KES Transactions on Sustainable Design and Manufacturing II
Sustainable Design and Manufacturing 2015 : pp.269-276 : Paper sdm15-065

Recommendations for Sustainability in Production from a Machine-Tool Manufacturer

Javier Diaz[1], Jorge Posada[2], Iñigo Barandiaran[2], Carlos Toro[2]

[1]IKERGUNE AIE, Elgoibar, 20870, Spain
jdiaz@ikergune.com
[2]Vicomtech-Ik4, San Sebastian, 20009, Spain

Abstract *Recently, a paradigm called Industry 4.0 has brought important concepts that can contribute to environmental, economic and societal sustainability. Technologies like cyber-physical systems, cloud computing or visual analytics may be linked to bring transparency to industry increasing sustainability. However, to implement those technologies in machines and factories shop floors, some important subjects like sensor technologies, data gathering systems, virtual simulation or human factor have to be outlined. As a result of an initiative towards Industry 4.0, use examples of the abovementioned subjects, based on analysis over relevant industrial companies, have brought up difficulties related with the possibilities to implement the appropriate infrastructure to push in the so-called industry paradigm shift. As preliminary result of this initiatives, recommendations based on Etxe-Tar own experience, are given in order to get a clear view of the opportunities to achieve an optimum implementation of Industry 4.0 technologies and enable sustainable process.*

1. Introduction

Sustainability has become a key aspect in nowadays sustainability has become a key aspect in the industrial sector. In order to decrease the environmental impact, improve business profitability and comply with local government regulations a reported need is found. In fact, as reported by the U.S. Department of Energy [1], if the worldwide energy consumption between end-use sectors and the industrial sector, the latest has the largest, with 51% of share. Essentially, 25% of this energy usage is due to energy losses. Oppositely, the next largest energy consumer, transportation sector, has 20% of share; nonetheless, the energy losses are around 2%.

Accordingly, industrial sector has begun to assume the need of a paradigm shift towards a factory of the future, where adaptation capabilities and sustainability will be value drivers [2]. This change can be seen in some smart machines, warehousing systems and production facilities that have been developed digitally and feature end-to-end ICT-based integration [2] [3]. Additionally, as explain by Brettel *et al.* [4] integrated engineering along the entire value chain using advanced methods of communication and virtualization promises significant optimization potential.

As a result, this digitalization can be translated as an increase of sustainability, where energy usage is more efficient, economy grows bringing its associated effects on employment, and more cost-effective business [4]. Currently, this progression is supported by concepts like Industry 4.0. Accordingly, Kagermann, *et al.* [2] explains that the beginning of the fourth industrial revolution has been stablished when Internet of Things and Services has been introduced into the actual manufacturing environments. The introduction of these internet-based technologies have supported the shaping of the Cyber-Physical Systems (CPS), where products efficiently control their own modular manufacturing systems [5]. In the other hand, Industry 4.0 promotes a vertical integration of factory floor, PLCs, SCADA/HMI, MES and ERP levels [7] supported in cloud-based technologies giving capabilities of distributed analysis and high level CPS.

Following the initiative of Industry 4.0, Etxe-Tar as a worldwide actor of high-end machine-tools manufacturer for the automobile industry, has understood that Industry 4.0 could be an important instrument to trigger sustainable manufacturing. As a result, this paper presents a list of example cases and recommendations, based on Etxe-Tar own experiences, to achieve sustainable products and processes through the development and implementation of Industry 4.0 concepts. Therefore, this paper will explain in section 2 the link between Industry 4.0 and sustainability, then in section 3 case examples implementation are shown, in section 4, recommendations for implementation are listed, and finally in section 5, the conclusion.

