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Simulation of an Electro-Hydraulic System for a P.E.T. Waste Baling Press

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Abstract: *Energy efficiency is nowadays a key factor in designing industrial machinery, where digital technologies, modeling and simulation software environments are beginning to have a deeper impact. Smart technologies have entered industrial field supporting machine design engineers to develop and optimize their technical solutions. In some cases, when energy efficiency of old machinery needs to be increased, retrofitting existing schematics is not always an easy task, instead of modifying the connections between components or replacing some of the existing components with new ones it is preferred to replace old and inefficient parts with new modular solutions. Hydraulics and pneumatics are still two types of industrial drives that are used widely, but their overall energy efficiency has not improved very much in the past years. There are conducted industrial researches having good laboratory results, but these solutions are not ready yet for the market – standardized equipment and modules being preferred. These researches are targeted not on the entire application itself but on specific functional phases or modules.*

In the particular case of an existing hydraulic P.E.T. waste baling press, functional cycle optimization and energy efficiency improvement can lead to entirely replacement of the hydraulic drive and control algorithm, where digital hydraulics might be taken into consideration as a modern technical solution. It must be paid attention not only to the engineering side of these improvements, but to the economical side as well because retrofitting costs depreciation is poor. In this paper, the authors propose a simple and energy efficient electro hydraulic driving system for an existing small capacity P.E.T. waste baling press that was modeled and simulated using FluidSIM Hydraulic software environment.

Keywords: *Modeling, simulation, electro-hydraulic, FluidSIM*

1. Introduction

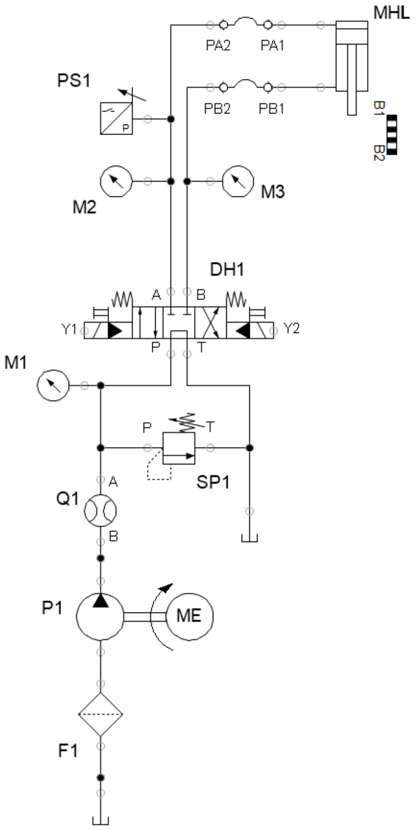
Most of industrial applications and machinery are using electro-hydraulic or electro-pneumatic drives [1, 2], even if their drawbacks are very well known by design engineers: energy dissipation, high maintenance costs and their reliability [3].

Modern industrial design is now targeting optimization through energy efficiency and digital solutions along with the use of virtual tools for design, modeling and simulation [4, 5]. One of these virtual tools, a modeling and simulation software environment is FluidSIM Hydraulics. This software environment includes a schematic editor using configurable standardized hydraulic components and a real-time simulation module that include digital and analogic data acquisition using FESTO EasyPort DAQ board.

In this paper, the authors present the modeling and simulation of a simple and energy efficient electro-hydraulic driving system for an existing small capacity P.E.T. waste baling press [6] using FluidSIM Hydraulic software environment.

2. Hydraulics system

Diagram of the hydraulic circuit that the authors propose is considered to be simple and can be used as a development ground for other engineering applications including lifting systems or elevators. Diagram and components of the hydraulic system are given in figure 1, mainly consisting of a fixed-displacement pump, a pressure-relief valve, an electro-hydraulic directional valve and a double-acting hydraulic linear motor.



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

In the hydraulic schematic in figure 1, there are shown three pressure gauges *M1*, *M2* and *M3*that are used in the simulation part to monitor pressure values in the hydraulic circuits. Also, *PS1* is a pressure activated switch used both in the simulation and the electrical automation schematic for signaling the end of pressing cycle and for controlling the press platter return movement in its initial position, unless P.E.T. bale must be evacuated.

