HYDRAULIC BENCH FOR ELECTRO-HYDRAULIC SERVO-ACTUATORS AND SERVO-VALVES TESTING

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Abstract – **This paper presents a hydraulic bench for electro-hydraulic servo-valves and servo-actuators testing. This bench was realized in the laboratory of the Avionics Division of the Faculty of Electrical Engineering. For the hydraulic servo-actuators, it is possible to study the time response for different test signals and the frequency characteristics in sinusoidal regime. The hydraulic bench construction allows also the study of different controller types, either P, I, D, or compound of these types, which are already provided in the construction, either an external controller of another type. The external controller may be coupled to the bench without any other changes, to the front panel terminals. So, the hydraulic this hydraulic test bench may be a useful tool in the research activity in the hydraulic servo-actuators and automation domain. For the servo-valves it is possible to study the stationary characteristics – dependence between the coil current and flow ratio and the dependence between feeding pressure and flow ratio. Because the components provided between the servo-valve ports it is necessary to use a correction calculus implemented in LabView in order to eliminate the pressure drop on these components. Due to the skills provided by LabView, the acquisition scheme (not presented in this paper) is very simple to be implemented an may incorporate the correction calculus, in order to obtain directly the servo-valve characteristics. The entire hydraulic and electric schemes are conceived and realized in the Avionics laboratory of the Electrical Engineering Faculty from Craiova.**

Keywords*:* Electro-hydraulic servo-actuators, servo-valves, test bench, time response, frequency characteristics.

1. INTRODUCTION

Electro-hydraulic servo-actuators are very important components of the aircraft command chain. Their construction differs from an aircraft to another but the main principles are the same and represents basic knowledge in the training of any system aerospace engineer. In this order, interest points are the main functioning principles, specific problems appeared in the construction of a servo-actuator and their performances. A test bench for these problems represents a very important facility in the aircraft hydraulic equipments laboratory.

From the point of view of the servo-actuator components, the most important is the electro-hydraulic servo-valve. This is the interface between the aircraft computer systems and the hydraulic power plant. A detailed study of the servo-valve is difficult to be performed in a laboratory oriented mainly to the aircraft maintenance, but it may be performed a good study for the static characteristic. The time response of the modern servo-valves is about 4 ms. It is very difficult to measure this variation speed for a flow ratio. Also, the 90^{o} phase lag is about 50-60 Hz, even more and they are also difficult to be measured with common equipments.

The realized hydraulic bench permits the static characteristics study for the electro-hydraulic servo-valves – dependence flow ratio upon command current and flow ratio upon feeding pressure, using as complementary equipments a signal generator and an oscilloscope.

Concerning the performed studies for electro-hydraulic servo-actuator, these are more complex because the stroke and the command current may be measured easier than the fast flow ratio variations. It is possible to study the time response – dependence stroke upon command voltage – and also frequency characteristics – dependence amplitude upon frequency and phase lag between output and input versus signal frequency. In addition, a study concerning the behavior of different controller types may be done. The electronic incorporated in this bench permits the study of P, I and D controllers. It may adjust the gain factor of the P controller and the time constants for the I and D controllers, and so one may obtain the behavior in each case, both time response and frequency characteristics.

The bench construction permits the study of any controller and so it is useful in the research activity for the aircraft servo-actuators controllers. The studied controller must be realized as an external electronic device and it may be insert in the control loop of the servo-actuator without any additional change. In consequence, the bench is useful not only for the hydraulic equipment testing, but also for the study of different controllers as fuzzy, neural, backstepping, sliding mode controllers.

