Automation of the lamination process for automotive applications

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Abstract. The article addresses the design of an automation system for the lamination process of the cars, which has as inputs different types of transducers, and as outputs the command of a linear pneumatic motor. The layered and self-supporting laminated structures of motor vehicles are manufactured from a thermoplastic substrate and a flexible sheet material in one direction rolling and cutting operation. The installation for producing these laminates is a casting press having two casting plates, each of which comprises a component of a pair of cutting means. It is used a CPU 315-2 PN / DP, which is a medium-sized program memory processor and it is often used in automation structures. This processor can also be used as distributed intelligence (master or slave). The implementation of the code sequence to work on this processor is done in one of the specific languages to the programmable machines. The software used in programming is STEP 7. The stored information is not erased when the processor is disconnected. The usefulness of programmable machines has simplified the approach of an automated system.

1. Introduction
The materials used for the manufacture of cars have undergone continuous improvements and their share has changed in favor of those requiring more advanced technologies, which lead to making parts lighter, more durable, more comfortable, and cheaper and with recycling possibilities. A special challenge that occurs in the rolling of parts is the bending that must be done on the edges and corners of the parts. When rolling the steering wheel for example. The material must be casted instantly and strongly to prevent deformation. The technologies for making parts of plastics depend on their complexity and size and on the essential characteristics of the raw material. Plastics and elastomers can be processed by injection, extrusion, compression, thermoforming, contact, spraying, wrapping, casting, foaming, stamping, cutting, welding, gluing, etc. Processes for the transformation of plastics can be classified according to several global criteria, such as: mould feed mode; the shapes (1-D, 2-D, 3-D) and the scale sizes; heat exchange in shape; average manufacturing cadence.

Pressing is the process by which a flowable material is forced by compression to fill a die cavity. The pressure material is hardened by heating or cooling the mold. At the transfer press, the previously heated material is passed through the working cylinder by means of a piston through the filling channels into the nest of the mold. After the hardening and cooling of the material, the mold opens.
and the pressed articles are extracted with the transfer network. When passing through the transfer channels, the molten material homogenizes and becomes compact and the volatile products are completely eliminated. Through this process the urea-formaldehyde, phenol-formaldehyde, polyester and epoxide thermoactive compounds, as well as the textotolite (textile backing) and lignite (wooden support) are processed [1]. Also by this elastomer process sealing gaskets, couplings, membranes, semerings etc. are obtained. The thermoforming consists in deforming, by mechanical means (stamping) or by means of pressure difference (in vacuum or compressed air), of a plastic blank, heated to a certain temperature in the softening range. The sheet of plastic material is heated up to the soaking temperature with hot air or thermal radiation. For products with a height-to-open ratio of more than 12.5, the mixed-suction procedure on the negative or positive mold can be applied.

Combined thermoforming can also be achieved by three modes:

- **I - Injection - stretching – suction mode in vacuum molds.** The process starts with the injection of a preformed, disk-shaped, hot-shaped piece, which is then subjected to stretching with a mandrel and drawing into the mold by vacuum.
- **II - Extrusion – thermoforming mode in closed molds.** The methods consist in extruding a tube of thermoplastic material, introducing it into a forming and molding mold using the compressed air (0.3 ... 0.66MPa) on its walls. Through this process, fuel tanks, windscreen washer wipers, brake fluid tanks, and containers with a capacity of up to 2000dm3 are run.
- **III - Injection - thermoforming” mode in closed molds.** In this case, the heat-homogenized material on a conventional aggregate is injected into a controlled cooling mold to form a preformed product. The preformed product is placed in the hot state in the mold by blowing and formed with pressurized air to its dimensions. The process is advantageous for the manufacture of empty bodies and small cylinders requiring a perfect calibration of the neck (central brake pumps). The layered and self-supporting laminated structures of motor vehicles are manufactured from a thermoplastic substrate and a flexible sheet material in one direction rolling and cutting operation [2]. The installation for producing these laminates is a casting press having two casting plates, each of which comprises a component of a pair of cutting means.

2. **Automation of the lamination process**

When designing an automation system, at the beginning it is established the process that needs to be automated. The automated system can be any simple or complex process. Secondly, the process inputs and outputs that will be connected to the programmable machine are set. Any sensors, switches, etc. can be input devices. Assigning inputs and outputs is important in building the program. The functionality of the system is assured by writing the program using a specific language. In the body these works will be presented an automated system that will have inputs different types of transducers and as output will have the command of a linear pneumatic motor. It is known that the actuated element of the rolling press is a linear pneumatic motor (cylinder) commanded by a distributor and the operator loads the piece in the working area (figure 1a, 1b). A photoelectric sensor that senses the presence of the piece is present in the process. When the sensor detects the presence of the piece, the process can start in automatic mode after pressing a button, with the following conditions: the door is closed and locked throughout the process, the piece is present in the work area and the cylinder is in the basic position. When the set temperatures are reached, the cylinder lowers and has a pressing time. After the pressing time has elapsed, the cylinder rises.

