includes design, sales, communication and maintenance, it is almost impossible to make the domain progress. A first major action at European level is the emergence of digital innovation centers that represent groups of companies, including research, whose main role is to provide expertise and digital transformation services, as well as services related to artificial intelligence, high performance computing and cyber security. Among other activities, these centers provide the group with training courses in the issues of hydraulic domain digitalization and in many situations the testing facilities. It is important that the field of expertise of the hubs differs. These hubs are specialized in these fields, but at national or even European level that implies a complementarity of their activity, which would allow them to expand the area of expertise on the essential issues of economic and industrial development. In the field of hydraulics, IHP has started taking steps for the development of a digital innovation center that, starting from the principles of Industry 4.0 and circular production methods, will be able to help productive enterprises solve some problems of digitalization and use of artificial intelligence.

3. Equipment and intelligent hydraulic systems

The specialists of Frost & Sullivan show in the material: Smart Hydraulics: Giving the Hydraulics Industry of Second Wind [10], their opinion on the comparison between technical-economic characteristics of electrical systems and hydraulic and intelligent hydraulic ones.

From Fig. 1 they conclude that intelligent hydraulics, although more expensive than ordinary hydraulics, are cheaper than electric drive and even if it is slightly below its efficiency, the differences are insignificant in most specific applications of hydraulics. It is also found that hydraulics, even in its intelligent form, is still in terms of power density above the level of electric drive, and slightly lower controllability is more theoretical, as in practice things are refined by the fact that they also use electronics and computing used by all systems.

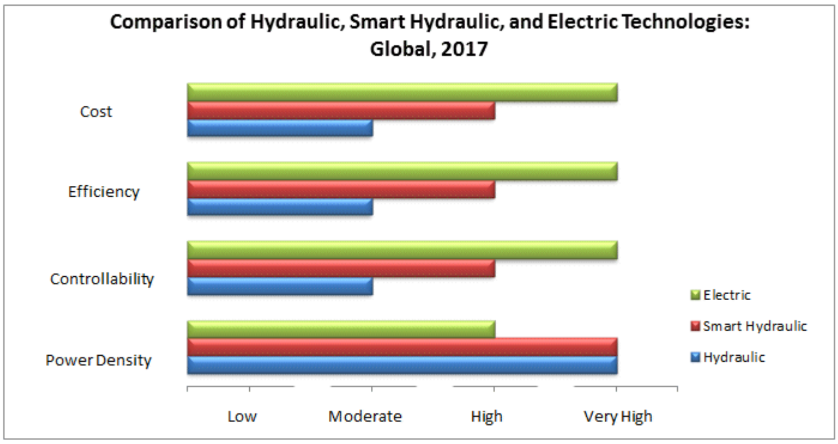


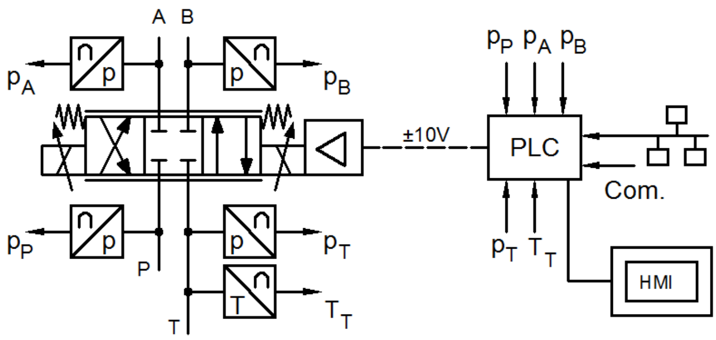
Fig. 1. Comparison of Electric, Smart hydraulic and Hydraulic (Frost&Sullivan)

Within the institute there are activities for the development of intelligent hydraulic equipment, from which a directional valve and an actuator is presented below.

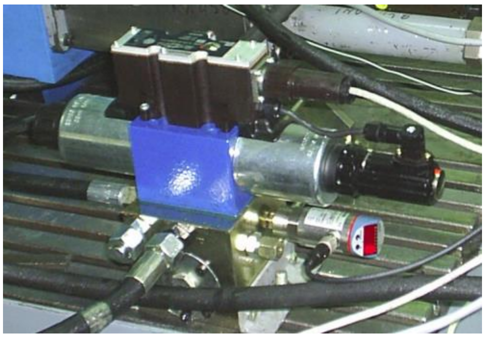
3.1. Smart proportional directional valve with pressure and temperature sensors

In our specialized laboratory a proportional hydraulic directional valve has been developed at a level that can be appreciated as intelligent (Fig. 2). In this sense, we attached to a proportional directional valve a plate (block) in which we integrated compact pressure sensors, and we control it with a PLC (Programable Logic Controller).

