Presenting the benefits of Industry 4.0 through agent-based simulation

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Abstract

The innovation in manufacturing processes from the Industry 4.0 concepts opens research gaps in current production models. The objective of this research is to demonstrate, from a comparison between a conventional manufacturing model and a smart manufacturing model, that the implementation of smart manufacturing brings benefits to the production indicators. The adopted method of comparison is the modeling and simulation of a conventional production process and a smart factory process, adopting some functionalities resulting from the Internet of Things and Cyber-Physical Systems. The modeling of both, standard and smart factory were performed through agent-based theory.

Keywords: Industry 4.0, Simulation, Agent modelling

Introduction

The world has been facing several transformations in the last years. The technological basis of these changes are the digitalization of process, products and services. According to (Schwab, 2016) the fourth industrial revolution occurs with the fusion of the physical, digital and biological environments. From the industrial point of view, the combination of the virtual and physical environments has generated the so-called cyber-physical systems (CPS). As a mention of the fourth industrial revolution in the industries, the name industry 4.0 (I4.0) in some countries or advanced manufacturing in another has been coined.

Considering the industry 4.0 or advanced manufacturing advent, the shop floor will change by the fact that the technology is turning the process more autonomous, connected and flexible. The role of the human in this scenario is more dedicated to strategic decisions instead the direct intervention on the production. The technological convergence allows substituting repetitive and handling work by systems capable to take decisions.

From the academic side, it has been observed an increase of works about the subject of I4.0 from 2014 (Kang et al., 2016) leaving the hype behind (Drath and Horch, 2014). The researches encompass all the components and technologies of the I4.0 considering the discussion of concepts and implementation. However, there is a gap considering the comparative methods and gains from the I4.0 approach to the production system.

Since in the smart factory the processes should be autonomous, the agent-based modelling and simulation appears as an important tool in this new factory scenario (Adeyeri et al., 2015), (Zhang et al., 2017), (Kannengiesser and Müller, 2013).

A multi-agent system (MAS) is composed by a net of computational agents that interact and communicate each other. This system emerges and interacts inside its environment, which is not completely defined by formal ways (Monostori et al., 2006). According to Macal and North (2010), a typical structure of a model based on agents has three elements: a group of agents, a set of relation among the agents and the agent environment. The agents interact with the environment and the other agents.

This paper compares the conventional factory and a smart factory considering the MAS modelling and simulation. The aim is to highlight the advantages of implementing a smart factory. All the simulations were carried out using the *Any-Logic* software.

Factory Modelling

The chosen standard factory has a process of welded subsets for the automotive sector. The process is composed by machines and storage elements, which belong to the productive flow from the delivery of blanks to the shipment. Figure 1 presents the process.

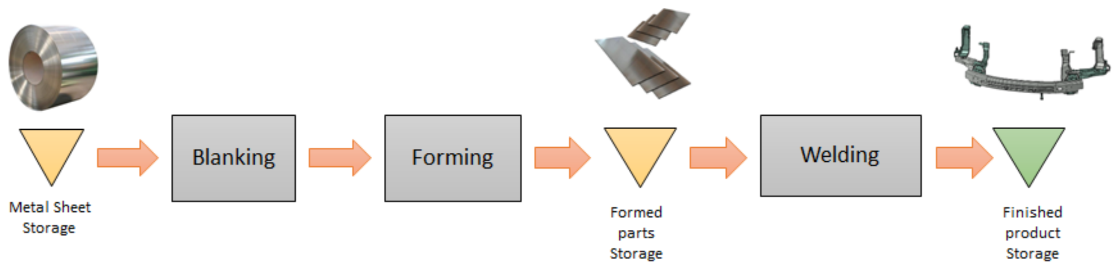

Figure 1 – Process flow

Considering the processes, the *Forming* and *Welding* are the most complex. The modelled *Forming* area is composed by four presses. The *Welding* area is composed by two robotic cells. In the model is assumed that the final subset is composed by eight different formed parts. The presses can work for any of these parts using the correspondent tools. The welding cells are independent and weld the entire subset.

