Automatic Electro-Hydraulic System for a P.E.T. Waste Baling Press

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Abstract: *Environmental protection is one of the leading factors when designing modern industrial machinery, their increased overall energy efficiency requiring the use of new industrial design concepts, smart driving circuits and digital concepts* [1]*. Classic industrial machinery is supposed to be changing in the next few years due to the development of INDUSTRY 4.0 concept for manufacturing technologies* [1]*. Improving energy efficiency, in most of the cases implies designing new driving schematics and their complexity seems to be significantly increasing. Rapid development of electronics technology and software industry supported the need for energy efficiency, but fluidic – hydraulic and pneumatic – installations are performing not so well on this field. There are known various constructive solutions for directional valves that traditional fluidic manufacturers promote, in order to improve overall energy efficiency* [2]*, but those solutions are centered on specific industrial application of group of applications. In a narrower case, a hydraulic P.E.T. waste baling press must be optimized taking into consideration productivity, ease-of-use, flexibility, energy efficiency and reduced maintenance costs* [3]*. Digital hydraulics might be a solution that can meet all the above criteria, but in the case of a small capacity P.E.T. waste press, retrofitting costs depreciation is poor. In this paper the authors propose a simple and energy efficient electro-hydraulic driving system for a small capacity P.E.T. waste baling press that was modeled using FluidSIM Hydraulic software environment.*

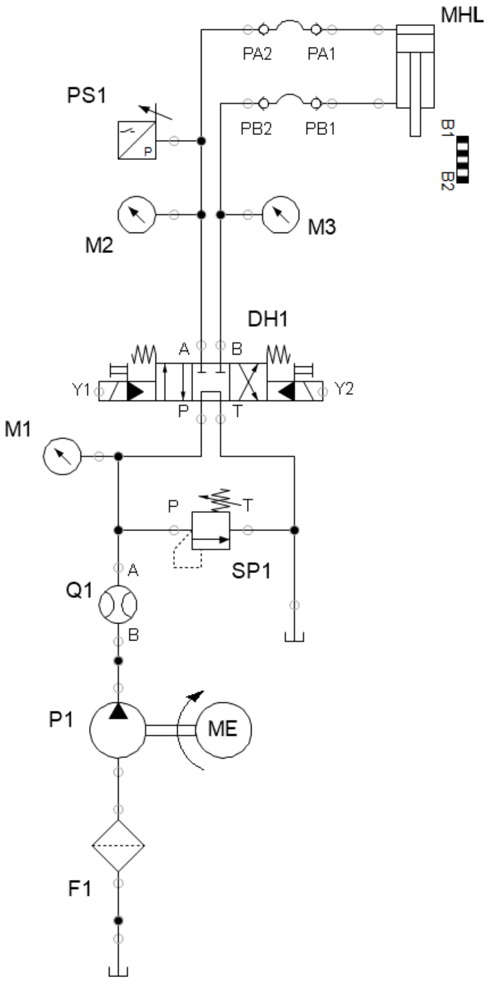
Keywords: *P.E.T. waste press, electro-hydraulic, FluidSIM*

1. Introduction

Modern industrial design must include modeling and simulation activities for engineering concepts or existing machines, using a *virtual tool* such as FluidSIM software environment. There are available on the market various modeling and simulation software environments, offering specialized packages of programs that are oriented on a single field of engineering (hydraulics, electrics, mechanics etc.) or on cross-field engineering (electro-hydraulics, mechatronics etc.). When modeling a physical object or a system, there must be taken into account, from the beginning, some hypothesis that induce, negligible or not, errors in the model itself. A simple physical object, in most cases, can be modeled similar to reality, but a much more complex object or a system – which comprises simple and/or complex objects – cannot be modeled having no discrepancies between reality and virtual environment. These discrepancies can lead to serious errors when simulating the model. Another aspect of modeling is not the object of modeling itself, but the model of the environment where the actions of the object are taking place. Here, also, a model of the reality having no errors is, yet, impossible to obtain. Errors in modeling can arise when trying to produce a mathematical model for the constraints between components of a system or between system's components and the working environment. Nowadays, powerful modeling and simulation tools can reduce "reality to virtual" errors, using component libraries that can be customized according to the real object or system's characteristics.
Hydraulic systems are used in numerous industrial fields, where main advantages of hydraulic drives cannot be overcome using other driving solutions (electric, pneumatic, mechanic, etc.) [4], [5,] [6], even though their reliability is considered to be medium and having relatively high energy losses. The authors propose in this paper new hydraulic and electric automation schematics for a small capacity P.E.T. waste baling press, modeling both the hydraulic and electrical parts using FluidSIM Hydraulics software environment.
The hydraulic and electrical schematics that the authors propose can be used on a P.E.T. waste baling press, having electro-hydraulic directional valves and a relay based electrical schematic.