2. Background: Sustainability and Industry 4.0

The fourth industrial revolution or Industry 4.0 is called to pull applications and push technologies enabling a high degree of sustainability needed in the factories of the future [5] [6]. Since the abovementioned technologies and applications are aimed towards producing goods with zero emissions, zero defects, increase process flexibility and demand highly skilled and educated employees, the impact over sustainability can be expected on its three pillars: social, economics and environment. Additionally, as explained by Kagermann *et al.* [2], Industry 4.0 solves today challenges related with resources and energy efficiency, urban production and demographic change, enabling continuous resource productivity and efficiency.

One of the main pushed technologies are Internet-based, i.e. Internet of Things and Internet of Services, favoured by new developments in computational power, leading to cloud computing and services. This technologies have the potential to give rise to a new generation of service-based industrial systems whose functionalities reside on-device and in-cloud [7]. However, in order to succeed developing these technologies and applications, talented personnel, comprehensive IT infrastructure, economic strength and enlightened manufacturers will be needed [8], closing the loop for sustainable production systems.

Regarding this strong relation with sustainability, Kemper *et al.* [5] describes Industry 4.0 as a collection of following seven concepts: smart factories, cyber-physical systems, self-organization, new systems in distribution and procurement, new systems in the development of products and services, adaptation to human needs and corporate social responsibility.

Herrmann *et al.* [7] states that one characteristic of an Industry 4.0 factory is its ability to foresee future products and to respond to the variety and complexity intensification with low cost and low environmental impact. Additionally, it has the capability to bring transparency to the process, applying prognostics and health management methodologies. PHM techniques have been successfully apply to achieve just-in-time maintenance and can give self-aware, self-predict, and self-configure (self-x) capabilities the machines [8]. Thus, high profitability and minimal consumption of resources within the production system can be adopted by a high machine utilization.

In Spain, as an example of this trend, Etxe-Tar has started to lead an Industry 4.0 initiative at national and regional level. In order to develop different key enabling technologies towards the smart machine concept some initial efforts have been made and although incipient, the permeability towards other industries has been shown as feasible and interesting. Among the different initiatives pushed the Basque Government has financed an initiative named Thinking Factory. It has the aim of creating the first step to harness the information found in a production plant through the deployment of an integrated platform of interconnected elements and developing a Cyber-Physical Production System or CPPS. The platform will be integrated in different stages.

3. Case Examples of the implementation of I4.0 in the context of a research project

As stated before, Thinking Factory, being the first realistic effort in Spain of the implementation of Industry 4.0, several stages are being carried out. During the first part of the project, the following case studies have being detected:

a) It has been found that during normal operation some sensors that are equipped into the machines are turned off. For example, a related company manufactures its machines with lot of sensors to check temperatures, forces, pressures and torque, directly related with energy consumption of the machine. However, these sensors are only used at production start-up due to its high complexity, where every part of the process has to be controlled. Nevertheless, when the machine goes to real production, the only process sensor that is left active is load sensor; part of a critical step that is needed for traceability, the other 38 sensors are off or not used (i.e. secondary forces, screw pre-tightening and tightening torques, screw tightening angles, etc).

b) Inside modern machines, many analogical sensors perform as digital, sending only alarms to the numeric control. As an example to this, there has been found in an Etxe-Tar machine model, that the coolant fluid thermocouple is analogical, thus, it only sends an alarm of over-temperature to the system, leaving the temperature curve out of the system and hence performing as a digital device.

c) Machine actuators and drivers can actually detect real-time information like power consumption. Moreover, some of this information is used to affect the machine control, for example jerk, which is useful for positioning. However, in a related company, real-time information is not kept inside a data logger, then, trends over time are not available for further analysis.

d) The misalignment between real operation and digital factory models are very relevant in terms of energy saving and can cost money. In a related company with 13.000 m^2 of factory plant, approximately a 40% of the compress air supply (extensive energy consumer) comes from machining department. That information was logged into a database, however, no data analysis system inside the digital model was used to evaluate it. That problem was detected on later physical analyses.

e) Virtual simulation can help to fine-tune the process parameters before real processes, saving raw material, energy and time [6]. In this case, Etxe-Tar has a localized heat treatment system for crankshafts that can be simulated before real process takes place. Using the virtual system, complete parameters can be selected and optimized prior to work over a crankshaft that can cost around 3.000€. A typical crankshaft cycle is 60/hour, which translates in 180.000€/hour.

f) High skilled people is leaving the companies due to age or over qualification. Many related companies are having this problem regarding the over qualification of the workforce, demanding more high added value employment.