Two simulation scenarios were based on the so called “standard factory” and “smart factory”. In the standard factory, several agents represent the process and the equipment: Press Agent, Tolling Agent, Technicians Tooling Agent, Welding Agent and Maintenance Agent. In the smart factory, the Press Agent and the Welding Agent were modified from inserting IoT sensors and its functionalities. Since the Press Agent and the Welding Agent were modified, these both agents will be presented in details to the standard and the smart factory.

Standard Factory

In the following, the Press Agent and Welding Agent for the Standard Factory are presented.

1) Press Agent: The agent called "Press" (Fig. 2), defines the press machine that performs the cut and forming operations to produce the final part. The press can be in two distinct states: "idle" state and "in operation" state. In the idle state the machine is waiting for a production order. In the "in operation" state the machine is in production of the batch of parts referring to the production order received. However, upon receipt of the production order, the machine must be prepared for the production of the selected product in the production order. This condition is represented by the state "in preparation". After completion of the preparation, the machine is switched to the operating state.

The machine in operation may suffer a malfunction that causes a production stop. The fault can be due to various causes such as wear of some component, misalignment of the machine settings, error in operation, product out of specification or external causes such as power failure. In this situation, the machine stops producing and passes to the state of "in corrective maintenance".

The machine may also have scheduled stops to perform preventive maintenance from a plan of action with tasks such as changing component with wear, cleaning filters, retightening screws and other actions recommended by the manufacturer. In this situation the machine switches to the "preventive maintenance" state. Preventive maintenance waits for the machine to return to the idle condition.

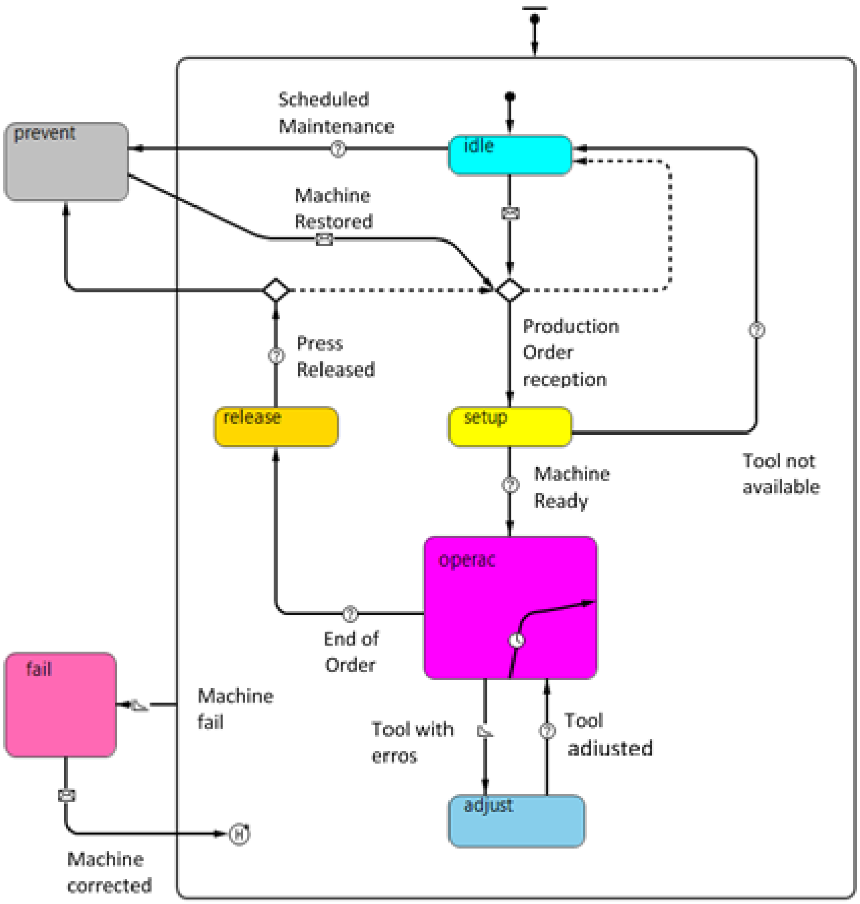

Figure 2 – Press Agent (Standard Factory)