2. Hydraulics system

Schematic of the hydraulic system that the authors propose is given in figure 1. As it is figured, the hydraulic schematic has a simple construction and can be used as a base for other engineering applications such as lifting systems or elevators.
The hydraulic system comprises a 7 liters hydraulic oil tank, which is used as primary source of fluid and return lines connection. Filter *F1* is mounted on the inlet port of a fixed-displacement hydraulic pump *P1* which is driven, through a flexible coupling, by a three-phase 1,5 kW asynchronous electric motor *ME*. The pump is used to convert the mechanical energy generated by the electrical motor into hydraulic energy, having a maximum flow of 4,9 l/min at n = 1450 rev/min. A pressure-relief valve *SP1* is used to limit the working pressure at 290 bar, being activated in case of an overload or the system has a fault that rises pressure to abnormal values.



F1: hydraulic oil filter
P1: fixed-displacement pump
Q1: flowmeter
SP1: pressure-relief valve
M1 … M3: pressure gauges
DH1: electro-hydraulic directional valve
PS1: pressure switch
PA1/PA2, PB1/PB2: flexible pressure lines
MHL: double-acting hydraulic linear motor

Fig. 1. Hydraulics Schematic of the Driving System

Pressurized fluid flows through the *P1* to *DH1* hydraulic circuit and then returns into the hydraulic oil tank. *DH1* is a 4/3 bypass mid-position electro-hydraulic directional valve. This type of directional valve allows the hydraulic pump to be unloaded while the hydraulic linear motor *MHL* has the ports blocked. This implies that the motor is locked into its current position, as long as the directional valve is in central position. There must be taken into consideration that the directional valve has metal-to-metal fit spool and it cannot block totally the hydraulic oil flow, implying that when an outside force is exerted on *MHL*, its rod will move very little even though the 4/3 directional valve *DH1* is in center position. On *DH1*, *P* is the pressure in port, *T* is the tank out port, *A* and *B* are pressure in/out ports for the hydraulic linear motor.

DH1 directional valve has two springs for centering the spool in absence of any electrical or mechanical command. The spool can move under the action of manual or electrical commands, having two electromagnets *Y1* and *Y2*, one for *P-A*, *B-T*, connections and the other one for *P- B* and *A-T* connections (see figure 1).
MHL is a double acting unilateral rod hydraulic linear motor is connected to the directional valve using two flexible pressure lines (hoses) *PA1-PA2* and *PB1-PB2*. The motor is mounted in vertical position because of the physical configuration of the pressing chamber in the P.E.T. waste press (see figure 2).
In the hydraulic schematic, *M1*, *M2* and *M3* are pressure gauges used to monitor pressure values in the hydraulic circuits and *PS1* is a pressure activated switch used in the electrical automation schematic for stopping the pressing cycle and returning the press platter in its home position, unless other conditions are met for P.E.T. bale evacuation. *Q1* is a flow-meter.

Fig. 2. P.E.T. waste electro-hydraulic baling press

In figure 2 is shown a constructive type for a P.E.T. waste baling electro-hydraulic press available in *D009* laboratory of Faculty of Biotechnical Systems (U.P.B.).
The components in the hydraulic schematic are the following:

Table 1: Hydraulic equipment

Equipment type	Schematic symbol	General parameters
Hydraulic pump	*P1*	fixed-displacement, 4.9 l/min
Directional valve	*DH1*	4/3 bypass mid-position, electric control
Hydraulic motor	*MHL*	double acting, unilateral rod ϕ50xϕ40x620 mm
Pressure-relief valve	*SP1*	manual adjustment safety valve, 315 bar
Hydraulic oil filter	*F1*	ESA22
Hydraulic oil type	-	HLP22
Tank volume	-	7 liters

3. Electrical schematic

Schematic of the electrical system that the authors propose is given in figure 3. The authors have designed and modeled using *FluidSIM Hydraulics* a relay logic automation schematic in order to materialize operation phases of the P.E.T. waste press, as are described in table 2 (see below).

As one can see in figure 1, the directional valve *DH1* has two driving electromagnets, *Y1* and *Y2* that need to be controlled in operation phases of the pressing cycle. The electrical schematic is using a 24VDC power supply for both the driving (electromagnets) and relay-automation parts. In the schematic (see figure 3) it was not figured the power supply or the start circuit for the three-phase asynchronous electrical motor.