3. Electrical schematic

Diagram of the electrical system that the authors propose here is given in figure 2. There was designed a relay logic automation schematic, modeled and simulated using *FluidSIM Hydraulics*. Functional phases of the P.E.T. waste press are given below in table 1, schematic symbols are in accordance with the electrical schematic in figure 2.
As can be seen from the hydraulics schematic in figure 1, directional valve *DH1* has two 24VDC electromagnets, *Y1* and *Y2*, which need to be energized according to functional phases of the pressing cycle.

Table 1: P.E.T. press 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

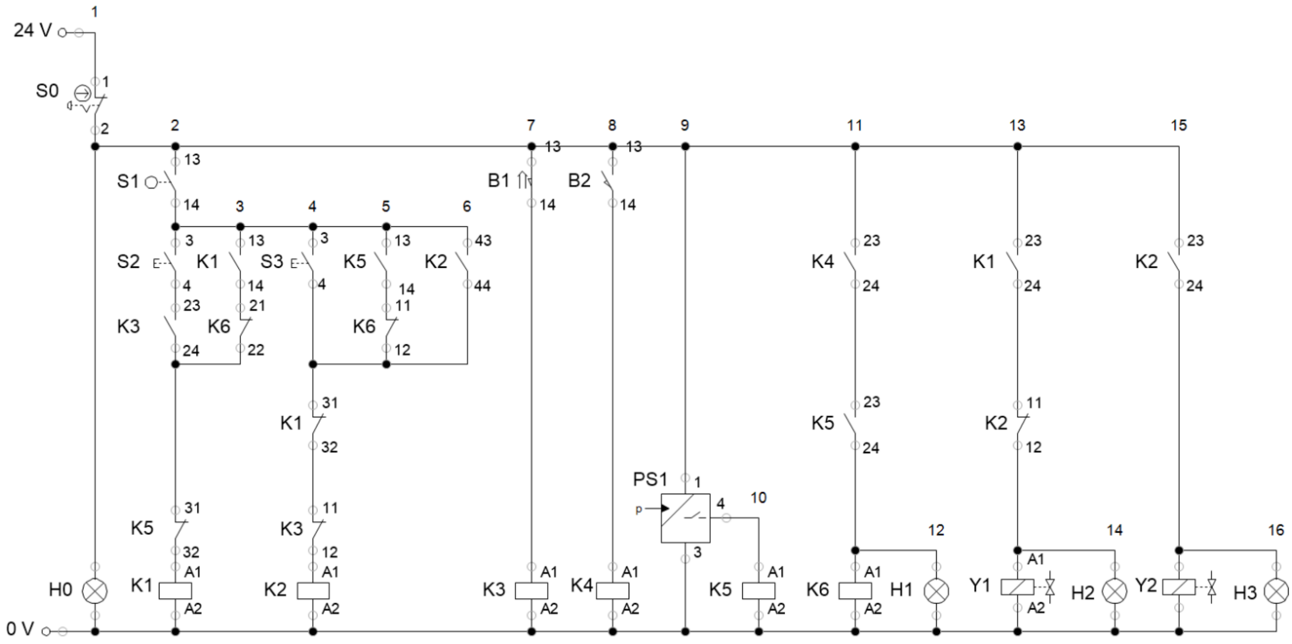


Fig. 2. Electrical schematic of the driving system

4. Simulation

The authors used for modeling and simulation the software environment FESTO FluidSIM having the *Hydraulics* module.

4.1 FluidSIM simulation environment

FluidSIM, having the Hydraulics extension module can be used for simulating hydraulics and electro-hydraulics schematics, in real time. Probably of the most important features of FluidSIM is its connection with CAD functionality and simulation. FluidSIM uses DIN-compliant drawing of electro-hydraulic circuit diagrams and can execute realistic simulations of circuits using physical models of electro-hydraulic components. FluidSIM is taking over a gap between the drawing of a hydraulic circuit diagram and its simulation.
All hydraulic components from FluidSIM’s libraries have ISO symbols, functional and connection descriptions and some of them have short animations that depict the working principle. User interface is easy to use and intuitive. Main advantage is that both hydraulics and electric circuit diagrams can be modeled and simulated in the same time. As an example, if the user clicks an electrical button, the associated relay or valve electromagnet will be energized, in the same time it will be driving a valve or a hydraulic motor (shown by an intuitive animation).