2) Welding Agent*:* The agent called "Welding" (Fig. 3) defines the robotic welding cell that performs the assembly of sets from the formed parts. The welding cell can be in two distinct states: "idle" state and "in operation" state. In the "idle" state the welding cell is stopped waiting for the production order and the arrival of the stamped parts for the formation of welded assemblies. In the "operation" state the welding cell is in production of the batch of welded assemblies referring to the production order received.

The welding cell may have stops due to problems or failures that require maintenance staff to perform repairs and adjustments. Periodic preventive maintenance is programmed from an action plan with tasks such as wear-and-tear component replacement, robot and welding machine overhaul, area cleaning, screw reattachment, and other actions recommended by the manufacturer. In this situation, the machine moves to the state "preventive".

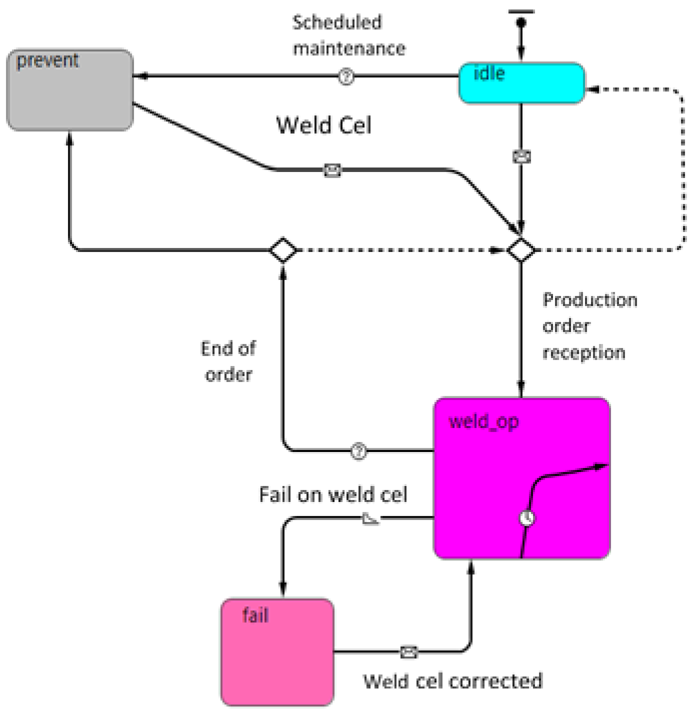

Figure 3 – Welding Agent (Standard Factory)

Smart Factory

In the modelling of the Smart factory the previous modelling of the Conventional Factory was used as starting point. The proposal is to add some I4.0 features to the previous agents' environments and behaviors.

We consider the agents defined in conventional manufacturing modelling with the incorporation of I4.0 functionalities such as IoT and CPS in their environments and behaviors. Presses, such as machines, will be constantly being monitored through their sensors connected through communication and will have their digital model constantly updated. The data collected will be being processed and so its behavior can be predicted through machine learning logic. In this way it can be foreseen when a predictive maintenance must be made with foreseeable anticipation allowing the advance purchase of parts and pieces. By sensing the structure of the press, it is possible to evaluate problems in the columns of the press, lubrication, trepidation, and other factors that can lead to damages that cause the stop.

The constantly monitored robotic welding cell will have the cell's digital control system informing the quality of the solder being performed, predicting the lack of inputs, predicting robot behavior and welding machine for optimum problem correction, and quality control of the welded assembly to determine deviations trends so that it corrects without the need to stop the cell.

