ICM 4.0 – Injection Moulding Machine Control and Monitoring

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Abstract. Today, gathering relevant information on a certain industrial process and being able to monitor and store that data is now more important than ever. In the plastic industry, there has been a necessity to retrofit injection machines that have outdated controllers and with no communication capability.

Therefore, it is pretended to conceive an automatic system, using a Siemens programmable automaton, that would allow the monitoring and supervision of the injection machine's process, and creating an OPC-UA interface following EUROMAP 83 specifications to communicated with the digital twin.

EUROMAP 77 is the new Industry 4.0's standard for data exchange between injection machines and automated process management systems (Building Management Systems-BMS, manufacturing execution systems–MES, Enterprise Resource Planning–ERP, etc.). EUROMAP 83 adds to EUROMAP 77 the communication between injection machines via OPC-UA interface.

In the Superior School of Technology and Management (ESTG) of Politécnico de Leiria, there is a plastic injection Moulding machine (Euroinj D-80), belonging to the Mechanical Technology Lab of the Mechanical Engineering Department. That machine will be the target of this study.

It is also pretended to study the quality control of the process to ensure the best quality of the finished product, through the measurement of parameters, such as the mould pressure and temperature.

Keywords: Supervision · Industry 4.0 · OPC-UA · EUROMAP 83 · Quality Control

1 Introduction

The concept of Industry 4.0 is constantly changing, presenting new concepts that adapt to the needs of the processes. The necessity to retrofit an old Injection Moulding Machine (IMM) so that they can meet the requirements to function with this concept has become more apparent.

Many companies have specialized in doing this sort of procedures, using PLC [1] or other controllers [2].

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To improve the potential of retrofit, it is important to make the commissioning using a digital twin, a virtual and reliable model that preserves all the physical and mechanical characteristics of the process in question [3].

2 Case Study

Considering the existence of an IMM (from 1998) in the Mechanical Technology Laboratory in the ESTG, it was decided that retrofitting this machine would be an advantage to the users of the laboratory (Fig. 1). This was considered something important to do, because this machine doesn't share its values with the outside, doesn't do its own quality control and has an outdated and confusing interface.

Fig. 1. Pressure Setpoints.

2.1 IMM Control and Monitoring

The goal of this project was to create an interface, using a programmable S7–1500 automaton from Siemens (CPU 1512C-1 PN 6ES7512-1CK00-0AB0). This interface would read the process values, like the pressure and temperatures, process them and make them available to external use. It would also allow the storage of different moulds and their injection cycle parameters, as well as manage the quality control of the pieces produced and the storage of the results.

Before the description of the developed project and interface, it would be beneficial to first briefly describe this machine's injection cycle. After the mould is closed, the screw moves forward with significant pressure to inject the fused material into the mould. After the desired material has been injected into the mould, the screw stays in the same position to maintain enough pressure so that the material won't go back to the screw area and stays in the mould. As the material inside the mould cools and turns solid, the screw will start rotating and going backwards so that the material that is falling in the screw cavity starts fusing. With this, the machine is already preparing the material to be injected in the next cycle. With the piece hard enough, the mould opens, and the piece is extracted, after which the mould closes again to start the next injection cycle.

The development of this project consisted of two fundamental steps, namely the acquisition of the relevant data from the injection machine and the storage and processing of said data for quality control. The gathered data was comprised of the injection pres sure, the temperatures of the 4 distinct areas of the injection zone, the movement of the cavity and injection screw transducers and, lastly, the room temperature.

First, the connections between the machine and the automaton were created, as well as the signal processing to not cause harm to the automaton and ensure the input signals that were being fed to the automaton where between 0 and 10 V.

For the processing of the temperatures, specific electronic circuits were used. These electronic circuits were used due to the lack of analog inputs of the automaton in question and the impossibility of using an analog cart for direct thermocouple measuring. The room temperature was measured with an electronic component, called LM35.

Second, after the signal processing was done, the graphic interface started being de veloped, allowing the monitorization and quality control of the injection process. Even though the goal was controlling the machine and replace her inner PLC, the infrastruc ture to do so was also developed but, for now, the programmed interface is merely visual due to the inability to communicate and share information with the internal ma chine PLC data.

By using 2D drawings of the main components of the machine, we can monitor the real process of the machine and observe the movements of the screw and cavity, the extraction of the produced pieces, among other things. It is also possible for the operator to introduce to the interface relevant variables such as the packing time, the injection pressure, etc.…with the goal of making the monitorization as faithful to the real process as possible.