In the figure can be seen the electric panel that is at the back, and the operator panel at the front. There are also two accessories, two lighting devices as well as the switch that controls the lighting of the station. The control element, a linear motor cylinder, is also added to the station. The total length of the station is 1400mm in length and 2245 in height. When it has reached the base position, the door is unlocked, and the operator removes the piece to be tested (figure 2).
Figure 1. CAD model for:

a. for rolling press with the control element - a linear motor cylinder (front view).

b. inside view of the work area

Figure 2. The piece to be tested (The surface on which the pressing is made).

The operating cycle resumes periodically. In manual mode, the command can be done using an operating panel, and the process described here is no longer relevant. The difficult part of hardware implementation is the logical solution to get a plan as accurate and safe from the user safety point of view. We took in consideration the risks to which the human factor is exposed. A pneumatic scheme is used that is based on moving parts and provides additional locking of the moving parts according to the risks presented. In the hardware section, these risks are taken into account. In addition to the implementation of the logic scheme, auxiliary devices are introduced to ensure a high level of safety during operation. The risks presented above are taken into account. For door locking system a PSEN sl-0.5p 1.1 with actuator will be used (figures 3a, 3b and 4).
Figure 3. The actuator:

a. PSEN sl-0.5p 1.1 [3].

b. control logic scheme.

Figure 4. Connection model of PSEN sl-0.5p 1.1 on the PNOZ s3 evaluation device.

As the PSEN sl-0.5p 1.1 [3] will be connected to the PNOZ s3 [4] connection device, the evaluation device will be presented for the correct gate safety function. PNOZ s3 is a safety relay (figure 5) for monitoring the emergency button (figure 6) and the safety gates [5]. A connector can be used to connect to a PNOZ sigma contact. It is a two-channel safety module. It has two normal-open contacts. The operating modes can be set via the rotary switch. It has an LED indicator to track the supply voltage, channel 1 input, channel 2 input, switch state, circuit reset, and error. The correct closing and opening of the safety function is automatically tested by an on-off loop. As part of the presence sensor, an OGH700 diffused optical sensor [6] is used (figure 7). It turns the beams into an electrical signal.
The optical sensor measures the physical quantity of light and then translates it into an interpretable form. The optical sensor can measure changes from one or more light beams.

2.1. The monitoring and control panel
For monitoring and control SIMATIC [7] Comfort panels of various types are used, including a S7-300 Touch-Panel 7 (figure 8).

SIMATIC Comfort panels are designed for application control and visualization and are intelligent control systems. For operational and monitoring control, the SIMATIC products are a necessity in complex processes for machine operation. Pixel resolution for this TP700 Comfort [8] is 800 pixels horizontally and 480 pixels vertical. All these pixels form the image resolution (16 million colors). The display is "touch". The input voltage is 24 V. It absorbs a current of 0.5 A. The TP700 Comfort communicates through ProfNet, Probus or MPI and configures WinCC Comfort (TIA Portal). Thus, graphical user interfaces can be created. The TP700 Comfort is equipped with both a USB port and a 2 Mbyte internal memory. Therefore, the automated process currently records 12 inputs (track attendance sensor, alarm reset, cycle reset, manual/automatic switching and 8 inputs on current detectors). At these inputs are also added pressure sensors and cylinder position sensors. To optimize the working process, when it is implementing the program, the following mandatory elements are considered: if there is a voltage of +24V, if the Emergency button has been pressed, if the shut-off button has been pressed or the door is closed. In the electrical diagram can be seen what inputs are presented in the programmable machine. There were 25 required entries in the programmable machine according to the described plan. The input module is an SM 321 with 32 inputs, powered at +24V with an input of 15mA (figure 9).
For Outputs, a module with 32 outputs is used. The outputs include the control of two single-phase relays, which control the electrical resistors commands, thus adjusting the temperature. On the module outputs are also the two signaling lamps (signaling error and process signaling at work). Let's not forget the linear motor (the cylinder) that is driven by a distributor that has the electric control. So in the outputs there is also the control on the cylinder which is made by the programmable machine. The output module used in the project is a SM 322 (figure 10). It is powered at +24V voltage, with a consumption of 160 mA. For these two modules to work, a control unit is needed. It is used a CPU 315-2 PN/DP powered at +24V, with a consumption of 750 mA. This CPU 315-2 PN/DP is a medium-sized program memory processor and it is often used in automation structures. This processor (figure 11) can be implemented via a PROFINET interface and as a PROFIBUS in the SIMATIC S7-300.