In figure 3, *S0* is a mushroom-type NC emergency STOP button having *H0* as optical indicator (lamp) for signaling that the P.E.T. waste press was switched ON and is currently in *stand-by* mode.

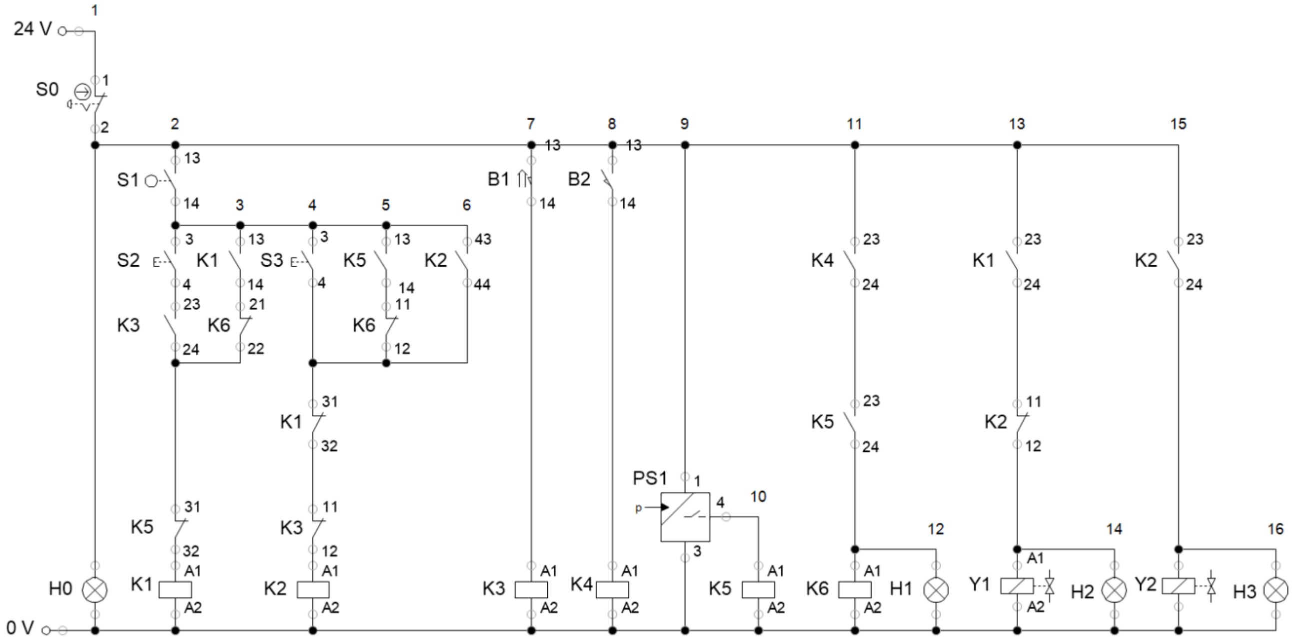


Fig. 3. Electrical schematic of the driving system

In the schematic above, figure 3, there are six electromagnetic control relays, *K1* … *K6*, that provide the operation logic. Pairs of relays' NO and NC contacts are connected in parallel or in series circuits in order to materialize operational phases given in table 2.

Fig. 4. Mounting detail of door switch (left) and *B2* limit switch (right)

One roller switch *S1* is used for disabling manual commands when the pressing chamber door is open, for human operator safety. The pressing plate is descending when *MHL* cylinder rod is extending and coil of *Y1* electromagnet of *DH1* is energized and it is ascending when cylinder rod is retracting and coil of *Y2* electromagnet is energized. There cannot be energized the coils of *Y1* and *Y2* electromagnets at the same time. The relay logic prevents this non-sense case to be encountered in normal operating cycle. If the pressing chamber door is accidentally or intentionally

opened, the current movement (extend/retract) will immediately stop, locking the pressing plate into its current position.
Button *S2* is used to start the automated pressing cycle after loading the P.E.T. waste into the pressing chamber and for safety reasons, the pressing will start only when the door is closed and the pressing plate is in home position (full retracted), travel limit switch *B1* through one NO contact of relay *K1* provides this second start condition. Self-latching of *START pressing* command is done by series circuit NO *K1* and NC *K6*. This command is inhibited when the door was opened while the pressing plate was in movement.
Button *S3* is a semi-automatic command for returning the pressing plate to its home position, *press plate retract*, being active only when:

- pressing chamber door was opened while the pressing plate was in movement (up/down) and it needs to be returned to home position, cylinder rod retracted;
- the P.E.T. waste press is in *bale out* mode, when travel limit switch *B2* and pressure switch *PS1* are both active at the same time.