4. Recommendations for the implementation of feasible solutions to the afore mentioned phenomena

a) Industry 4.0 is not about putting more sensors inside a machine. As it has been seen, there are machines that are already designed with the appropriate sensors. Those sensors can be useful to have a complete overview and depth understanding of the machine during production, hence, energy consumption and cost-effective process can be analysed. Consequently, having a deployed sensing infrastructure in the machines/plants, it is important to implement best practices in order to keep sensors working during production instead of switching them off.

b) The usage of analogic systems where the evolution of the measured variable is critical, because it is important to give relevant information to the control systems. Therefore, in order to prepare the machine sensors to be compatible with Industry 4.0, a migration from digital alarm signal to analogical data sensor technologies is needed. Because the higher costs of analogical systems, a previous study of relevant sensors has to be made. As a result, having the information over time, allows earlier failure detections, reducing costs and energy loses.

c) Data logging of information over time is important in order to analyse trends and cross-match variables in order to detect related effects. For example, the work piece temperature can be linked with coolant flow rate, enabling the possibility to give the optimal coolant flow rate depending on the workpiece. This will help to optimise coolant consumption and reduce energy consumption. However, data loggers have to be able to sniff large amount of data (synchronous and asynchronous) from field bus and dump it into a database.

d) A complex manufacturing line from a reference company can produce near 20 TB per year of data. Generalising to the complete factory the amount of data is becoming unmanageable. That means, that powerful data analysis techniques like big data, data mining, visual analytics and technologies like cloud computing has to be implemented in order to have a complete factory outline. The use of these technologies will allow to monitor and analyse factory performance in terms of resources consumption and productivity.

e) As explained by Industry 4.0, inside the cyber-physical systems, the cyber part is perfectly matched by the virtual simulation. At present, computing technologies are able to give useful processes simulations in order to increase processes sustainability. As with thermal process simulated in Etxe-Tar, these technologies can be applied to other complex manufacturing processes like machining and other physical or chemical processes. In fact, virtual prototypes can help to reduce the need of test beds, pilot plants or prototypes but also, it can help to reduce time-to-market needs for the individualization on demand explained by Industry 4.0.

f) The social aspect of Industry 4.0 relays in the concept of humans as the central aspect of future factories. In this scenario, these factories will need highly skilled and trained people with the capability to make decisions based on information flows through the manufacturing plant. It is important to note, that at the moment, an employee and not a machine must always take most critical decisions. This situation will help to bring back highly skilled workforce.

The aforementioned recommendations are summarised in the next table:

Recommendations	**CPS**	**BIG DATA**	**CLOUD**	**DATA MINING**	**VISUAL ANALYTICS**	**HUMAN FACTOR**
To activate sensors	X	X				
To convert alarm to analogical sensors	X	X				
To implement data logger	X	X	X	X	X	
To implement data analysis techniques		X	X	X	X	
To develop virtual simulation	X				X	
To bring high-skilled people					X	X

Table 1. Recommendations vs. Industry 4.0 Critical Aspects

At the moment, many of these recommendations are being implemented and applied inside Thinking Factory project's companies.

4. Conclusions

The main conclusion of this paper is that the fourth industrial revolution can have an important role inside factories sustainability, however, there are important aspects that have to be taken into account at machine and factory level in order to enable its possibilities. Those aspects are related to the machines and factories real life, where the only premise is to have a profitable business.

