# Industrial Internet of Things and Big Data Techniques for the Smart Press Shop 4.0 Development in Automotive Industry

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**Abstract.** In recent years, one of the main challenges in industry has been to obtain work parameters in real time for later analysis to understand the process better. The purpose is to obtain substantial information about the process for better decision-making and to find out what happens during manufacturing to know both the state of the equipment and the product, looking for savings in maintenance costs and quality controls among others. This has not been an exception for the automotive industry. These challenges have been associated with the concept of Industry 4.0, specifically with Big Data and IIoT (Industrial Internet of Things) techniques. Following this concept, many of the companies and research teams develop their algorithms and ideas based on the installation of new sensors without taking into account the implications that this proposal has in real factories. The cost of the sensor, the installation setup, maintenance, machine modifications and replication for hundreds of machines make many of the ideas fail when innovation is implemented in the companies. For that reason, in our previous work we have introduced a novel concept in Industry 4.0, the development of algorithms by using exclusively the information that is available in the equipment. Machines, as well as presses and general automated systems, include sensors for their automated normal production. These sensors are installed and the information they provide is almost free. Following this philosophy, the present paper proposes the Criterion-360 for real press shops. With this criterion, it is possible to measure a lot of variables with no cost, not only the tonnage, but also, many variables such as the press speed, Counterbalance and overload pressure, Cushion Pressure & Position, lubrication, etc., and therefore with this amount of information many possibilities arise. As the new developed system does not need new sensors and additional installation setup, it is easy and cheap to replicate it in other presses and plants.

This article presents two tools that have been developed from the information obtained with this criterion, these tools are currently in operation and have been used to modify work processes and get the press to work in optimal conditions.

## 1. Introduction

It is a fact that the world is increasingly being digitized for the advantages that this entails, in addition to the easy access that there is today to technologies that can make this transition possible. In the technological section and more specifically in that of manufacturing, great benefits can be achieved by applying these technologies of Industry 4.0. It is easy to see this trend with the increase in publications that have been made in recent years [1] regarding the different areas that the manufacturing industry encompasses today. Adopting IoT technologies to improve production quality and reduce downtime by digitalization in manufacturing [2] and combining IoT and Cloud, enable equipment to be adjusted, thus allowing energy consumption to be monitored in real-time and activating service-oriented energy [3] and in addition, production data can also be used to increase the automation of certain crucial activities such as resource allocation and scheduling [4]. In the automotive world this is no exception and two of the great pillars that are pursued with this transition are, on the one hand, obtaining greater knowledge and control over the process that gives us an advantage in decision-making and on the other, it seeks to achieve economic savings by minimizing possible losses that may happen as it is in the case of unexpected stops of the equipment due to breakdowns with the aim of having a plant that improves competitiveness compared to other manufacturers. In the stamping process different techniques are applied to achieve this saving as is the case in modifying the material used, such as using thinner sheets, which results in a reduction of the amount of material used. Also, regarding the use of lighter materials, in which these two factors lead us to a lower weight of the finished chassis of the vehicle. Another process is the use of optimization techniques in the design of both the sheets to be cut and the final part in order to reduce the amount of material that can be discarded in the stamping process. In this paper we are going to show two tools developed that we put into operation in the Press Shop of Ford Valencia which has allowed us to obtain new information about the process and the advantages that this entails, therefore continuing with the purpose of digitization pursued by the company but also ensuring a reduction in costs. Here is where the real challenge lies, since on many occasions there are very promising projects or improvement proposals but due to the high cost involved it is difficult to amortize the investment and therefore the realization of these projects in the industry may not be considered viable.