This command is also self-latching through one NO contact of relay *K2*. Series circuit NO *K5* and NC *K6* is the automatic command for pressing plate retraction to home position after it was started with *S2*. When pressing the P.E.T. waste, the pressing force encounters two opposing forces, one given by the resistance to pressing of the P.E.T. mass and one given by the friction between the P.E.T. waste and the pressing chamber's lateral walls. In order to counterbalance these two forces, the hydraulic pressure in the active cylinder chamber increases to a maximum value determined by the degree of compaction of the P.E.T. bale. This is implying a pressure peak on the pressure switch line, activating its output and energizing *K5* relay's coil. While not in *bale out* mode, NC *K6* is closed and NO *K5* will be closed therefore the pressing plate will return automatically into its home position.
In table 2 is given the operation logic of the P.E.T. waste baling press, as the authors designed it, where *0* is *no operation/retract* (*MHL*), *1* is *operation/extension* (*MHL*), *X* is *state does not matter* and *LK* is *locked* into current position.

Table 2: Operation logic

Functional phase \ Schematic symbol	S0	S1	S2	S3	Y1	Y2	B1	B2	PS1	MHL
Emergency STOP (manual)	1	X	X	X	X	X	X	X	X	LK
Stand-by mode	0	0	0	0	0	0	1	0	0	0
START pressing (auto)	0	1	1	0	1	0	1	0	0	1
Press plate retract (auto)	0	1	0	0	0	1	0	X	1	0
Press plate retract (semi auto)	0	1	0	1	0	1	0	X	X	0
Bale out (auto-stop)	0	1	0	0	0	0	0	1	1	LK

Vertical position of *B2* travel limit switch is related to bale's height, while its length and width (usually for this type/size of press: L×w×h: 800×600×600mm, weight 70kg) are determined by the physical characteristics of the pressing chamber. Modifying *B2* vertical position will modify accordingly bale size and weight. The degree of compaction can be adjusted by modifying the setpoint value of pressure switch *PS1*, a lower value mean a lower compaction degree. A higher compaction degree of the bale can be obtained in the same mode, but it must be taken into consideration the maximum working pressure of the system, pressure-relief valve setpoint and safety regulations.
Pressing cycle is entering *bale out* mode when both *B2* and *PS1* are activated, optically signaled by lamp *H1*. The human operator can now safely open the pressing chamber door and bind the bale using metal wire or plastic ties, while the pressing plate is locked into last position (*Y1* and *Y2* not energized). After binding, the bale must be evacuated from the pressing chamber, but in the first place the pressing plate must be returned to home position by closing the door and pressing *S3*. The P.E.T. press enters into s*tand-by* mode and the door can now be opened to evacuate the

bale. A new pressing cycle can be started with *S2* after loading the pressing chamber and closing the door.

Table 3: Electric equipment

Equipment type	Schematic symbol	General parameters	Constructive model
Electrical motor (figure 1)	*ME*	1.5kW, 3 phase asynchronous motor	ASU 90L-4
Valve electromagnet	*Y1*, *Y2*	24 VDC, 1A,	HC-16, KVN193
Mushroom type STOP switch	*S0*	emergency STOP with housing, 1 NO, 1 NC,	MSG13400RD
Door switch	*S1*	proximity limit switch, 1 NO, 1 NC	ELOBAU 17127113
Manual NO switch	*S2, S3*	pushbutton with green indicator light	MST14100C
Relay	*K1 … K6*	miniature control relay, 24VDC, 4 CO contacts, 6A	PT 6A 4C 24VDC
Pressure switch	*PS1*	adjustable pressure switch, micro-switch commutation	F4YX3TG/150D/P2P1
Optical indicators	*H0 … H3*	indicator LED light 24V AC/DC	BZ501210-B (*H0*) BZ501213-B (*H1, H2*) BZ501211-B (*H3*)

4. Conclusions

Engineering field of electro-hydraulics has encountered a large development in the past years because of rapid technological advances, especially in electronics, IT and material’s science. Modern P.E.T. waste presses use closed-loop analogic, digital or hybrid control, depending on its pressing capacity and functional requirements, most advanced constructive types use PLCs. The authors propose in this paper a simple and energy efficient electro-hydraulic automation schematic. Future work, the authors will try to obtain a simulation model for the solution presented in this paper and analyze its adequacy.

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