The integrated pressure sensors can be used to monitor the operating status of the appliance or to control the pressure [11, 12]. The control and monitoring of the operation of the smart hydraulic equipment is done through a PLC and a PC (personal computer) application [13, 14, 15]. The communication is made through the LAN. Via the PLC, the proportional directional valve can be controlled in three ways: via serial port, via analog signal 0… 10 V or via Ethernet LAN. Also, for local control, an HMI (Human Machine Interface) can be attached to the PLC.



a) Schematic



b) Directional prop. valve with sensors block

Fig. 2. Smart hydraulic proportional directional valve

3.2 Smart hydraulic actuator

Another hydraulic equipment is the smart actuator which consists of a hydraulic cylinder (C), an servo-valve (SV), a displacement transducer (DT) with electronic amplifier included, a PWM driver (D) and a Programable logic controller (PLC). The actuator can be controlled via the serial interface, with an analog signal 0… 10 V or via a specific application via Ethernet LAN. Fig. 3 shows the diagram of a smart hydraulic actuator and a view of such an actuator provided with displacement transducer. To test the actuator, a function generator application is used (Fig. 4) obtaining the position response and the error.

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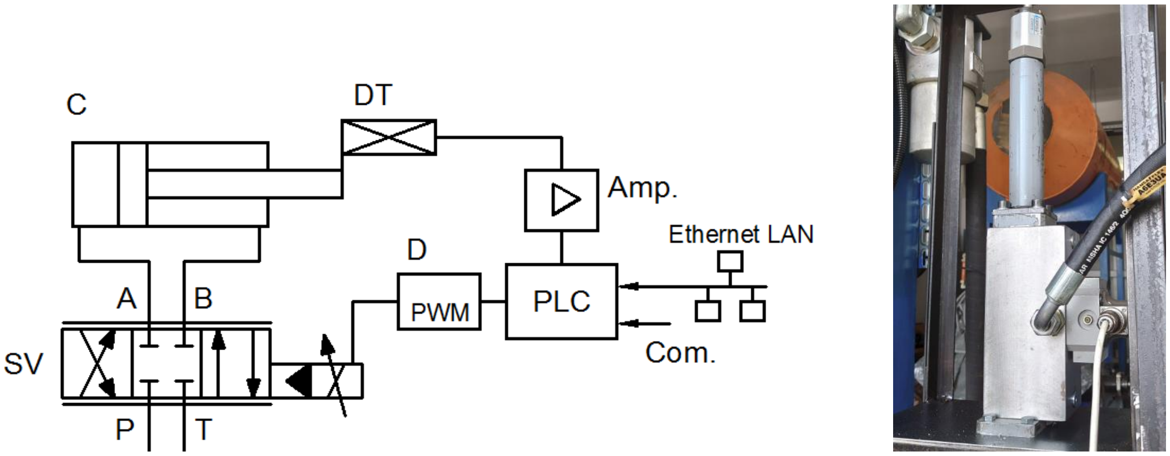
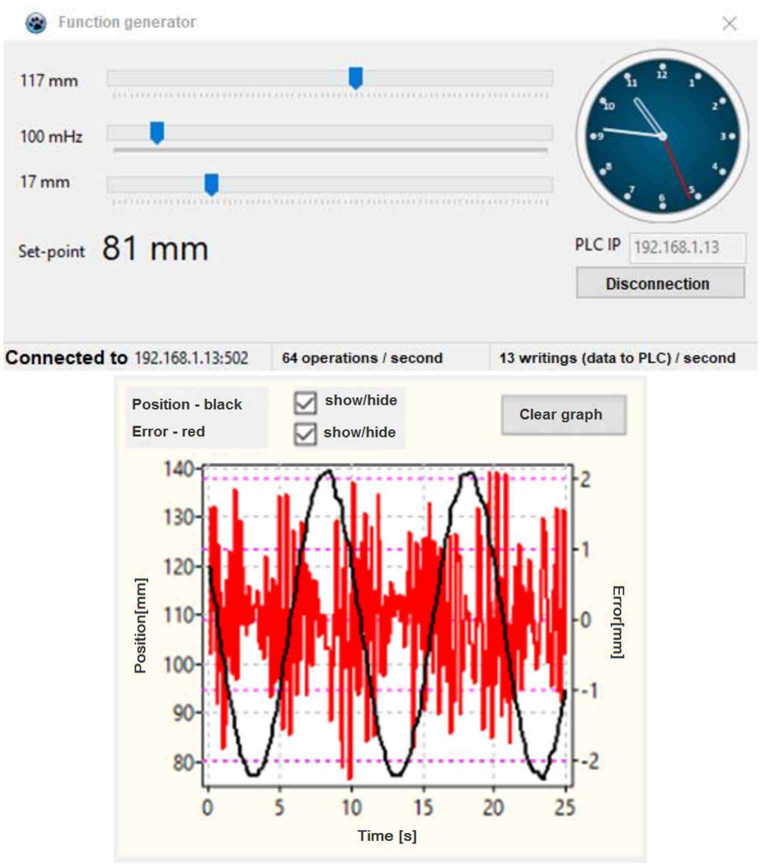