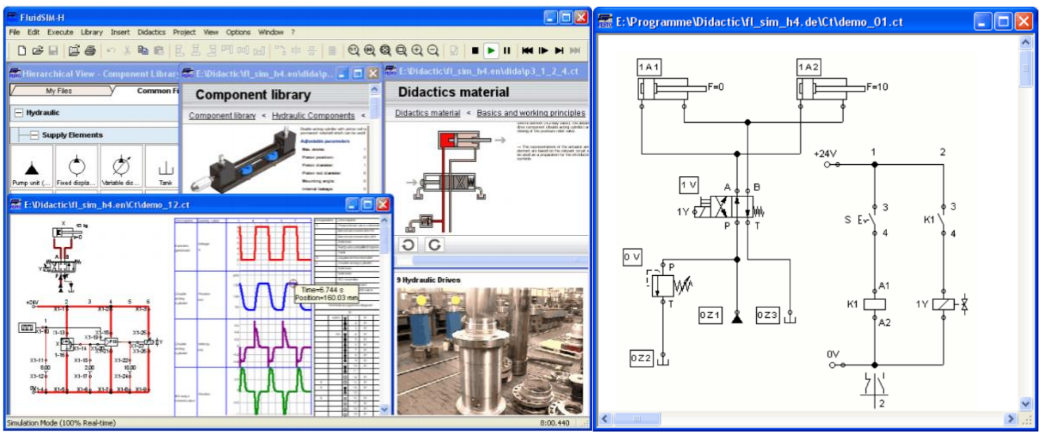


Fig. 3. FluidSIM Hydraulics modeling and simulation environment [7]

4.2 Simulation results

There are certain advantages using FluidSim Hydraulics, because of its modeling capabilities and connection of its virtual component libraries with real-life physical equipment. All virtual hydraulic components can be parameterized according to physical technical specifications given by the equipment's manufacturer. The simulation extension of FluidSIM allows dynamic movement of virtual hydraulic system components.

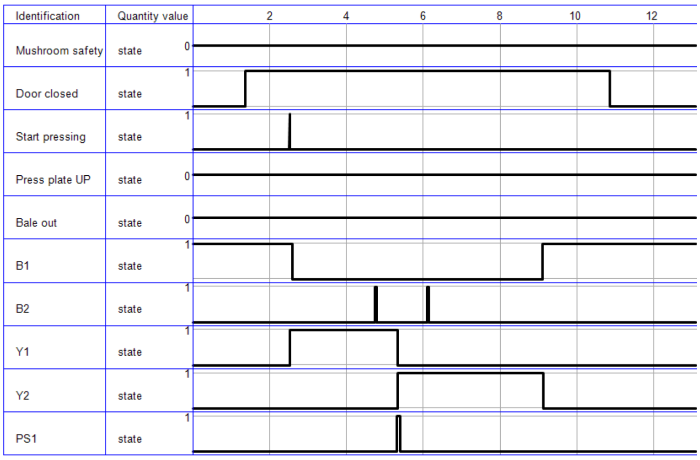


Fig. 4. State diagram showing normal start conditions on the electrical diagram

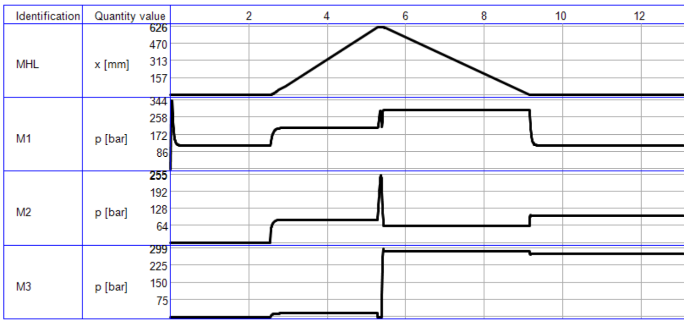


Fig. 5. State diagram showing normal start conditions on the hydraulic diagram

In figures 4 and 5 there are shown simulation results using *FluidSIM Hydraulics*, for normal start conditions, when button *S2 (Start pressing)* is pushed, press plate is in initial position and press chamber door is closed. From figure 5 it can be seen *MHL* hydraulic motor rod travel and pressure variations in all three measurement points – pressure gauges *M1*, *M2* and *M3*.