In the agent called "Smart Press" (Fig. 4) two new functionalities were inserted to improve the performance of the presses. The first one consists of changing the state of operation. In this operation state there are two possibilities: the "normal" state where the product is inside the tolerances and the "attention" state where the product is inside the tolerances but there is a tendency of deviation and the system performs the self-adjustment without stopping the production. The second one consists in the advanced production planning system that monitors the next production orders aiming at anticipating some executions in the press without changing tools.

In the agent called "Smart Welding" (Fig. 5) one change was inserted to improve the performance. In the welding operation state, two new internal states were included. The first one is the "normal" operation where the cell is operating properly, and the second one is the "attention" state where there is a deviation from the normal operation with a trial of automatic correction.

It is important to mention that all the states included in the previous agents are possible to achieve by the inclusion of IoT sensors as well as the use of big data and machine learning to improve the decisions and actions on these manufacturing components.

Chosen Results

After simulating both, the standard and smart factory, using agent theory it was possible to notice the gains in production. Figure 6 presents this comparison between the standard and smart factory in a daily production.

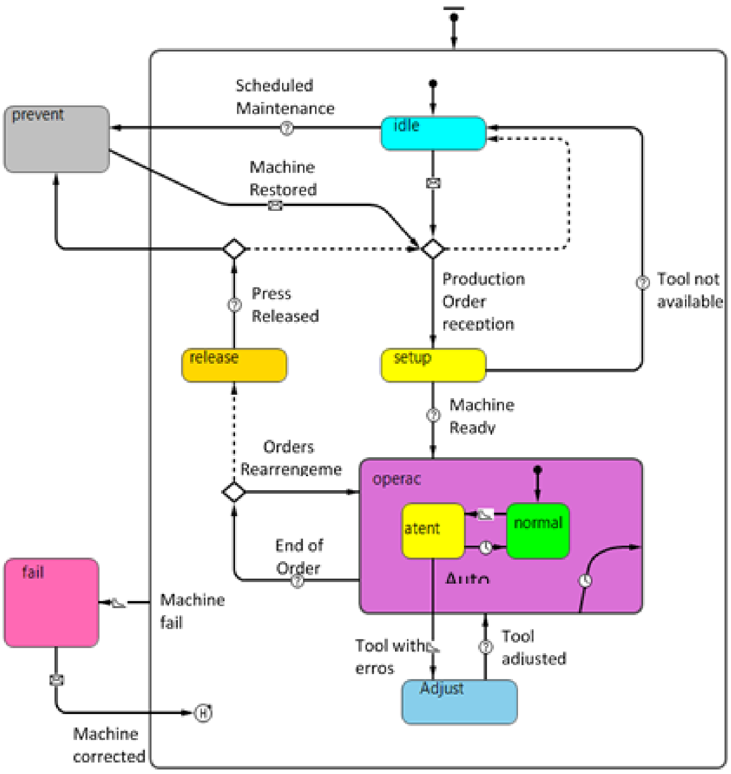

Figure 4– Press Agent (Smart Factory)

