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On the Analysis of Effectiveness in a Manufacturing Cell: A Critical Implementation of Existing Approaches

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Abstract

OEE (Overall Equipment Effectiveness) is a widely used indicator in the evaluation of effectiveness of manufacturing systems. However, several authors published alternative approaches for its computation, complicating the implementation step for practitioners. This study analyses the literature regarding OEE, selects four main methodologies for its evaluation and examines the underlying differences between them. A real life case study is analysed to illustrate problems arising during data collection and the differences in results obtained, together with traceable conclusions for improving the performance of production systems, both in traditional and in innovative industrial plants, following Industry 4.0 principles.

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1. Introduction

The development in recent decades towards a global economy and the last global economic recession has intensified the need for manufacturing companies to improve their competitiveness. In order to retain and improve the ability to compete in the market, productivity optimisation has become a central issue, which can be achieved by

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detection and elimination of production losses. In such a context, process measurement and evaluation plays an important role in understanding the current operational performance and in recognising possibilities for improvement (Or 2010).

Overall Equipment Effectiveness (OEE) is a tool for monitoring how manufacturing resources' time is allocated and identifying those margins available for improvement. Specifically, OEE is computed from an initial operational environment and subsequently monitored at regular time intervals, in order to evaluate the existence and effectiveness of upgrades, implemented and consolidated year by year, as suggested by the Total Quality Management (TQM) approach (Kumar et al., 2009). Furthermore, OEE is particularly useful when the production of new items is carried out using existing resources and whose operating conditions are preferably modified as little as possible. As described in Gamberini et al. (2006, 2009a, 2009b), changing the operating conditions of manufacturing resources incurs costs, related to: acquisition of deficient knowledge, execution of new working procedures, execution of new maintenance operations and setting of new workstations. Hence, OEE is a tool for evaluating the future performance of manufacturing resources and comparing them with the initial situation by considering alternative operational scenarios. Specifically, those processes with high standards of quality and throughput are addressed (De Groote 1995). This context is of particular interest for the development of Industry 4.0 principles and for supporting their implementation in real life production environment.

Published contributions on OEE mainly focus on three different research fields. The first describes OEE using different definitions proposed by the various authors. The second addresses using and computing OEE. The third considers the extension of the OEE index, such as by: Sherwin (2000) who proposed Overall Process Effectiveness to measure the performance of entire processes; Oechsner et al. (2003) who proposed a metric for the evaluation of effectiveness of an entire factory; Garza-Reyes et al. (2008) who developed Overall Resource Effectiveness, which considers material efficiency; Braglia et al. (2008) who presented Overall Equipment Effectiveness of a manufacturing line; Ahire and Relkar (2012), who correlated OEE and FMEA approaches, Andersson and Belgran (2015) who combined OEE and productivity analysis as a driver for improvement;

This paper focuses on OEE formulations for singular equipment and particularly on four alternative approaches proposed by Nakajima (1988, 1989), Ames et al. (1995), De Ron and Rooda (2005) and Wauters and Mathot (2007). Their application to the study of effectiveness of an automated productive cell is presented. Specifically, differences emerging during data collection, OEE computation (and particularly during the computation of the component named availability), results analysis and the definition of future actions for improvement are underlined. The topic of problems emerging in OEE data collection and computation is a recent and consistent problem, recently presented also in Hedman et al. (2016), where the aspect of automated collection of data is studied.

The paper is organised as follows. Section 2 presents the alternative aforementioned formulations. In section 3, a real life case study is proposed; specifically, the computation of effectiveness of a manufacturing cell is faced. Section 4 presents a discussion of results and finally, section 5 offers conclusions.

2. Alternative formulations for OEE

In the following, alternative formulations of OEE are presented, by considering those most used in practice (i.e. in automated computation and in multi-criteria approaches, as reported respectively in Singh et al. 2013 and in da Silva et al. 2017) and cited in literature.

2.1. Nakajima (1988, 1989) approach

Nakajima (1988, 1989) gave the pioneer definition of OEE by describing the "six big losses" that are the main causes of idle and/or wasted time. Specifically, the author classifies them as follows: Downtime losses (D_l), due to equipment failure, breakdown, set-up, adjustment; Speed losses (S_l), due to idling, minor stops, reduced speed; Quality losses (Q_l), due to reduced yield, quality defects.

As a consequence, the OEE is computed as described in equations (1)-(8):

$$OEE = A * P * Q \tag{1}$$

where:

$$A = Availability = O_t / L_t \tag{2}$$