Chapter 21
Digital Twin-Driven Condition-Based Maintenance

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EXECUTIVE SUMMARY

The world is witnessing an all-level digitalization that guides the industry and business to a restructuration in order to adapt to the new requirements of the surrounding environment. That change also concerns the labour of the technical professionals and their formation. As a consequence of this deep consciousness-raising, this chapter will investigate and develop simulation models based on the current digitalization. The aim of this chapter is the exposition of a real case development of "digital twin" models framed as part of the condition-based maintenance paradigm to improve real-time assets operation and maintenance. This model contributes by providing real-time results that could turn into a basis for the industrial management decisions and place them in the Industry 4.0 paradigm environment.

1. INTRODUCTION

Nowadays, the digitalisation is guiding industry and business to a restructuration in order to reach a deeper control of the products and assets in the real physical world. In manufacturing, this leads to a smart factory and a production activity controlled at real time, which enables to reach different benefits, amongst others an improved production efficiency and advanced capabilities to make diagnosis and prognosis, thus minimizing the maintenance times and delays related to equipment unavailability.

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The present work is positioned in this research scope, and proposes the adoption of the Digital Twin concept and the development of a simulation model to monitor the health of a physical asset that, together with a reference framework, represents a key enabler in order to implement multi-disciplinary simulations to improve manufacturing applications. This piece of research comes as the result of a long-term collaboration between the Intelligent Maintenance Systems group at University of Seville and the Manufacturing Group of the School of Management at Politecnico di Milano. In particular, the Digital Twin (DT) concept was applied from both maintenance and operation perspectives in the context of Industry 4.0 Laboratory of Politecnico di Milano, allowing the implementation of the work at laboratory scale, on an edge experimental technological manufacturing environment.

2. TECHNOLOGICAL BACKGROUND

2.1 Industry 4.0

The Industry 4.0 is a well-known concept emerged during the Hannover fair in 2011 (Kagermann, H., 2011), originated from a project within the German government's high-tech strategy focused on the computerisation of manufacturing. The major technical background and challenge (Raj, A., 2020) of Industry 4.0 is the introduction of three main internet technologies – i.e., Internet of Things (IoT), Big data, Cloud computing – into industries in combination with simulation techniques. Big data is a well-known term nowadays, it is used to describe data sets that are so large and complex which are difficult to be analysed using standard statistical software. Therefore, the management and evaluation of comprehensive data from numerous sources and Machine Learning technology, will be an essential part of the Industry 4.0 environment, to support decision-making (Ru¨ßmann, M., 2015). Then, Cloud computing is the essential enabler for data sharing across sites and companies, even across countries. With Industry 4.0, machine data and functionality will increasingly be deployed to the cloud, enabling more data-driven services for production systems. Even systems that monitor and control processes may become cloud based (Ru¨ßmann, M., 2015). Last but not least, the main enabler for the collection and integration of data from different sources is the IoT. IoT is the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data, and providing an Internet-based information architecture facilitating the exchange between physical objects and the virtual representation in information technology (IT) systems. IoT can be categorised as "consumer" IoT, that is human centred, and Industrial IoT (IIoT), that covers the domains of machine-to-machine (M2M) and industrial communication technologies with automation applications, connecting with the information systems and business processes (Boyes, H., 2018). Another important aspect to be defined in the Industry 4.0 environment, is how it changes the role of simulation of systems and processes. The role of simulation changes with the pressure due to the increasing product variety and customization, that require more flexible production systems modelling for a dynamic performance assessment and optimization. Therefore, simulation in the Industry 4.0 environment will leverage real-time data in order to mirror the physical world in a virtual model, allowing operators to test and optimize the machine settings, even in a systemic perspective. The major expression of this new simulation paradigm – run on line, synchronized with the physical system – is embodied by the Digital Twin (DT) concept. It represents the virtual and computerized counterpart of a physical system that can be used for various