Since the beginning of the so-called Industry 4.0 this trend is increasingly on the rise and numerous methods of detection, prediction and correction of anomalies have been developed [5] in many processes of all kinds thanks to the connectivity and technology available today. In general, by installing sensors in certain critical parts of a machine we have been able to obtain more information about the process, having the ability to know in real time what is happening and this is very good, but most of these tools are developed in laboratories in specific equipment that works very well so the problem comes when trying to apply these solutions to the real industry and this is caused by several factors. The first issue is the cost and return time of these systems, since it is a new technology with high cost, that is why from the clients' point of view this return is not considered profitable. The second issue is the behaviour of certain equipment in real production that sometimes differs from that tested in laboratories or previous tests carried out so that sometimes you can obtain biased or even erroneous information of the process under the appearance of false negatives and the third issue is the difficulty of implementing this whole system in the large number of devices that can be found in a factory such as Ford. For example, we may have a solution that could be applied to find errors in gears by vibration but when we try to apply this to the large number of gears that we can have in the factory and the complexity of the installation needed, the cost may increase prices that the company will hardly accept. To this we must add the bad situation the automotive world is going through today where the cost savings go in parallel with the modernization of the plants in order to be more competitive against rivals and therefore the development of these systems becomes more complex.

This paper is divided into 4 sections, in the following section we will explain the work done previously and how the tool that allows us to digitize information from the stamping process has been developed. The monitored process variables and examples of these data will be shown in section 3 and finally the tools developed from the information obtained and the conclusions will be described in section 4 and 5.

## 2. Previous Work

Under the need to obtain process information to be able to anticipate breakdowns and unexpected stops during production, the Mini-Terms standard has been implemented in Ford Valencia in order to get information directly from the equipment to be monitored. As an initial hypothesis, it is proposed that the later a mechanical element performs the action in the process, the closer a fault is to appearing in that component. We have found behaviour patterns that validated this hypothesis in sub-elements of the work cells such as a hydraulic cylinder that actuates the movement of a welding clamp, or the movement time of a claw that is assembling a part of the chassis. We have been able to validate that a change in trend with positive slope in the operating time of the equipment indicated a wear in it and shortly after a breakdown happened. To date, the standard has been extended throughout the entire factory and there are already more than $25,000$ items monitored with the Miniterms system.

The main objective of the Miniterms philosophy is to obtain the maximum possible information available in industrial equipment. This means that information is obtained from the sensors already found in the equipment, without the need to install new ones. We can take advantage of the existing communication of these sensors to extract the information from the PLC and store it in a database, and thus have access to them later. From this, we have found out new possibilities in which tools can be developed to provide additional and more detailed information about the process. Therefore, with the new paradigm of Mini-terms [6] developed by the co-authors of this paper at Ford plant where the time of action of subcomponents in the different assembly plants has been measured, we have been able to understand in more detail the operation of the majority of the equipment. We have therefore been able to predict a large number of faults and reduce repair and maintenance work since the system is in operation [7]. To be able to obtain this information from any PLC and make this system easy to implement in other plants, we have standardised the routines created for programming the PLC. Therefore, from now on the data available in the PLC can be extracted and stored in a database which can be accessed from any device with an internet connection, something that we had not been able to obtain until the implementation of this tool was carried out. This has given a great power of analysis to the staff at the time of addressing a breakdown or performing a maintenance task.

In the stamping plant the same need arises since the monitoring parameters of the stamping process do not follow the same pattern as in the processes followed in the assembly plant. This is because unexpected stops and equipment failures are caused by different reasons than those taking into account the initial hypothesis of the Mini-Terms. It should be clarified that there is equipment in the stamping process which does not directly affect the result of the process and therefore we have been able to know its status through the Mini-terms standard, this equipment is currently implemented and monitored on the platform. Examples of this type of equipment are: the actuation time of the brake and the clutch of the presses, the die fasteners and, if any, the automatic tables for changing the dies. But the scope sought in this case is to understand what happens during the stamping process both in the press and in the die at the time of performing the stamping process. Thus, we will be able to anticipate major breakdowns and also predict whether we will manufacture the parts that may be below quality standards and may be classified as scrap during the production process.

For this purpose, the so-called Criterion 360 has been developed based on the Mini-Terms standard. The initial approach is to obtain a value from the sensors installed in a press and available in the PLC for each position of the press cycle. It is known that, in a press cycle, the position of the movable part referred to as slide, where we have the upper die tied, is defined between a range from 0 to 359 depending on the rotational position of the main shaft of the eccentric gear motion transmission system. By implementing a routine designed from Mini-terms in the PLCs of the presses in order to obtain 360 data per cycle, we have been able to monitor a large amount of process information and subsequently store it on the servers. In the next point we will describe the digitized variables and show several examples of the visualization of the data that are stored on the server.