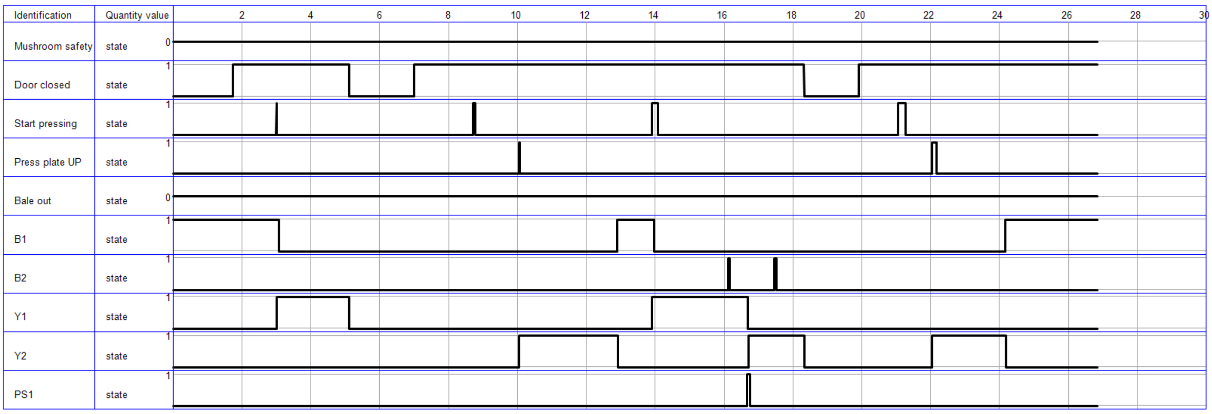


Fig. 6. State diagram showing abnormal condition,
when press door chamber is opened during pressing – electrical schematic

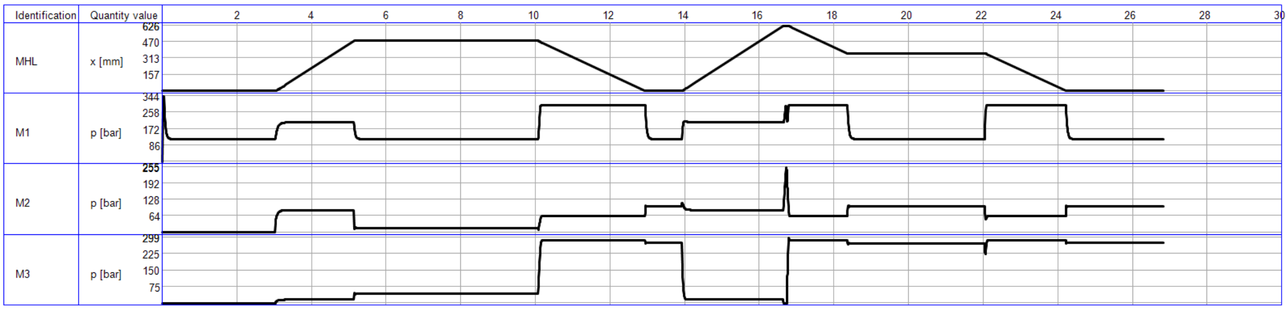


Fig. 7. State diagram showing abnormal condition,
when press door chamber is opened during pressing – hydraulic schematic

In figures 6 and 7 there is shown an abnormal functional condition, both on electrical and hydraulic state diagrams. After pressing the start button, pressing cycle takes place normally, until the pressing door chamber is opened (seconds 5 to 7 on electrical state diagram), causing *Y1* electromagnet to be no longer energized and locking the pressing plate into its current position. The *S3* button must be used now for retracting the press plate into its initial position, causing *Y2* electromagnet to be energized.