The case examples explained in this paper bring up the industry reality towards industry 4.0 concepts. As seen, it is expected that manufacturing systems will experience real problems during first basic steps of implementation like data gathering or communications, fundamental for smart systems. Issues with incompatibilities, process stability and robustness will arise. However, the abovementioned recommendations to use already deployed sensor architectures, to implement more advanced sensors for relevant variables, to implement data loggers, to work with data analysis techniques, to use virtual simulation, and bring high-skilled workforce to the companies can help the industry sector to accelerate the upgrading.

However, it is understandable that an industrial paradigm shift will be a long term challenge for factories and machine manufacturers, nevertheless, it will be a powerful tool to pull technologies like CPS, Big Data, Cloud Computing, Data Mining, and Visual Analytics to come to the factory shop floor as this paper has shown.

Therefore, if the initial problems are solved and the technologies are bring closer to the industry, the fourth industrial revolution will start bringing economic, environmental and social sustainability. Nonetheless, the recommendations are being applied, the efforts and initiatives will continue towards the techniques and technologies expressed under the umbrella of Industry 4.0.

References

[1] U.S. Department of Energy, "eia - How much energy is consumed in the world by each sector?," 7 January 2015. [Online]. Available: http://goo.gl/U3Ccql.

[2] H. Kagermann, W. Wahlster y J. Helbig, «Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative INDUSTRIE 4.0,» National Academy of Science and Engineering (ACATECH), 2013.

[3] S. Karnouskos, A. W. Colombo, J. L. Martinez Lastra y C. Popescu, «Towards the Energy Efficient Future Factory,» *7th IEEE international conference on industrial informatics,* p. 367–371, 2009.

[4] M. Brettel, N. Friederichsen, M. Keller y M. Rosenberg, «How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective,» *International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering ,* vol. 8, nº 1, pp. 37-44, 2014.

[5] H. Kagermann, «Change Through Digitazation - Value Creation in the Age of Industry 4.0,» de *Management of Permanent Change*, Wiesbaden, Springer Fachmedien, 2015, pp. 23-45.

[6] H. Lasi, P. F. Privatdozent, H. G. Kemper, T. Feld y M. Hoffmann, «Industry 4.0,» *Business & Information Systems Engineering ,* vol. 6, nº 4, pp. 239-242, 2014.

[7] L. Gide, «Key Aspects of the European Strategic Research and Innovation Agenda,» de *Industrial Cloud-Based Cybre-Physical Systems*, New York, Springer, 2014, pp. vii-viii.

[8] S. Karnouskos, A. W. Colombo y T. Bangemann, «Trends and Challenges for Cloud-Based Industrial Cyber-Physical Systems,» de *Industrial Cloud-Based Cyber-Physical Systems*, London, Springer, 2014, pp. 231-240.

[9] Ö. S. Ganiyusufoglu, «Chinese Approach to Sustainable Manufacturing,» de *11th Global Conference on Sustainable Manufacturing - Innovative Solutions*, Berlin, 2013.

[10] C. Herrmann, C. Schmidt, D. Kurle, S. Blume y S. Thiede, «Sustainability in Manufacturing and Factories of the Future,» *INTERNATIONAL JOURNAL OF PRECISION ENGINEERING AND MANUFACTURING-GREEN TECHNOLOGY,* vol. 1, nº 4, pp. 283-292, 2014.

[11] J. Lee, B. Bagheri y H. A. Kao, «Cyber-Integrated Big Data Analytics Agent for Industry 4.0 Applications,» de *Agenten im Umfeld von Industrie 4.0*, Munich, 2014.

[12] J. Posada, C. Toro , I. Barandiaran, D. Stricker, R. de Amicis, E. B. Pinto, P. Eisert, J. Döllner y I. Vallarino, «Visual Computing as Key Enabling Technology for Industry 4.0 & Industrial Internet,» *To Appear in Journal of Computer Graphics and Applications (CG&A),* pp. 50-64, 2015.