## 3. Data available through Criterion 360

More than 40 different types of variables are involved in the stamping process. The ideal would be to be able to digitize them all in real time but with the technology we have at our disposal today this becomes a very complex challenge. In the future the vast majority of these variables, if not all, may be able to be measured in real time. So far, the working parameters shown in the following table are being obtained from the PLC of a factory plant press.

**Table 1.** Monitored variables of a stamping press.

| Process Value | Sensors qty. | Units | Criteria |
|---|---|---|---|
| Tonnage Force | 4 | Tm | 360 |
| Cushion Cylinder Pressure | 8 | bar | 360 |
| Cushion Cylinder Position | 2 | mm | 360 |
| Counterbalance Pressue | 1 | bar | 360 |
| Overload Pressure | 2 | bar | 360 |
| Energy consumpion | 1 | W/h | 360 |
| Clutch activation time | 1 | ms | Miniterm |
| Brake activation time | 1 | ms | Miniterm |
| Slide Position | 1 | mm | Miniterm |
| Pres speed | 1 | hit/min | Miniterm |
| Die clamp travelling time | 12 | ms | Miniterm |
| Lubrication mapping* | 1 | l/s | - |

In addition to this information we also have the properties of the coil provided by the supplier with their respective tolerances, such as thickness, minimum and maximum yield, the minimum % of stretch, the min R and the type of material, among others. Another important information of the process and considered as a critical variable is the mapping* of the amount of oil for the blanks, we have found out this information directly from the pc of the Coil-Fed Lubricant Brush Washer. The great advantage of the data collection system presented is that it allows us to have a large amount of free information in each cycle and thus being able to store up to 5400 data per cycle, that is, every 8-10 seconds in which the acquisition of the data is done in about 4 seconds and the sending of the packets to the servers is done during the idle operation.

With the large amount of information available to us, new opportunities have arisen for development and creation of tools that allow us to achieve the requirements pursued by the company through the digital transformation. An example is the web tool developed for the visualization and analysis of information in real time from any device of the company, where we can check the process variables mentioned in table 1. In the figures shown below two signals obtained from the press can be seen. The first one is from a tonnage sensor, where we can see the force applied by the press in a cycle, and the second is the pressure sensor of the cylinder of a press cushion, where we can see the force exerted by the drawbed to control the material flow inside the die.

In the next section we will explain two of the tools that have been developed taking advantage of the amount of data that we have at our disposal which allow us to have a greater knowledge of the process and obtain an improvement of both the equipment health and savings.