2. HYDRAULIC SCHEME

The hydraulic scheme of the test bench in presented in figure 1. This is composed from the coupling ports ST1 and ST2, an electro-distributor D, one filter F, a hydraulic servo-valve SV, four pressure transmitters TP1 – TP4, one hydraulic bridge composed of four

check valves S1 – S4, two taps R1, R2, one flow ratio transmitter TD, and one hydraulic cylinder CH.
The electro-distributor has a 28 Vdc feeding voltage and it is necessary for the fast cut of the hydraulic feeding in failure situations. The filter F has a filtration rating of 5 μm. It is necessary to ensure a very good hydraulic liquid clearance in order to maintain a long time life for the servo-valve. It is well known that a electro-hydraulic servo-valve needs a clearance class 14/11 subsequent to ISO 4406 standard. A lower clearance class leads to a severe decrease of the servo-valve time life.
The hydraulic servo-valve SV is a DY 05 from Parker-Hannifin. It has a rated flow ratio of 9.5 l/min and a rated current of 25 mA. It is a force feedback servo-valve with lamellar spring, like the most used servo-valves in modern aircraft command chains. This kind of servo-valves ensures the higher performances at this moment.
The transmitters TP1 – TP4 permits the pressure measurement at the servo-valve ports. The measurement system – both the transmitters and indicators are recovered from a IAR 93 aircraft out of service. It's precision class is not very high, but it is enough for the studies performed with this bench. In the future it may be replaced with better transducers.

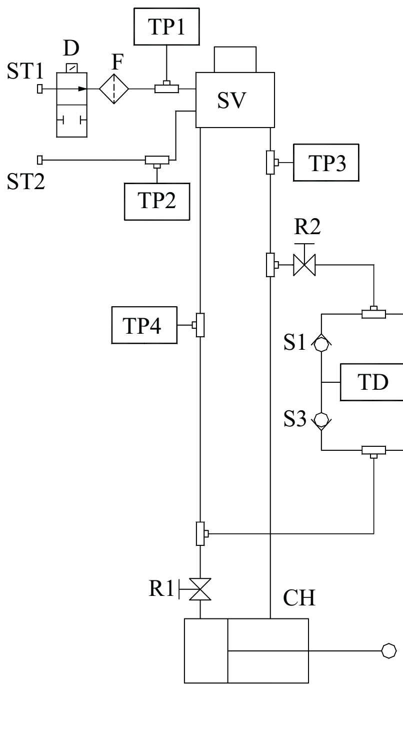

Figure 1

The flow ratio transmitter is a turbine transmitter also from Parker Hannifin and is mounted in a hydraulic bridge so the flow ratio through it has always the right sense. It has electronic incorporated so the output is in d.c. and may be gathered from a terminal from the front panel.
The hydraulic cylinder CH is the actuator of the servo-system. It is recovered from a landing gear trap actuation, also from an aircraft out of service.
The tap R1 ensure the liquid access in the hydraulic cylinder when the bench is used for the servo-actuator study. It is used in counter time with the tap R2. When the servo-actuator is studied it is not necessary to measure the flow ratio, so in this situation the tap R2 is closed and the tap R1 is open to ensure the servo-actuator functioning.
The tap R2 ensure the cylinder by pass when the bench is used to servo-valve study. In this situation it is necessary to maintain the same flow sense for a long time and this is not possible if the cylinder is in the hydraulic circuit. By the tap R2 opening the flow ratio pass through the flow ratio transmitter and the servo-valve static characteristic may be obtained. A servo-valve load may be simulated by a more or less opening of the tap R2.

3. ELECTRIC SCHEME

The electric scheme is designed in order to allow the work in many modes, each of them performing one kind of studies concerning the servo-valves and servo-actuators. This scheme is presented in figure 2.