The data that the operator introduces will, subsequently, be stored in a data base with the possibility to be associated with a specific mould. There is also the option of creat ing several different moulds, with different values, and store them. Also, if the operator wishes to update or change certain parameters, he can do so by simply selecting the pretended mould within the stored ones. This can be used to, for example, modify cer tain parameters that change with the season in question (E.g.: Spring, Summer, etc.…).

or with the room temperature that could affect the characteristics of the produced pieces and the performance of the machine.

The operator can also set specific pressure setpoints for 8 different zones that are seen as relevant for the quality control of the process (Figs. 2 and 3). Five of these setpoints are in the injection phase, corresponding to a specific position of the screw, and three are in the mould compression phase, to ensure a constant pressure. There is also the possibility to update those setpoints.

In the beginning of the injection phase, the screw is in the position necessary to inject the amount of material needed, also known as the dosage, and it will advance through the defined setpoints until it reaches the mould and setpoint 5. At this setpoint, it will begin the packing phase where cushion will be injected. This cushion, the material left at the front of the screw, allows us to know the amount of material needed and ensures the amount of material necessary for the injection.

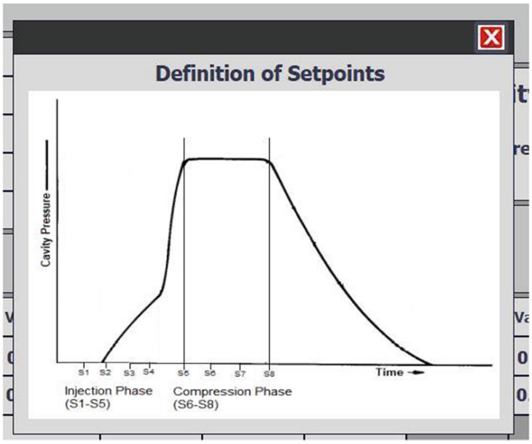

Fig. 2. Pressure Setpoints

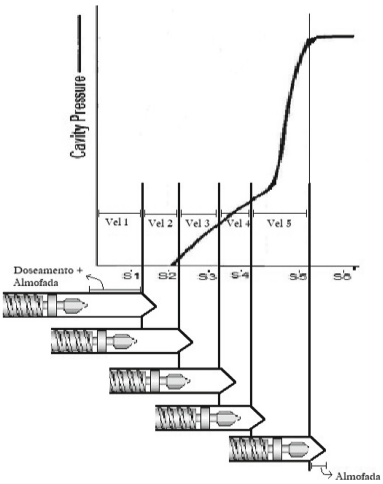

Fig. 3. Pressure Setpoints.

For the quality control of the process, the interface compares the measured pressure in a setpoint with the defined value for that setpoint, with an error margin, also defined by the operator. It is programmed that, with one or less measured pressure setpoints not within the acceptable range, the piece is in conformity, between 2 and 4 the piece will require visual confirmation and with 5 or more the piece is not in conformity. With the same parameters and mould, the outcome of the quality control may be different depending on the error margin used. For example, if we have a 2% error margin, a piece may require visual confirmation but with a 5% error margin, the same piece may be considered as in being in conformity.

By also measuring the temperatures of the four areas of the machine in each of the defined setpoints, it is possible to more easily discover the reasons why the pressure was not within the desired range. For this same reason, the injection speed is also meas- ured in the first five setpoints (Figs. 2, 3, 4 and 5).