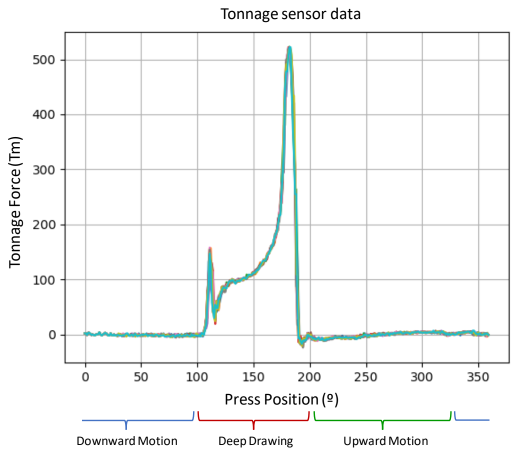


**Figure 1.** Tonnage data for 1 cycle.

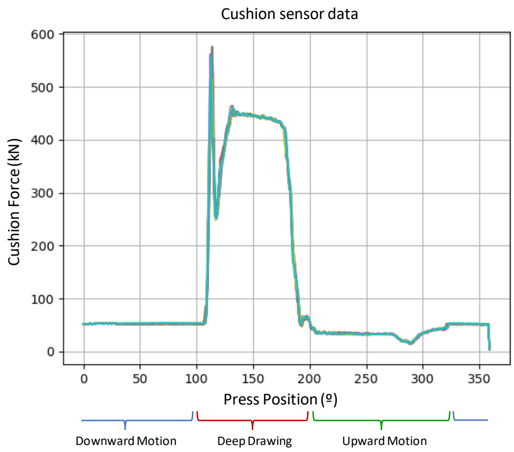


**Figure 2.** Cushion data for 1 cycle.

## 4. Developed tool and real cases

Of the tools developed, the first one to be presented allows to know the state of the stroke during the stamping process [8]. This tool is developed under the need to know the state of the different mechanical elements that make up the kinematic drive system of the press. With the passage of time the mechanical elements may deteriorate, such as for example the lower part of the connecting rod, the gears of the eccentric system or even cracks may appear in the structure of the press. If these faults are not detected, the press will work under unfavourable conditions and this may trigger a major breakdown. This type of damage has a great economic impact for the company. So, it is important to anticipate the fault or adjust the press when it is working in forced conditions in order to prevent this type of breakdown from happening. Apart from the major faults, we may find other problems such as press slide unbalance which may affect the wear of the die surface and therefore the quality of the manufactured part.

To have greater control over the process and avoid what has just been discussed in the previous paragraph the Gravity Centre Monitoring tool has been developed with which the value of the gravity centre of the slide can be monitored for each press position within a cycle. The theory states that the more centred the gravity centre of a press is during a work cycle, the better it will work. Therefore, by monitoring this parameter we are able to find out when it begins to unbalance or even detect anomalies in operation with the amount of information available.

We have been able to get this information from the data of the tonnage sensors that we have available in the press where this tool has been developed. With the monitoring of the tonnage data we can find out the gravity centre of the slide in each cycle, where we obtain 360 values of each sensor, calculating the gravity centre for each of the 360 data obtained we have,

$$GC_j = \frac{\sum T_i D_i}{\sum T_i}, \quad i = 1, \ldots, 4, \quad j = 0, \ldots, 359. \tag{1}$$

With $T$ being the value of the tonnage of each sensor and $D$ the distance from the point of the forces to the centre of the slide. Under the hypothesis of the more centred the stroke, the better the health of the press, some restrictions have been defined for the working limit of the press which are provided by the manufacturer, therefore being able to identify when there are work values outside what is defined as normal. Several tests have been performed to verify that the developed tool works correctly. By forcing the unevenness between the corners of the slide with values between 1 and 2 mm of difference, we were able to check that the system can detect this imbalance. The test was successful and the tool was implemented in production including an alarm system that reports when work patterns happen outside the desired conditions. With the system in production, we have detected different real cases of parts in which the press was working under overstress conditions. By making the appropriate adjustments, we have reduced the overstress and ensured the correct functioning of the equipment.