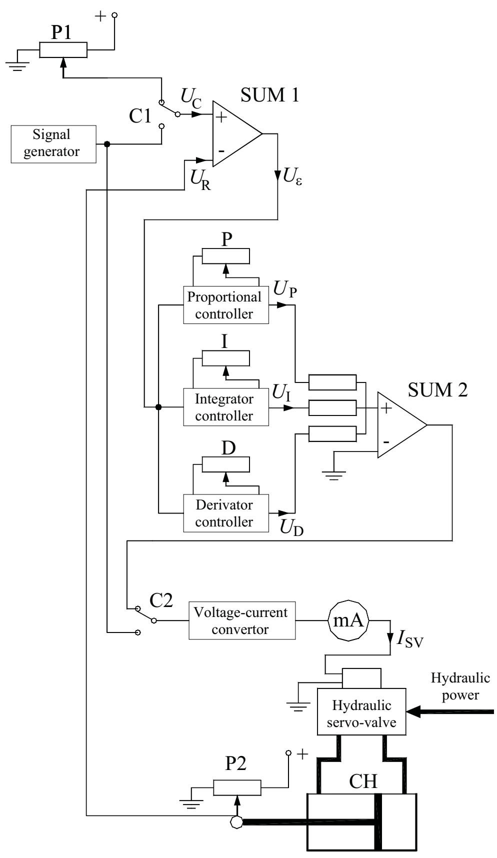

Figure 2

Two variable resistances P1 and P2 represents the position transmitters, P1 for the stick position and P2 for the command surface position. These variable resistances provide the command signal U_C and the feedback signal U_R . The difference between these signals is made by the summator SUM1 and results the error signal U_ε . Three parallel disposed controllers follow – one proportional controller, one derivative controller and one integrator controller. For each of these controllers, the characteristic parameter may be adjusted, so from variable resistance P it may be adjust the gain of the proportional controller, from the variable resistance I it may be adjusted the time constant of the integrator controller and from variable resistance D in may be adjusted the time constant of the derivative controller. The controllers parameters may be adjust from 0 to a maximum value so by a right adjust one may obtain simple P, I or D controllers or compound PI, PD PID controllers.
The controllers output signals are summed by the summator SUM2 and the result feed the voltage-current converter. The voltage-current converter has a linear characteristic, providing a maximum current of 25 mA. The output current pass through a miliamperemeter and than feeds the servo-valve coils. The servo-valve coils are series disposed so their resistance is summed and the maximum necessary current is the servo-valve rated current – 25 mA. The resistance of the two coils is 200 Ω for each one.
The switches C1 and C2 establish the scheme functioning regime. When C1 is in the up position, the servo-actuator command is made from the variable resistance P1 (from the stick). When C1 is in the opposite position the servo-actuator command is made using an external signal generator. In this way, one may study the servo-actuator behavior at different test signals.
From the switch C2 one may bring the scheme in servo-actuator mode (up position) or in servo-valve characteristics mode (down position). In this case, the signal from the generator is applied directly to the voltage-current converter and commands the servo-valve. Following the miliamperemeter indications and the flow ratio transmitter one may obtain the current versus flow ratio characteristics of the servo-valve. It is possible to obtain slightly different characteristics than the producer's because the hydraulic resistance between the servo-valve ports is not negligible The inside pipe diameter is about 4 mm and the valves bridge S1 – S4 produce a supplementary resistance. This resistance will distort the obtained characteristics. It is known that standard condition for servo-vales characteristics study is with the load ports linked with a negligible hydraulic resistance pipe. Despite this, obtained characteristics are good enough from didactical point of view. By minimum constructive changes one may obtain the standard conditions for the servo-valves study.

4. CONSTRUCTIVE ASPECTS

In the test bench construction one followed to obtain as many as possible test capabilities. So, many signals may be gathered from the front panel BNC terminals (figure 3). The signals provided by these terminals are the command voltage U_C , the feedback voltage U_R , the error voltage U_ε (difference between U_C and U_R) , the controllers output voltages U_P, U_I and U_D , the output of the flow ratio transmitter U_{deb} and the output voltage from the pressure transmitters U_{M1} , U_{M2} , U_{M3} , U_{M4}. The servo-valve coils current is provided as a voltage, proportional with it at the I_{SV} terminal.
The front panel is provided with terminals for signal generator coupling and scheme ground coupling, necessary when the signals are sent into oscilloscope or in a data acquisition board.
On the front panel appear also the variable resistances P1, which command the position of the hydraulic cylinder in manual mode and P2 which is the feedback transmitter. In order to realize a fast and simple adjustment of the incorporated controller, variable resistances P, I, D are also an the panel.
For the functioning mode selection, there are fixed on the front panel also the taps R1 and R2.