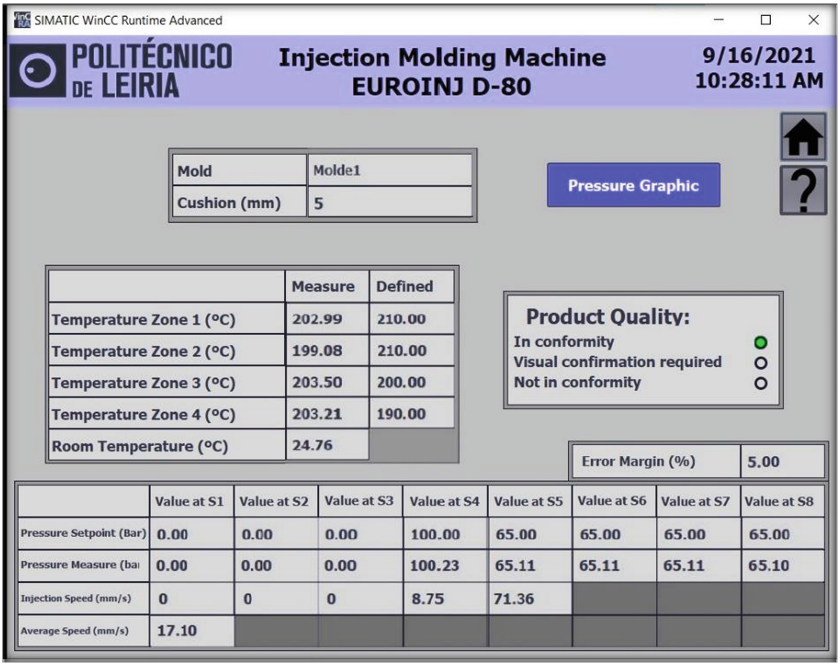

Fig. 4. Quality Control Interface with 5% error margin.

The pressure can be constantly recorded in a graph, obtaining a pressure curve (Fig. 6). Also, in all injection cycles, a programmed script will create an excel file that will store the entire pressure curve with a 100ms resolution. This will allow the user to draw the pressure curve on the excel file with the stored data and use that information to, for example, compare the pressure curves of pieces from the same mould but with different parameters.

Along with the automaton's internal mould storage (that can only save up to 30 moulds), there is also the possibility to store all the mould information and parameters in a MySQL database and store all the pieces produced and the quality of said pieces.

To make the measured values and the quality control results available for external use, an OPC-UA communication protocol was programmed. This will allow the stored information to also be available in other devises or data bases, or even be able to com municate with a digital twin of the machine.

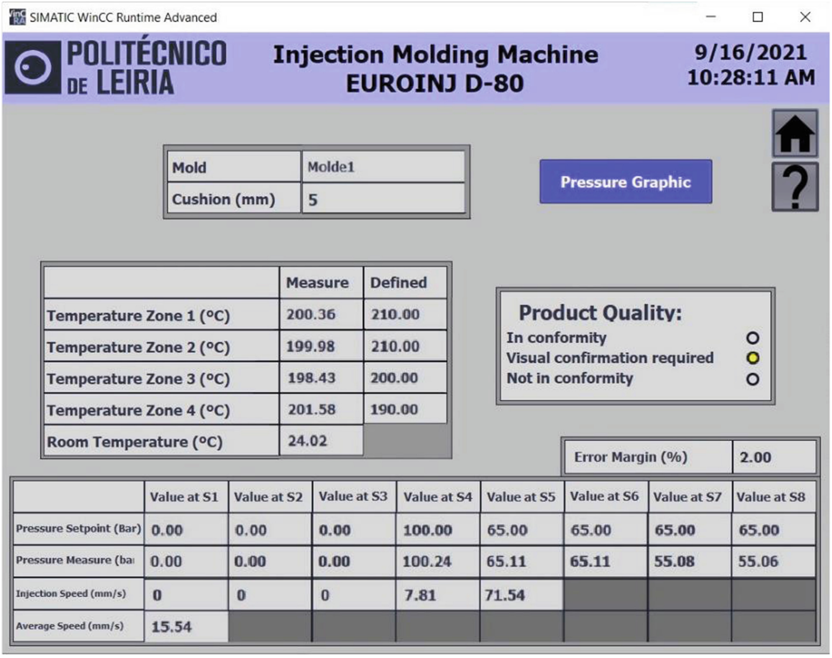

Fig. 5. Quality Control Interface with 2% error margin.

