PRACTICAL APPLICATION OF MASTER-SLAVE MANIPULATOR WITH FORCE REFLECTION

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SUMMARY

The Department of Mechanical Engineering of the Banki Donat Polytechnic has developed a master-slave manipulator with force reflection. In its present developed form the master-arm has a rotating four freedom force reflection. Its potential measuring and force reflection units - which are hydraulic cylinders - are of module system. The master slave provides two solutions for the hydraulic realization of force reflection. The first operates according to the so called direct pressure perception.

The other solution produces the pressure signal proportional to the force in the fields of the force inducing cylinders. The force perception can be disconnected by electronic control, by pre-selection according to freedom degrees or in any moment.The technical solution which has been developed can be universally used for force reflecting operation of manipulators (cranes). The paper reported on the preparatory works, summarized the structure of the master-slave and part of the examinations necessary for the qualifications.

1. ANTECEDENTS

Commissioned by the Special Machine Factory of Csepel Works in Budapest, the Department of Mechanical Engineering of the Banki Donat Polytechnic has developed a force reflection hydraulic master-slave for ATR-HD-500 type industrial robot manipulator (Daido licence, Japan).

In support of the development, the Department has carried out slave measurements and cast-cleaning examinations as it was required

by the factory's profile. For calibrating the force reflection master slave the Department has made measurements in order to define the hydraulic characteristics of the robot manipulator.

In the first part of our paper we are going to describe the force reflection master-slave which is followed by the description of some examinations illustrating its services.

2. AIMS OF THE DEVELOPMENT

The robot-manipulator described in the Antecedents serves for moving 500 kg of useful mass. This robot has another type of 1000 kg. The robot-manipulator has hydraulic control, four degrees freedom and pantograph arm-mechanics. The work-space, its drawing with the master-slave and with the hydraulic-oil power can be seen in Figure 1. The two turning freedom degrees make a 270 degrees turn possible. In robot operation the control is PTP.

According to the objectives the robot - after the above mentioned cast-clearing examinations - had to be equipped with a so called master-slave which by speed-control ensures a four degree freedom manipulator control in a way that in the freedom degrees of the master-slave there is a force perception proportional to the force originating according to the movement directions of the robot.

In order to define the features of the robot-manipulator arm, we have examined the dynamic and static characteristics of the arm [1].

The master-slave development was preceded by the definition of the pressure functions depending on the loading, prevalent in the hydraulic executive parts of the robot - in the hydro-engine, in the cylinder [2].

3. FORCE REFLECTING MASTER-SLAVE

The development of the master-slave was completed at the end of 1989. The master-slave is universally appropriate for operating four degree freedom. The direct principle of the force reflection see

description below - can be applied to any hydraulic manipulator (cranes). The electronic-hydraulic so called indirect principle might as well be used with electrically controlled manipulators, but in this case the fluid should be supplied separately. The developed master -slave in its present form has four rotating freedom degrees, (Figure 2) its potential measurement units and force reflection units - which are hydraulic cylinders are of module system. The master--slave provides two technical solutions for the realization of the hydraulic force reflection.

No.1 it operates according to the so called direct pressure perception, when the pressure signal is originated in the two fields of the hydraulic executive body (the engine) of the robot, and it is directed to the appropriate fields of the force perceptive cylinder. It can be used for the force reflection of the freedom degrees of the horizontal turning, where the weight is slightly dependent on the robot configuration (Figure 4.).

No.2 It produces the pressure signal with proportional hydraulic valve to the force in the fields of the force inducing cylinders after having transformed, having intensified the signals of the perceptors measuring force at the final point of the robot (extension measuring cells). The principle of the realization of, the force perception for one degree freedom is shown in Figure 3. After intensifying the signals of the force measuring cells these signals go to a filling element changing electronic transformator which generates the magnet of the proportional valves. The valves transform this digital signal proportional to the force into pressure signal. This arrives in the cylinder realizing the force perception, which through the master slave transmits the force proportional to the force at the final point of the operator.

The movement of the robot can be activated by electric control, by pre-selection according to freedom degrees. Switching on or off the force reflection can be controlled at any moment by the button placed at the final point of the master-slave handle.

The main technical characteristics of the master slave

Freedom degrees: 4

Type: rotating

Degree turning: ± 30 degrees

Control unit: precision layer potentiometer (1 turn)

Force perception: 20 ... 2000 N or
200.. .20000 N depending on the force measuring cell

Force reduction: max 100 (position: optional)

Digital force perception indication of master arm: optional

Adjustable force limiting: optional

In order to qualify the master slave we have made a series of measurements to close the subject. It is briefly discussed below.

