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Emulation of System as Strategy for Teaching of Mechanical System

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Abstract--*The purpose of this work is to demonstrate how emulated systems can support teaching-learning processes, as well as supporting tools for mechatronic systems design practices of low and medium complexity. In the engineering design process, it is necessary to make a prototype to verify compliance with the parameters and restrictions posed in the design conditions, but the construction of these prototypes can be expensive, especially as the device becomes more complex, in order to show the usefulness of emulated systems in the context of mechatronic systems projects, an experience was developed aimed at developing a filling and sealing system for plastic tubes, following the steps of the engineering design process, to build a virtual prototype and emulate it in order to test the control strategies of the equipment with commercial devices (LCD), the process was carried out with excellent performance and at low costs, evidencing its potential for teaching and stimulating skills and abilities in the design phase.*

Keywords--*Design Process, Emulation, Mechatronic Systems, Significant Learning, Virtual Models.*

I. INTRODUCTION

In the solution of technological problems where products or processes are developed, clearly defined areas of knowledge are highlighted, such as engineering: Electrical, Mechanical, Electronics, Software, and Control, among others. The application of methodologies and techniques of each area have proven appropriate in solving these problems separately, however, there are a set of these problems where the solution requires the combination of different areas, such asMechatronics Engineering, where the application of these tools and methodological techniques donot have the same performance, especially in the design phase (Atoche&Marrufo, 2011; Emilio, 2005; PIERO, Alejandro, Francisco, & Manuel, 2015).

The word Mechatronics originates in Japan, in 1960, the term was registered by the Yaskawa Electric Company and arises in response to the need to address multidisciplinary problems, which lead to the use of their own methodologies, resulting in a faster design and cash (Alciatore&Histand, 2011; Macías& Martinez, 2019; Menéndez *et al.*, 2019). Mechatronics Engineering is transdisciplinary and arises from the need to integrate the design of systems: electrical, electronic, mechanical, control and software (Robles, Fernández, & Corona, 2018). This has led to plans for training in Mechatronics engineering, undergraduate and postgraduate worldwide, where studies reveal that more than 60% of these plans are focused on design (Rojas, 2013; Palacios *et al.*, 2019; Paramita *et al.*, 2018).

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Design is a fundamental activity in the training of the future mechatronic engineer, hence he must have knowledge in techniques and methodologies aimed at solving problems in the area, so his training in CAD, CAE, CAM tools (Abdullah &Hamouda, 2005; Ahmad &Hamouda; Crespo, Trujillo, Taco, & Martinez, 2019; Chacon Fuentes & Restrepo Rodriguez, 2018; Fernández & Muñoz, 2018; Kuna, Hašková, Skačan, &Záhorec, 2018), programming, interfaces, sensors and actuators, communication protocols among others, are of vital necessity, as well as the management of the concepts of mathematical modeling, computational simulation and emulation of systems among others (Ortega, Salazar, Becerra, Valdivia, & Leyva, 2018; Rojas, 2013).

The elaboration of the model raises Persé, a simplified representation of reality, which needs to be submitted for its preparation, to a set of hypotheses, which allow the compression and analysis of the element that needs to be represented (Blanco Gulfo&Riaño Romero, 2007).The simulation contemplates the design of the model of a real system, which through the experience of its variables facilitates the characterization of its behavior. The simulation supported by computer resources allows to experience wide numerical scenarios, which are used for decision making, prior to the installation of a system (Arango Serna, Campuzano Zapata, & Zapata Cortes, 2015; Render, Stair, & Hanna, 2006; Rodríguez-Borges, Sarmiento-Sera, &Gámez, 2015), but also, for industrial training (Arredondo & Ramírez, 2017; Rico, Rodríguez, & Melo, 2018) and teaching of engineering methods and processes (Burbano Pantoja, Pinto Sosa, &Valdivieso Miranda, 2015; Cano, 2018; Gelves& Moreno, 2012).

In particular, the simulation allows an active role of the student, due to the immediate feedback of the results in the simulation, and given the possibility of modifying values, testing and experimenting hypotheses, which represents the great contribution to the significant learning of the simulation (Gelves& Moreno, 2012; Primatanti&Jawi, 2019; Tuarez*et al.*, 2019).The emulation is a system capable of imitating or replicating other systems (software or hardware) or part of it, this emulator system imitates and allows the user an experience of interaction similar to the original entity, so the introduction of data in the system The imitator should yield exactly the same output data as the imitated system (Kyslan&Ďurovský, 2013).