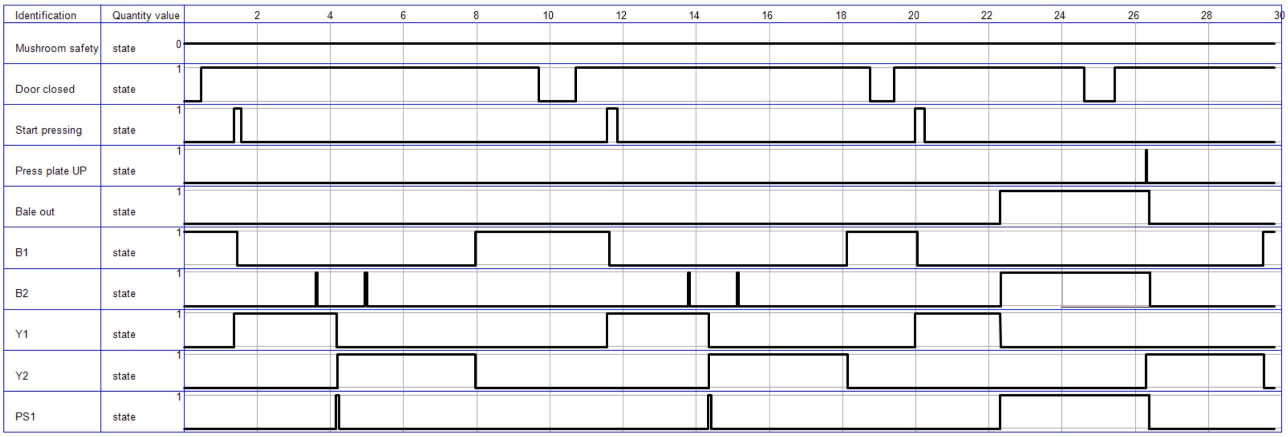


Fig. 8. State diagram showing two pressing cycles and bale evacuation – electrical schematic

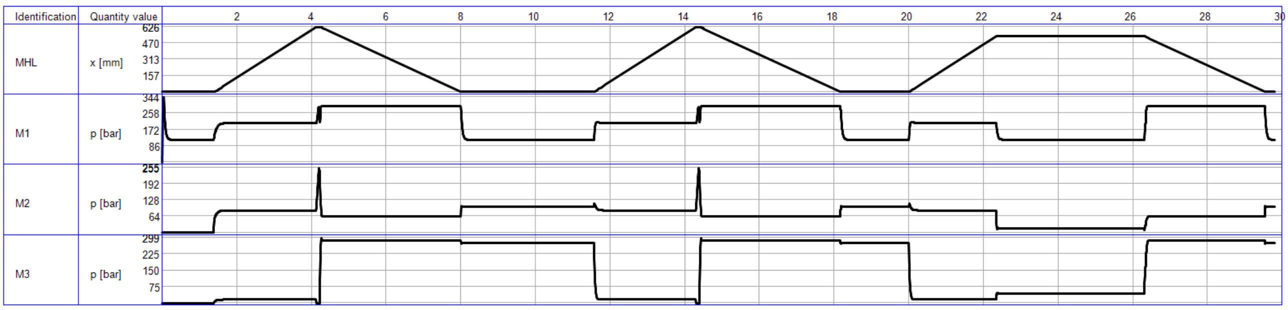


Fig. 9. State diagram showing two pressing cycles and bale evacuation – hydraulic schematic

In figures 8 and 9 there is shown two normal pressing cycles, the pressing plate starts from its initial (up) position, *B1* limit switch is pressed, and travels down until *B2* limit switch will be pressed (no pressure load) or *PS1* pressure switch electrical contact will be closed (with pressure load). The pressing plate will now return into its initial position.
The electro-hydraulic press will enter in bale evacuation functional state (*bale out* in figure 8) when both limit switch *B2* and pressure switch *PS1* are activated at the same time. Now, human operator can safely open the pressing chamber door and proceed binding the P.E.T. bale, while the pressing plate is locked into last position. After binding, the bale must be manually evacuated from

the pressing chamber. Before evacuation, the human operator must press button *S3* in order to retract the pressing plate.

5. Conclusions

Electro-hydraulics field of engineering has developed largely past years, due to the benefit of using technological advances in materials science, electronics and informatics. Reliable and accurate hydraulics systems include digital or analog electronic control made with computer assisted systems or dedicated solutions using industrial PLCs or microcontroller-based modules. Electronic digital transducers provide new measurement solutions with self-calibration, auto-diagnosis or bus communication modules. Data acquisition and virtual instrumentation enabled the development of intelligent measurement software, data processing, data storage or plotting various graphical diagrams.
Modeling and simulation of electro-hydraulic drives is a part of modern engineering design, drastically reducing production costs and time-to-market for a product or a system. Taking into consideration the discrepancies between physical systems and virtual models of the same system and using appropriate software environments, design engineers can easily put to the (virtual) test and optimize their ideas. The authors used for modeling and simulation FESTO FluidSIM Hydraulics.

Acknowledgments

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