4. EXAMINATIONS, MEASUREMENT SYSTEMS

While examining the master slave we examined all the four freedom degrees one by one.

- Vertical movement

During this measurement a weight was used for loading (0, 1000, and 2000 N). We have measured under different loading in movement the pressure emerging in the fields of the hydraulic cylinders. These pressure registrations of the two function cylinder work-space are shown in Figures 6.

- Horizontal movements

For the horizontal loading we used long stroke pneumatic cylinder. The diameter is 75/20, the useful surface of the 1000mm stroke cylinder is 42 cm^2. These data plus the pressure of the used compressed air make it possible to calculate the loading force in static state. The force could be changed with the help of a pneumatic reductor by fixing 0-5 bar pressures. Examples on registrations are shown in Figures 6.

For the examinations we have worked out two types of measurement. The connection shown in Figure 3. is used for the measurement of the

pressures generated by the proportional hydraulic valves which belong to the force-inducing vertical and horizontal movements. The pressure measuring device which is suitable for measuring maximum 200 bars, and the amplifier are Hottinger made. The time functions were fixed by X-Z recorder while the robot was moved. With the connection shown in Figure 4.the pressures of the two turn freedom degree hydro-engine branches were measured. The pressure measuring devices are of 500 bars, Hottinger made. The registrations were made by X-Y recorders.

Evaluation of the measurement results has been made on the basis of p = f(t) functions (Figures 5,6.).

After numeric evaluation of the pressure-time registrations the figures of measurements were tabulated, the force-force and weight-weight diagrams related to the different freedom degrees were drawn up, taking into consideration the mechanic transmissions of the master slave.

SUMMARY OF MEASIREMENTS

	Loading F [N]	Arm of loading R [m]	Moment M [Nm]	Pressure difference Δp [bar]	Cylinder 's measurement A [cm2] sirface	Arms' transmission k [mm/mm]	Force on master arm. F_k [N]	Moment on master arm. M_k [Nm]
Arm - turning	0 630 1260	4,61	0 2904,3 5808,6	19,0 62,0 85,0	0,60	30/210	16,36 53,38 73,18	3,44 11,21 15,37
Wrist turning	0 420 630	0,3	0 126 189	0,5 1,0 1,2	0,26	30/16	2,41 4,82 5,78	$3,9\cdot10^{-2}$ $7,7\cdot10^{-2}$ $9,3\cdot10^{-2}$
Lifting - lowering	0 635 1270	-	-	0,9 6,5 10,7	4,41	30/309	3,85 27,81 45,77	-
Forward - Backward	0 630 1260	-	-	1,1 4,8 6,9	2,36	30/120	6,50 28,37 40,78	-

REFERENCES

[1]. Attila Bencsik: Die Untersuchung.der statischen und dynamischen Kenngrößen des Industrieroboterarms im Dienst der Roboteranwendung. JUROB'89. 1989.

[2]. Attila Bencsik - Tibor Kegl: Többszabadságfoku erövisszajelzéses mesterkar ipari robot - manipulátor vezérléséhez. (Ein mehrfreiheitgradigen Meisterarm mit Kraftrückmeldung zur Steuerung der industriellen Robot - Manipulatoren.) Automatizálás'89 Konferencia, Székesfehérvár 1989.