There are several design methodologies in the area of Mechatronic Engineering, for the development of products and systems, having in all cases the need to simulate the designs (Ortega *et al.*, 2018; Espinosa *et al.*, 2018; Estevez *et al.*, 2018), so it is essential to make designs with CAD technologies, CAE, CAM, through which 2D and 3D models are made, in addition to studying, the functioning of the mechanisms and their structural behavior, and finally simulating their manufacturing processes (Chowdary & Kanchan, 2013).

In this sense, there are a set of programs on the market that enable these processes, among which Autocad, Mechanical Desktop, SolidWorks, among others, in addition to the programs for the simulation and interface of communication and control processes, within which can be mentioned LabVIEW, MyOpenLab, among others (Carrasco, Nandayapa, Abad, Marrufo, & Jorge, 2016). It is the conjunction of the methodologies and these tools that materialize the first versions of the prototypes (Ortega *et al.*, 2018; Akpomedaye, 2019; Delgado *et al.*, 2019).

Once the virtual prototype has been developed and tested by CAM-CAE programs, it is necessary to implement its control by means of control circuits or systems carried out for this purpose, such as control interfaces, dedicated controllers and programmable logic controllers (PLC). This is why it is important to describe a methodology based on the techniques and procedures described above, to carry out the design of the control system (De Tres & Sánchez; Kyslan&Ďurovský, 2013;

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Suryasa, 2019).This work raises the procedure to perform the emulation of the prototype designed with the purpose of carrying out the control scheme with its respective algorithm.

II. MATERIALS AND METHODS

The methodology that was followed was the engineering design process, during the courses of mechatronic systems projects, The student performs the design of the mechanical devices, to then select the sensors, actuators and their respective algorithms and control strategies, in this sense, it is necessary to have the prototype, to establish the location of the sensors and the respective drives, which traditionally it is carried out in physical prototypes, resulting in a high cost in tests (Valera, Soriano, &Vallés, 2014; Dewi, 2018; Djahimo*et al.*, 2018).

It is proposed to make a virtual model of the equipment or mechatronic device to be designed using CAD-CAE-CAM development systems, and then, based on the control strategy, determine the number and type (analog/digital) of input and output signals, for the development or configuration of the interface.The implementation of the interface will communicate the controlled devices with the controlling devices, which in most cases are PLC, in this way the platform is configured to execute the control algorithms and that way the design adjustments will be made, such as is shown in Figure 1.

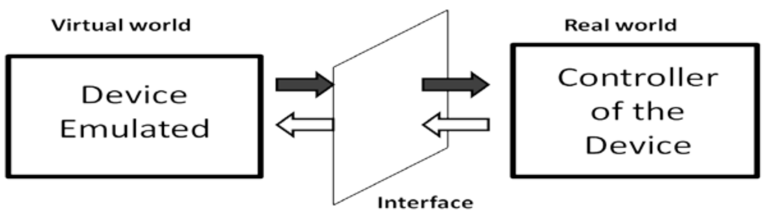

Figure 1. Strategy for the control of emulated systems

In order to carry out the control scheme by means of a PLC interacting with the emulated process in real-time, the communication is carried out with the USB port of the computer and the PLC input and output terminals, using the interface based on developments with microcontrollers or embedded technology (González, Pérez, & Dunia, 2018; Gonzalez, Dunia-Amair, & Pérez-Rodríguez, 2017; Wirawan, 2019), as shown in Figure 2.

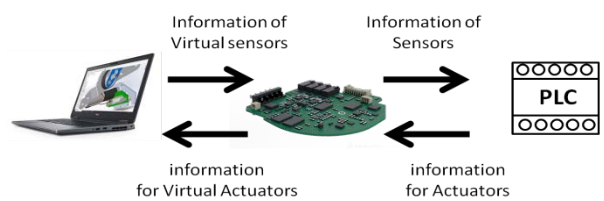

Figure 2. Communication architecture between the emulated system and thecontrol device

III. RESULTS ANALYSIS

The implementation of the design following the proposed methodology, f In a real situation, it was developed in an end-of-course project, where the students made the design of a system for filling and sealing plastic tubes, the design was developed in 3D, with AutoCAD, andsimulated with the Mechanical Desktop program, verifying the design parameters, as shown in Figure 3