a) Schematic b) Actuator view

Fig. 3. Smart hydraulic actuator



a) Function generator interface

b) Actuator response and positioning error

Fig. 4. Application for testing the smart actuator

4. Intelligent test stands

4.1 The international development of hydraulic testing equipment

In recent years, there have been quite a few stands that have included elements of intelligence in their structure, but an extremely interesting option will still be presented.

The stand proposed by NOVOTEST (Fig. 5) is equipped with a fairly simple interface programmed in Windows, in a simple solution, but functionally efficient.

Data retained:
- Analog data
- Digital data (SSI etc.)
- CAN data (with analog data synchronization)

Stored data:
- Data export as a text file (.csv), DIADEM file
- Database connection ODBC, MS Access, SQL Server

The stand allows creating and editing test programs.

Fig. 5. The intelligent stand proposed by the Novotest

4.2 Test stands made by authors at IHP Bucharest

4.2.1 Servo technique test stand

In the context of the large-scale digitalization of industrial processes, IHP researchers have started a computerization program of existing laboratories [16, 17]. Thus, the servo technique stand, having as main components two linear hydraulic axes, was equipped with a hardware/software automation system that allows the integration of the stand in the computer network of the institute, which can be accessed on any computer from the network and also through the Internet. Also, *the operating data collected* from the transducers on the stand or *command data* of the various execution components are managed by an existing MySQL database in the computer system of the institute.

The automation system of the stand is built around a general-purpose programmable controller *Modicon M221 Logic Controller from Scheneider Electric*, TM221CE16U (Fig. 6).

The programmable controller monitors the positions of the rods of the two hydraulic axes from the stand component through two analog/digital inputs and commands the electrohydraulic servo-valves, which consists the components of the linear hydraulic axes, with two digital PWM (Pulse Width Modulation) outputs.

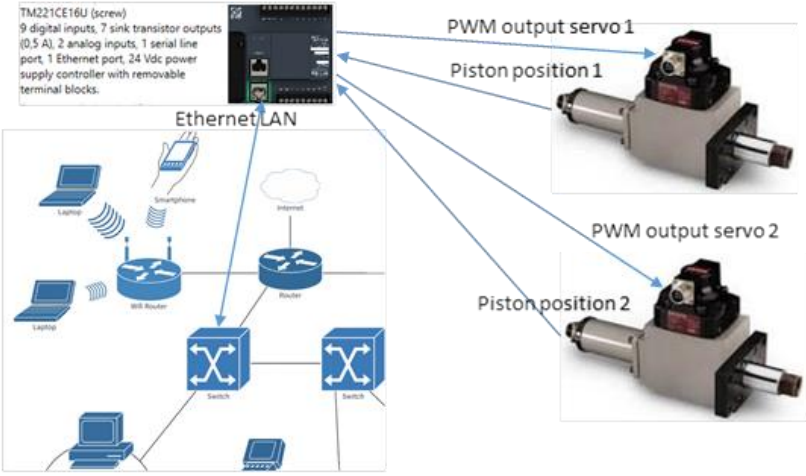
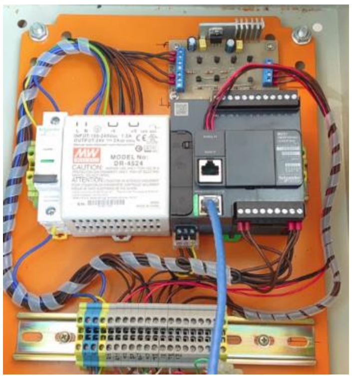


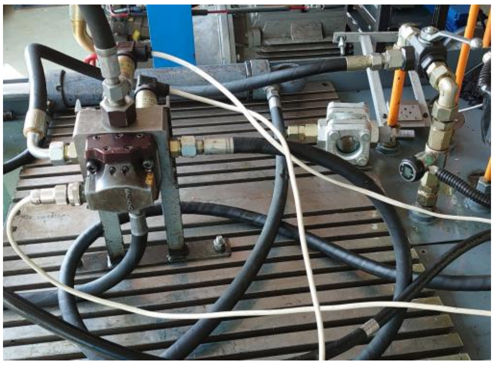
Fig. 6. Automation system of the Servo-technic test stand

It should be mentioned that a read out cycle, command calculation with PID controller and PWM output update, lasts 1ms; the desired values for the positions of the two linear axes are taken over by the PLC from a computer connected to the same Ethernet data network as this one.