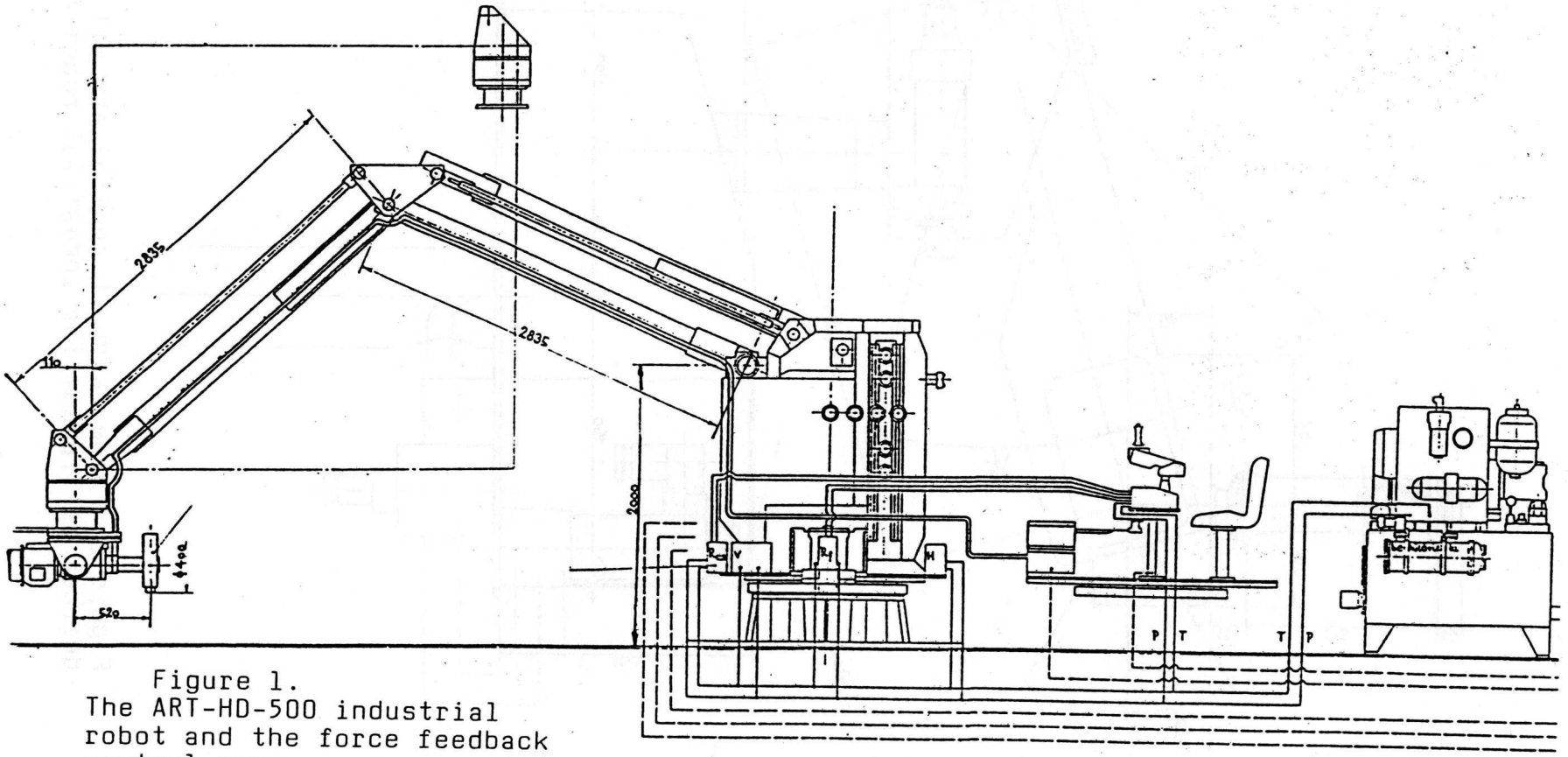


Figure 1.
The ART-HD-500 