This processor can also be used as distributed intelligence (master or slave). The implementation of the code sequence to work on this processor is done in one of the specific languages to the programmable machines. The software used in programming is STEP 7. The integrated processor communications options allow network automation solutions to be implemented without additional components. The processor has two communication interfaces: MPI/DP combined interface and an Ethernet interface; To store the part of the program, a 512 kilobyte Flash-EPROM (MMC) memory is used. The stored information is not erased when the processor is disconnected. The usefulness of
programmable machines has simplified the approach of an automated system. There is a start button and a shutdown button that is hardware deployed. The start button switches the machine to the control voltage, and the shut-off switch is disconnected from the voltage. So we need a relay with at least two N/O contacts [9]. A contact will be for the self-holding of the relay, and one for the + 24V coupling. A relay with 4 N/O contacts is used with a + 24V coil (figure 12):

![Relay with 4 N/O contacts](image12)

**Figure 12.** The relay with 4 N/O contacts with its electrical diagram, [9].

Since it has been completed with the electrical components required in the electrical diagram, the power supply + 24V is selected, all the components are operating on this voltage and all the consumers get a current of 1.685A. It should be a source that outputs a current of 5A. Because the output, input and analog output modules are not used at 100%, the difference will remain as a backup. It cannot be predicted which consumers will be added to the installation in the future. So you can choose a source that has a current of 10A [10] for the backup (figure 13):

![QUINT power supply](image13)

**Figure 13.** The QUINT power supply with +24V 10A, [10].

It can optimize the circuit with an auxiliary electronic circuit MICO 4.4 (figure 14). MICO is a 4-channel electronic auxiliary circuit [11] and serves as an electrical monitoring. It is an intelligent power distribution. The QUINT power supply operating voltage (+24V DC / at least 10A) feeds the 4 channels. By applying the supply voltage, the channels are activated with a 75ms delay to avoid power supply overload. The channels are independent and have operating currents between 1A and 4A. When the operating current is reached, the channel acts as a fuse that disconnects the power supply according to the disconnect feature. Each channel can be connected or disconnected manually via the buttons on that channel. There is an LED on each channel. The LED has green color if it operates and the red color is
misleading. It also has a N/O contact (pins 13 and 14). This contact will be used as a condition in automatic mode. Check that there is + 24V on the station. A channel will be used to power the CPU and processor of the programmable machine. A channel is used to feed sensory. A channel is also used to power the programmable machine modules. In the pneumatic channel there will be a safety pressure switch designed to engage the linear pneumatic motor brake. The pressure switch that locks and the control on the cylinder will be passed through an electric relay. For this it is used a 4 N/O contact relay [12] (figure 15):

![Figure 14. The auxiliary electronic circuit MICO 4.4. and its electrical diagram, [11].](image1)

![Figure 15. A N/O contact relay with 4 auxiliary switches type "changeover" and its electrical diagram, [12].](image2)

The connection and uncoupling of the rolling mill to the single-phase voltage of + 230V is made by means [13] of a main switch (figure 16):

![Figure 16. The main switch [13].](image3)
distributor outlet, the droplets with which the speed of the cylinder is adjusted in both positions are followed. Pilot valves are present in the immediate vicinity of the distributor that controls the cylinder. These allow the air to pass on, if an external air control is applied. The pressure flow must overcome the strength of these valves. If their resistance is defeated, then only the cylinder is commanded. An initially closed distributor, 1V2, disengages the brake on the cylinder if it provides air at the outlet.

It is also the one that acts the pilot valves. This distributor's order is made after the door has been closed. If the supply to the distributor falls, the brake engages, so the engine is blocked. A pressure switch, 1Z1, checks the pressure on the cylinder brake circuit. If the air is present, then it is certain that the brake is off, so it is possible to control the linear pneumatic motor. The process is repeated. Therefore, an air preparation ensures the flow of air into the circuit. An inlet distributor (with electrical valve - Y5.7) controls the air supply of the pneumatic circuit. The control on this is conditioned by the emergency button and the door position. The pressure sensors will read the pre-command pressure on - Y5.7 but also after driving -B10.1 and -B10.2 respectively. When the door is closed, the control panel on the distributor 1V2 with the electrical valve Y5.2 releases the brake from the linear pneumatic motor. At the same time the pressure is read with a mechanically actuated sensor on the pressure from the branch (-B5b.6). Only then is it possible to control the distributor with which the cylinder 1A1 is actuated by a relay -K5b.7. The electrical valves from the 1V1 distributor are: -Q20.3 and -Q20.4. The position of the cylinder is given by the sensors -B9.2 and -B9.3. All these operations are schematically represented in the following diagram (figure 17):

\[\text{Figure 17. The operating principle of lamination process automation.}\]

An automated system needs to be understood in a broader approach as a system faces reality. The usefulness of programmable machines has simplified the approach of an automated system. The CAD result of the 3D model is shown in figure 18. Figure 19 shows the final experimental model.
3. Conclusions
In its construction, several factors have been considered (supply voltage, cable section, risk to the operator, consumers, sensors, etc.). There was an attempt to get the most accurate hardware schema and the description of the process was considered. The planning of the electrical scheme has attempted to eliminate some of the risks to which the operator is subject. A sensor is placed at the door that will lock the door during the process, which means that the operator can not introduce inside the hand. There is also an emergency button for critical situations that actually involves circuit breakout and the electric plan had to synchronize with the pneumatic plane. In case of compressed air interruption due to lack of electric power, the cylinder which drives the floating plate remains locked in the position where it is. Thus, additional locking of the floating part was provided. It went on a cylinder with a brake whose braking is only operated in the absence of the air. The biggest benefit of this automation process is that it saves time and work and improves both the quality and the precision of the finished product.
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