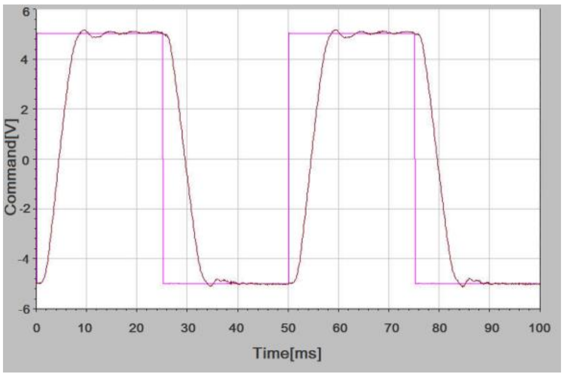
a) Command Panel and HMI



b) PLC and PWM driver



c) The servo-valve during testing



d) Dynamic response of the servo-valve tested

Fig. 7. Servo valve test stand

From the point of view of the software architecture, the client/server configuration was used; thus, the PLC is configured as a server using the *MODBUS TCP / IP* protocol [18]. The developed client applications; test signal generator, the parameterization and control application of the linear hydraulic axes and the monitoring and data management application, respectively are connected with the institute database. It should be noted that software applications are developed to work on Windows or Linux operating systems, one set for each operating system; the average communication speed with the programmable controller of the software applications is approximately *50 transactions per second* under the Windows operating system and *100 transactions per second* under the Linux operating system, given that all three applications (generator, servo-controller and parameter visualization) run on the same computer located in the same LAN network with the programmable controller of the servo technique stand.

In Fig. 7 one can see the panel of the servo-technique stand provided with control buttons and HMI interface. Fig. 7 also shows the electrical panel of the stand with PLC, PWM driver and power supply, as well as a step signal response diagram for a servo-valve.

4.2.2 Digital hydraulic cylinder test stand

For the testing of the digital hydraulic cylinders (Fig. 8) designed and manufactured in the institute, a test stand was made.

Digital hydraulic drive is a new approach to linear drive [19, 20]. The basic principle is the division of the active surface of the cylinder. By dividing the working area of a piston into binary multiplier ring areas, or according to other criteria, the selective pressurization of the ring chambers results in a cumulative output force that can be actively controlled in relation to the system requirements.

The stand (Fig. 9) contains a mounting device with hydraulic load cylinder, transducers, data acquisition system and a pumping unit.

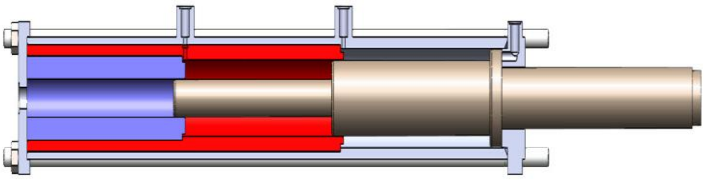
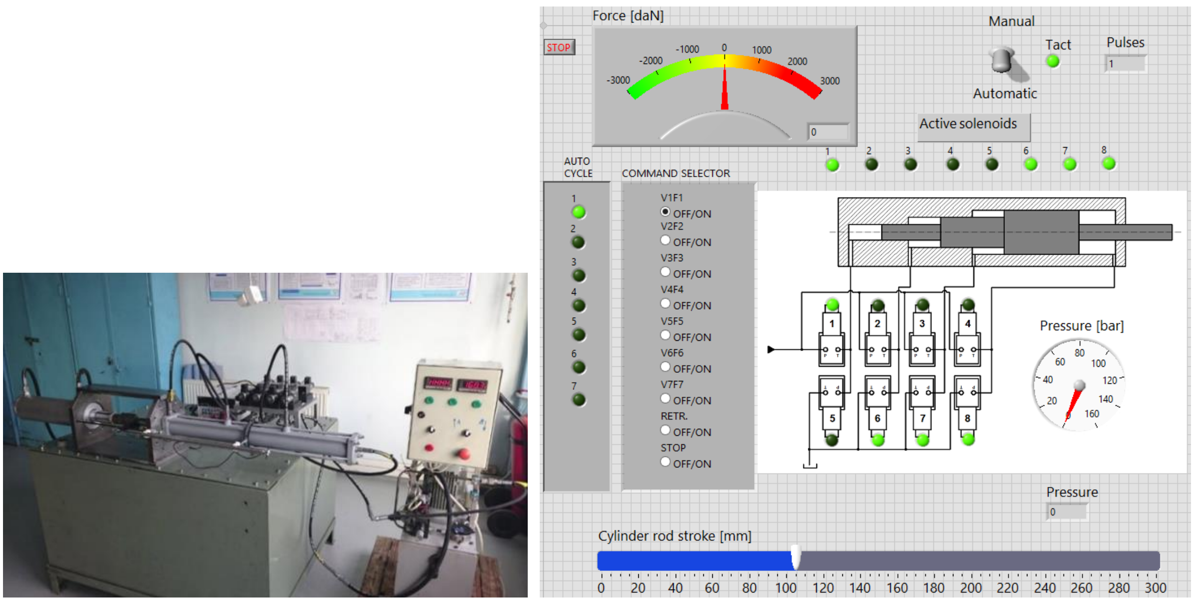