industrial robot and the force feedback control arm

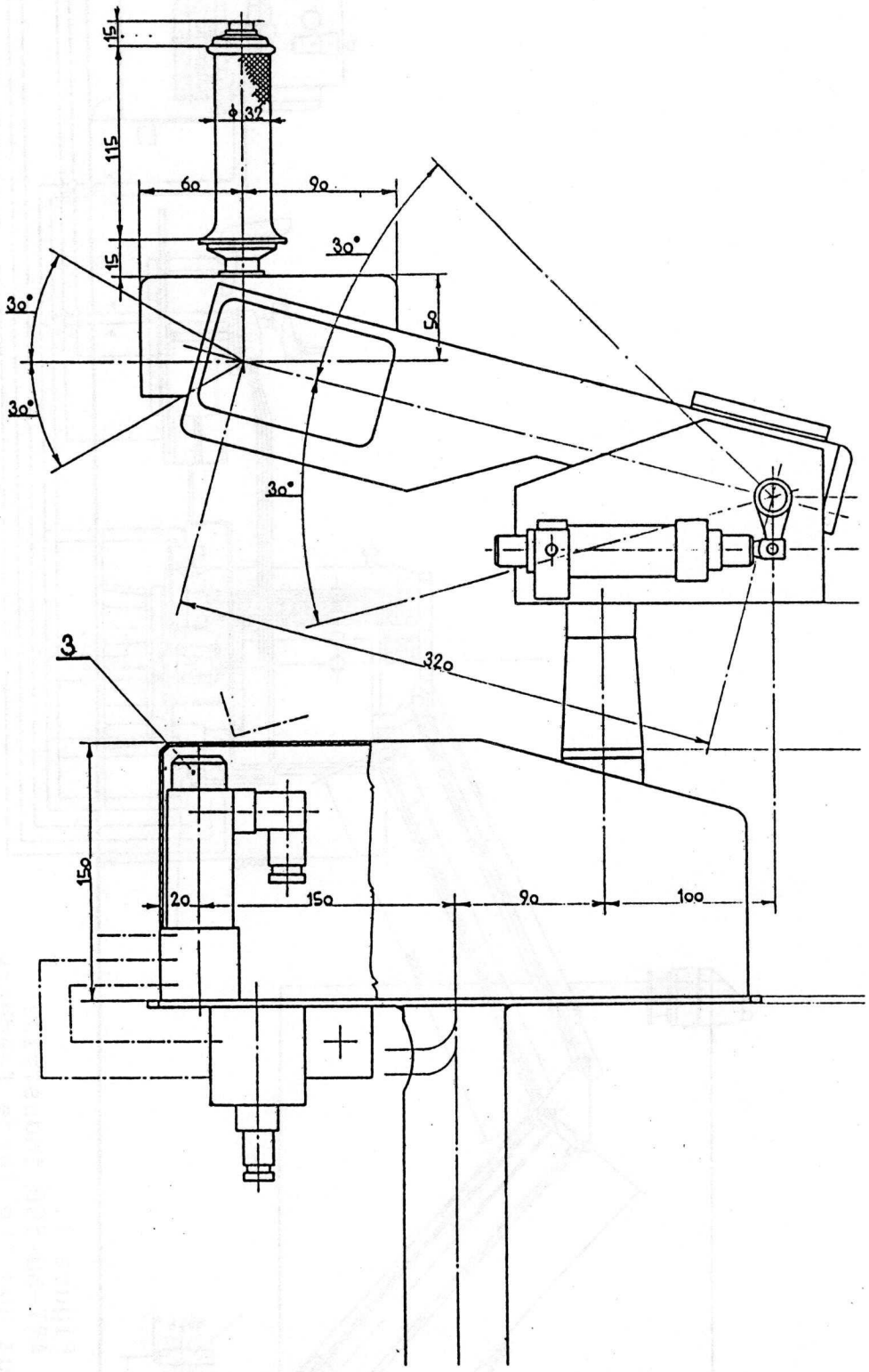
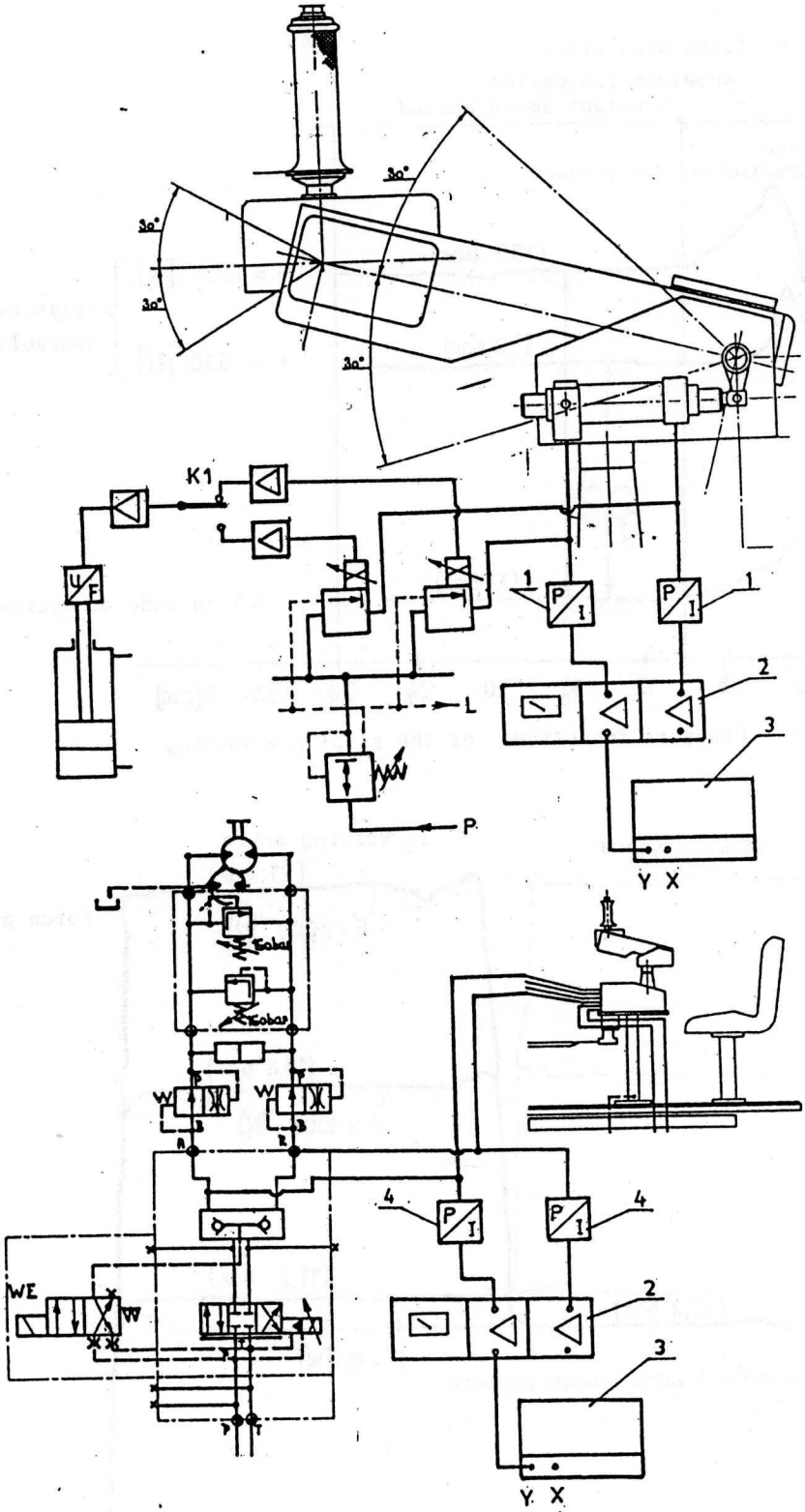