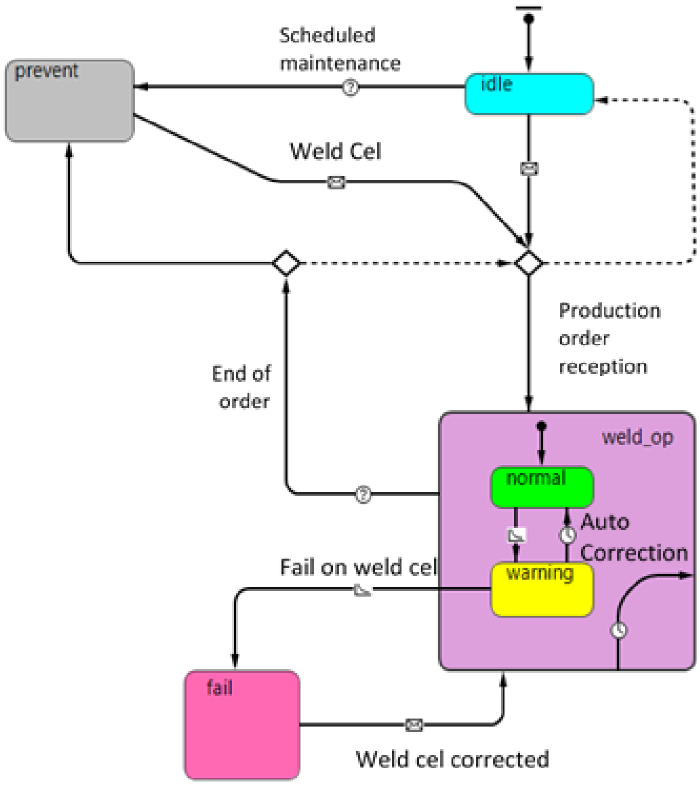

Figure 5 – Welding Agent (Smart Factory)

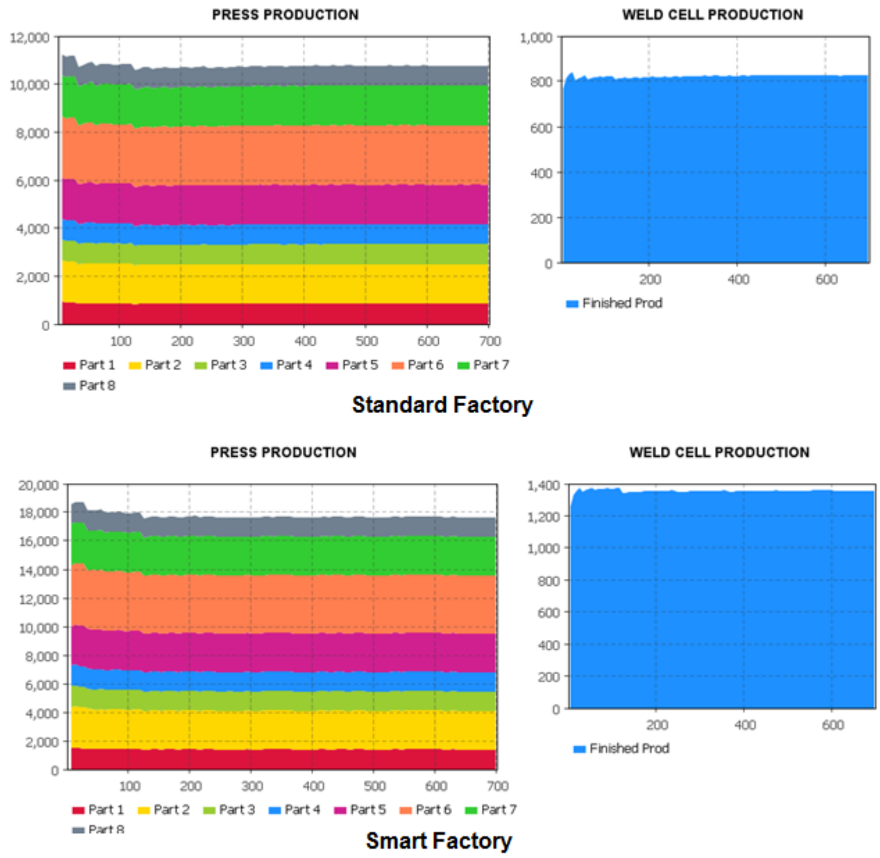

Figure 6 – Daily production level

Conclusions

The results demonstrate the differences between the conventional factory and the smart factory production. These differences highlight the benefits that the smart factory provides. The work demonstrates that some small process changes based on technologies derived from Industry 4.0, lead to a significant increase in productivity. The main concept used in the simulation was the use of intelligent sensors for monitoring and control of the processes. In production planning, the use of advanced production planning system that uses the product information being produced can be achieved from the proposed modelling. Moreover, the use of the agent-based modelling and simulation fits the industry 4.0 requirements.

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