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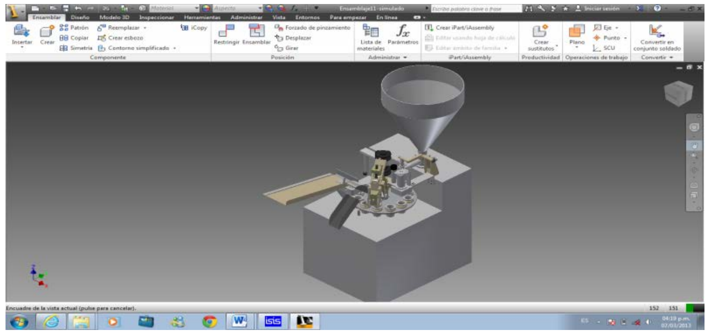

Figure 3. 3D model of the plastic tube filler and sealer

Once the virtual prototype was developed, the model was passed under the SolidWorks platform, for the simulation of The LabVIEW program was used to control the use of control strategies in the model, as shown in Figure 4.

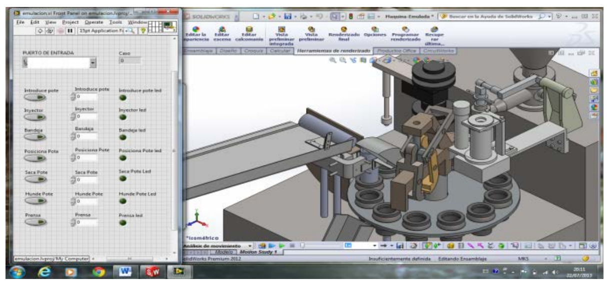

Figure 4. Simulation of the control of the 3D Model

Through this procedure, the students were able to try different strategies to control and verify its correct operation, in addition to correcting possible design defects, without causing significant expenses.

As the last stage, the interface was carried out, taking into account the number of inputs and outputs necessary for the control, in addition to the communication buses for the transmission of information, as shown in Figure 5.

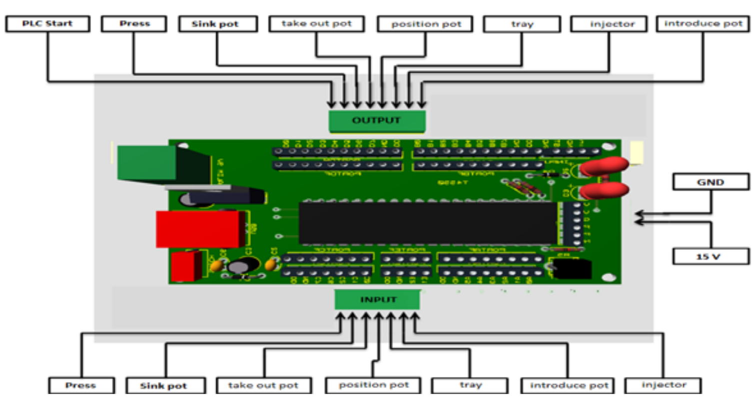

Figure 5. Communication interface developed by the Students

In the implementation of the interface, a card based on a PIC microcontroller was designed, with 7 inputs and 8 outputs, equipped with relays, once the interface was implemented, the system was integrated to perform the control practices with the PLC, and experience the control strategies planned for the device designed, the response times of the emulator were satisfactory compared to the planned control schemes, the automation performed, allowed to test different response times, the assembly is shown in Figure 6.

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Figure 6. Control system with process emulation

The equipment used is commonly used in the industry, which makes The student enters the work reality, in addition to making the designs with professional procedures and tools, at low costs, opening a set of possibilities and innovative developments, with the only limit the imagination.

Among the significant comments provided by the students are that the combination of the different programs that allowed them to achieve the development of the virtual prototype, combinedwith the system for emulation, represents for them a challenge that integrates knowledge of multiple subjects of the career to a real design of utility, both in the industrial and academic fields.

The motivation of the students throughout the design, and the emulation, was high and interactive, showing their interest in applying these tools, manifesting the need to continue with these types of practices.

IV. CONCLUSION

The evolution of simulation and emulation concepts are useful in the development of mechatronic devices or devices because they are low cost and show speed and efficiency. The availability of developing emulated systems through the use of professional use programs enhances student learning in techniques and methodologies of the professional area. In the industrial field, emulated systems represent tools that facilitate the design and testing phase.The proposal to use emulation as a strategy for teaching mechatronic systems generated the integration of the set of knowledge in a transdisciplinary way, a circumstance desired in this discipline, in addition to high motivation of the students participating in the project.

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