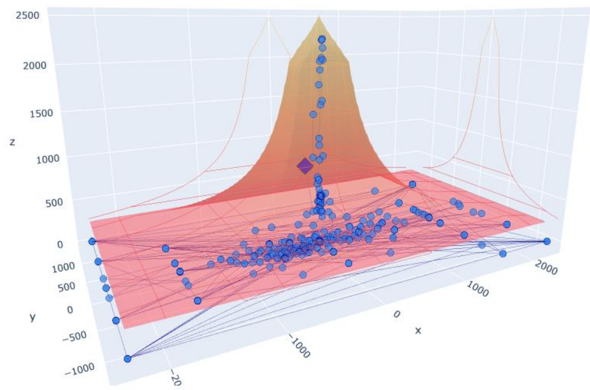


**Figure 3.** Gravity Center 1 Cylce.

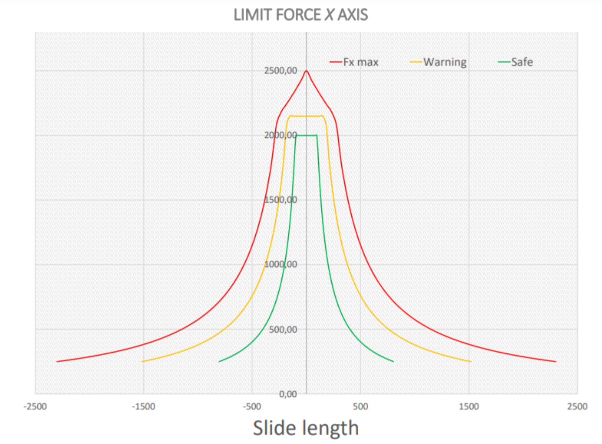


**Figure 4.** Gravity Center Limits Monitoring

In figure 3 we can see the calculated values of the gravity centre with the data obtained from the tonnage sensors for each of the positions of a cycle. In figure 4 we can see the safety limits defined to classify the alarms. Depending on the type of level exceeded by the value of gravity centre and the number of repetitions found, we can decide when to track and review what is happening in the equipment or intervene in it.

Continuing with the premise of developing new tools that cover the needs demanded by the process, an automatic adjustment of parameters is proposed to ensure the minimum consumption carried out by the company. This tool [9] has given us the following advantages. Energy efficiency: optimizing consumption by modifying the working parameters of the press. Improving sustainability in manufacturing: reducing consumption contributes to reducing the company's carbon footprint and therefore, achieving a reduction in polluting emissions and contributing to a sustainable future. And also, increasing the competitiveness of the company: with the savings obtained they can become more competitive compared to other manufacturers in the market. Background information indicates that a reduction in energy can be obtained by the press through the modification of working parameters such as pressure compensation and slide adjustment. An in-depth study of the behaviour of the consumption of the electric motor is carried out with respect to the change of the values of these parameters without affecting the quality of the material. A common denominator is observed, that is, for a certain weight of the upper die there is a non-linear relationship for the value of the compensation to be configured provided by the manufacturer that does not adjust to the day-to-day in plant since, as production progresses, each technician responsible for the line performs his/her own adjustment procedure for a problem that has been developing over time and thus taking into account his/her experience acquired. This affects both the compensation and many other parameters that are modified through tests in order to carry out a production according to demand. Another factor difficult to control that was discovered at the time of the study is that there are presses with compensation pressure values above the value advised by the manufacturer, which is different to the value that ensures a minimum consumption of the press. This is mainly due to the existence of small leaks in the pneumatic circuit, where a higher pressure is required to ensure the optimal work in raising the slide within the press cycle, resulting in minimum consumption. After carrying out this, a pattern is obtained that is repeated in all the dies regardless of their weight. And it has a similar consumption curve with a minimum point for a specific compensation pressure value. This can be extrapolated to the different items from the study carried out with the equation obtained that describes the pattern we have just defined. Therefore, a polynomial approximation of the behaviour of the measured electrical consumption of the engine has been made,

$$p(x) = a_0 + a_1x + a_2x^2 + \ldots + a_nx^n. \tag{2}$$

Where the function obtained $p(x)$ is an approximation to the real function $f(x)$ of the consumption made by the press, thus $p(x) \simeq f(x)$. And to find the minimum point within our function automatically we use the expression of the gradient descent,

$$x_{n+1} = x_n - \alpha \nabla f(x_n). \tag{3}$$

In this way we are able to find the proper working value of the compensation pressure to ensure a minimum consumption by the main motor of a press during production, ensuring its optimal operation.

These are two tools developed by the potential of obtaining the amount of information from the Criterion 360 presented in this article. They are currently operating in a press at Ford factory and are giving good results since working parameters have been modified under certain unfavourable conditions found thanks to these systems.

## 5. Conclusions

In this article we have seen how we are able to obtain a large amount of information from the process and store a large amount of data for analysis without the need to make a large economic investment and therefore, improving the knowledge of the process and decision making. Following the philosophy of Miniterms developed in the factory years ago makes it possible to obtain great results by using Industry 4.0 techniques, meeting the needs of a large company such as the Ford factory in Valencia, improving its efficiency, reducing costs and being able to manufacture better products. It can also help the company stay competitive in a rapidly changing market.

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