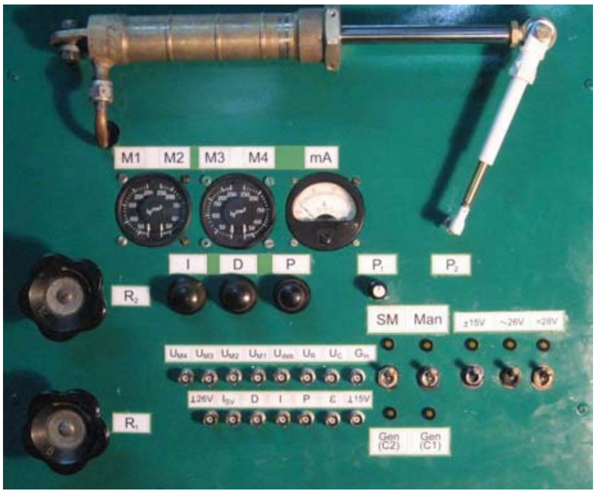

Figure 3

For the study of the characteristics one may use either the indications of the indicators M1 – M4 and of the miliamperemeter from the front panel, either the electrical signals available at the front panel terminals and.
On the front panel are also switches for the scheme feeding with 28 Vdc, ±15 Vdc and 26 Vac/ 40 Hz. The 28 Vdc voltage is used by the distributor D and the 26 Vac / 400 Hz is used by the pressure measurement system.
From the bench use point of view a big importance has the 28 Vdc switch which permits the hydraulic feed cut in failure conditions.

5. OPERATING MODES

Combining the front panel commands one may obtain the following operating modes:
- servo-valve characteristics mode: the tap R1 is closed, the tap R2 is opened and the switch C2 is in the down position so the signal from generator commands directly the voltage-current converter . The flow ratio is available at the U_{deb} terminal and the servo-valve coils current at the I_{SV} terminal;
- manual command of the servo-actuator: The tap R2 is closed, the tap R1 is opened, the switch C1 is up and the switch C2 is up. In these condition one may visualize the signals from the scheme on an oscilloscope or to take them in a data acquisition board and send them to a computer. The hydraulic cylinder stroke will be proportional with the P1 stroke. The servo-actuator behavior will depend on the P, I , D controllers parameters, adjusted by the corresponding variable resistances.
- signal generator commanded servo-actuator: the taps and the switch C2 are in the same position like above but the switch C1 is down. In this mode one may perform detailed studies for the servo-actuator performances by the processing of the signals provided to the front panel terminals. Also in this mode, the servo-actuator behavior will depend on the three controllers parameters
- external controller study mode: the taps R1 and R2, the switch C1 is up and the switch C2 is down. The signal generator is no more used and the external controller is coupled with the input at the U_{ε} terminal and the output to the G_{in} terminal . By this way, the external controller short circuits the controllers from the scheme 2. One may study in this mode the behavior of the external controller at manual command of the servo-actuator. With a minimum change in the scheme one may study also the external controller behavior to signal generator command.

6. CONCLUSIONS

The realized hydraulic bench allows many test capabilities concerning the servo-valves and servo-actuators study and is very useful in the student's activity. Also it may be used in the study of the P, I, D and combined controllers. An interesting capability is to study different external controllers without scheme changes. The data processing may be done either by the students, either by the computer using a data acquisition system. In the future one follow to develop this bench using a data acquisition system and some LabView schemes in order to obtain a fast processing of the results.

7. References

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