Figure 2. Force feedback control arm with four degrees of freedom for industrial robot manipulators.



1. Pressure measuring sensors /P 11/200; 6198, 6197/
2. Measurement amplifyer /AE 3407; kW 3073, Hottinger/
3. X - Y recorder /EMG 79812/
4. Pressure measuring sensors /P 11/500; 13061, 14033/.

Figure 3, 4. Measuring sensors of pressure the cylinders of master arm.

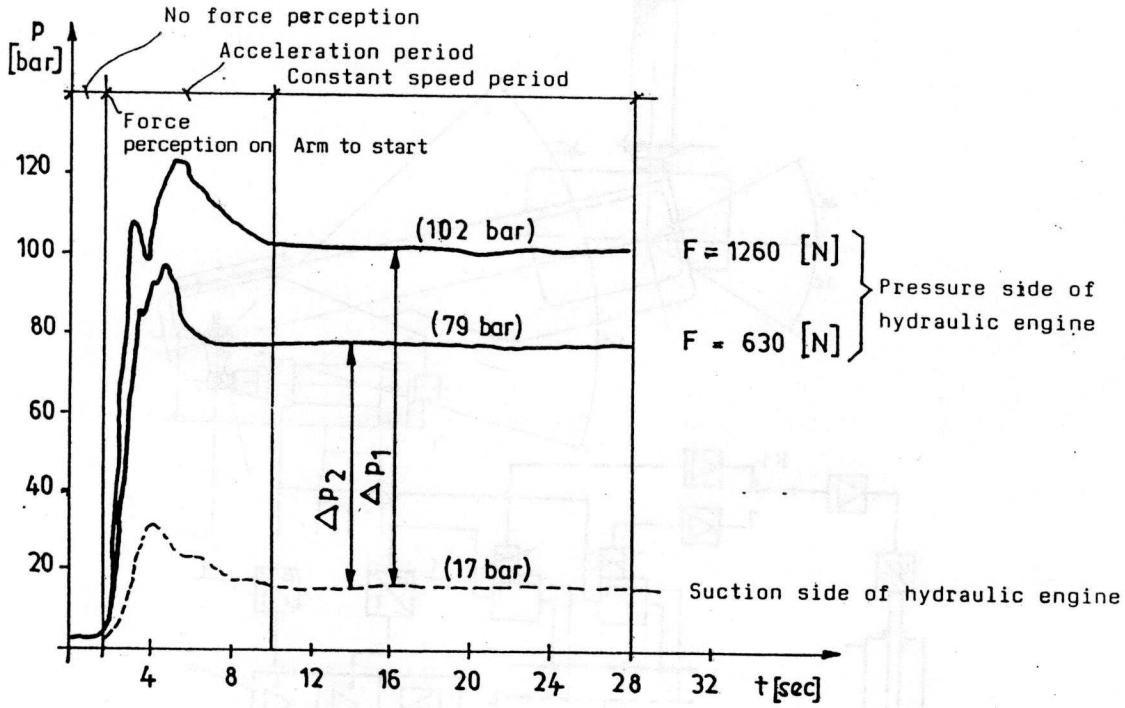


Figure 5. Pressure funkctions of the robot arm turning.

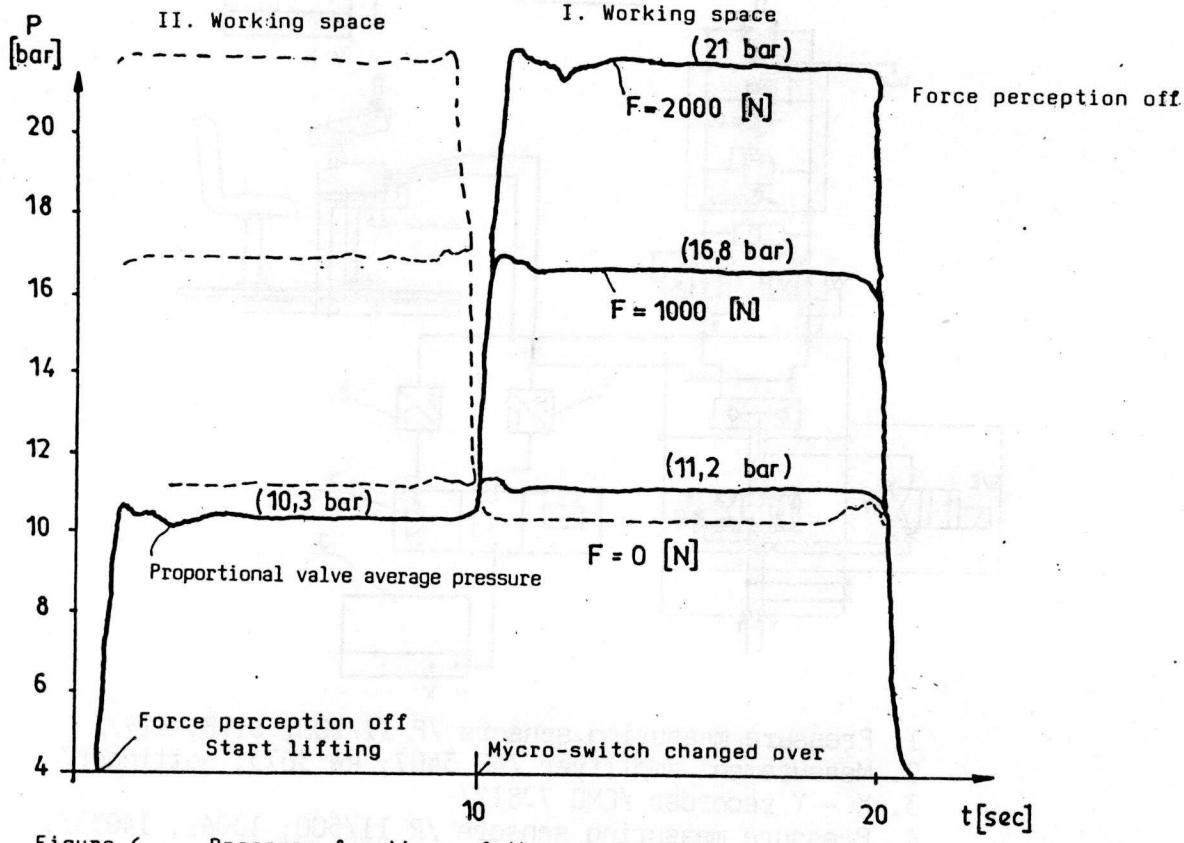


Figure 6. Pressure functions of the robot arm's lifting and lowering.