Fig. 8. The structure of a digital hydraulic cylinder

A Virtual Instrument made in the LabView environment software was used for testing, but for industrial or mobile operation it is very convenient to use a programmable logic controller (PLC), which controls the solenoids of the hydraulic directional valves according to a diagram of forces and speeds necessary in hydraulic actuation and allows Modbus TCP / IP communication.



a) View of digital hydraulic cylinder test stand b) Labview virtual instrument for test stand

Fig. 9. Digital hydraulic cylinder test stand and software application

In the Fig. 10 one can see the diagrams obtained with the LabView virtual instrument tool and the data acquisition system. The diagrams represent the evolution of the following parameters: rod displacement, rod speed, system pressure and pump flow.

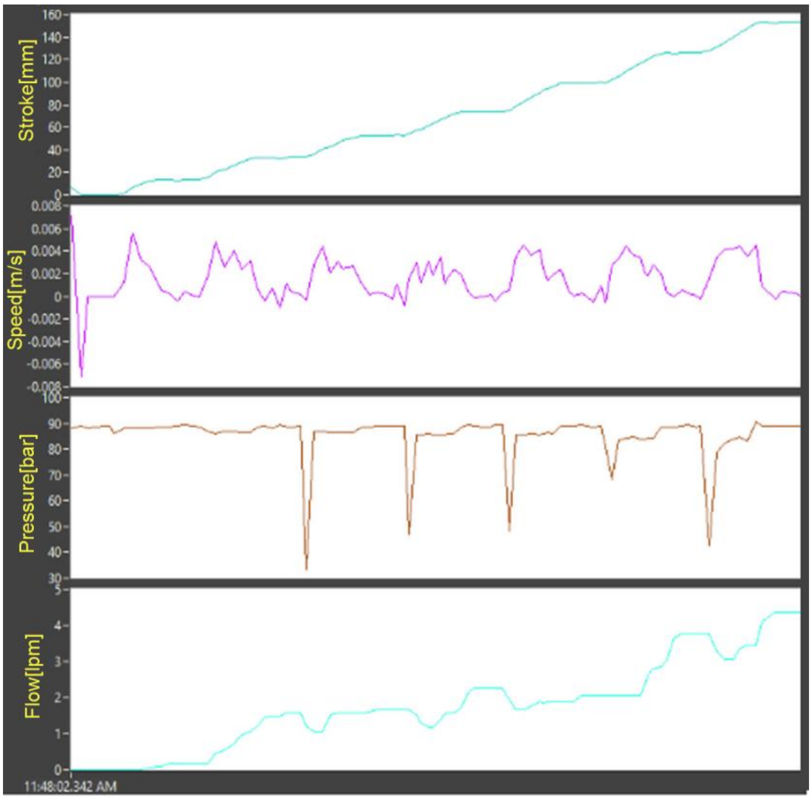


Fig. 10. Diagrams obtained during testing of the digital hydraulic cylinder

5. Summary

Hydraulics remains one of the basic drive systems and through the intelligent hydraulics variant it strengthens this role.

Testing is an important branch of intelligent hydraulics.

In order to modernize hydraulics to be included in Industry 4.0 it is necessary to understand exactly the new directions and their correct definitions.

As electronics will make hydraulic equipment smarter, hydraulic specialists will soon acquire many skills in electronics.

The 4th industrial revolution, Industry 4.0 will develop the manufacture of hydraulics, but will also use as a basic element the hydraulics in many revolutionary technologies.

Maintenance in hydraulics, in its modern forms, will become increasingly important in increasing the life of systems and their economic efficiency.

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