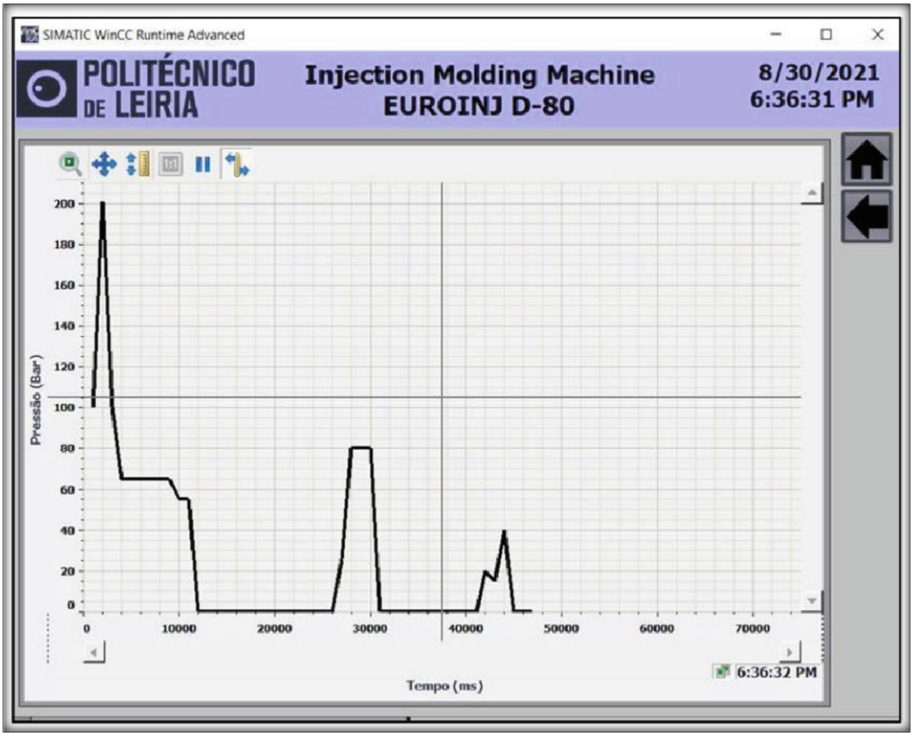

Fig. 6. Pressure Graph.

2.2 IMM Digital Twin

The OPC-UA protocol has been developed by the OPC Foundation as an open communication platform for integration and combination with other based standards. For industrial purposes and applications this protocol takes in account issues like security and reliability. Furthermore, this protocol allows the identification of variables and methods independently from their brands, what becomes a great advantage.

In this case it was created an OPC-UA server through the PLC in use, which allowed to access all the information available by the controller. With that, we can use the data through the OPC-UA protocol to establish a connection between the server and a digital twin. The digital twin is a complete and trustworthy representation of the real world in a virtual environment. These characteristics make the digital twin an important tool for the testing control and the identification and debugging of errors.

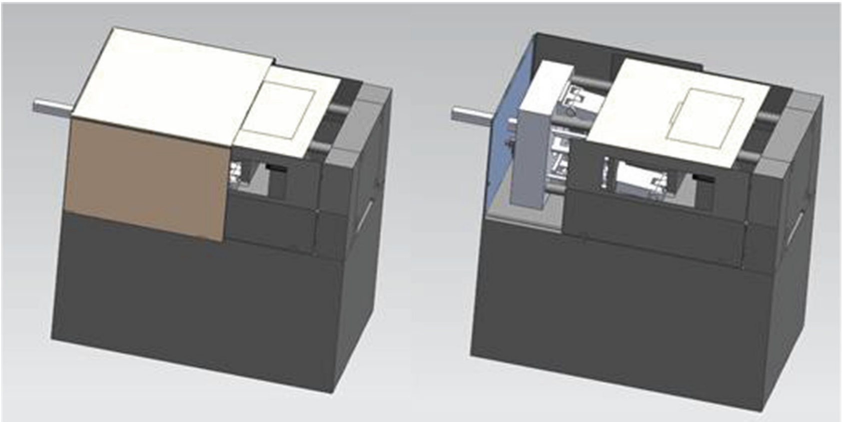

Fig. 7. Digital twin model in use.

In Fig. 7 we have a digital twin, developed in Siemens NX Mechatronics Concept Designer, that can be used for the virtual commissioning. Although the model isn't the same as the one used in the real world, his behavior is the same, which allow is use in this case. With this virtual image and the OPC-UA communication, we have a cyberphysical system that can be used for all the testing before his implementation in the real model, creating in this way an important tool for analysis and study of the behavior that we want to apply to our real system, in this case the IMM.

3 Conclusions

This project presents the implementation of an IMM control and monitoring interface, where we could implement the quality control of the process to ensure the best quality of the finished product, through the measurement of parameters, such as the mould pressure and temperature, and make the monitoring of the process using a SCADA solution.

Using the digital twin there is a reliable representation of an industrial process, with the possibility of studying and testing its control in this model, thus applying virtual commissioning.

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