Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 57 (2016) 556 – 561

www.elsevier.com/locate/procedia

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

The use of engineering tools and methods in maintenance organisations: mapping the current state in the manufacturing industry

Jon Bokrantz[a]*, Anders Skoogh[a], Torbjörn Ylipää[a]

[a]*Department of Product and Production Development, Chalmers University of Technology, Gothenburg 41296, Sweden*

* Corresponding author. Tel.: +46-706518051. *E-mail address:* jon.bokrantz@chalmers.se

Abstract

Digitalisation is the future of the manufacturing industry, and it will entail production systems that are highly automated, efficient, and flexible. The realisation of such systems will require effective maintenance organisations that adopt engineering approaches, e.g. engineering tools and methods. However, little is known about their actual extent of use in industry. Through a survey study in 70 Swedish manufacturing companies, this study shows to what extent engineering tools and methods are used in maintenance organisations, as well as to what extent companies have maintenance engineers performing work related to engineering tools and methods. Overall, the results indicate a potential for increasing the use of engineering tools and methods in both the operational and the design and development phase. This increase can contribute towards achieving high equipment performance, which is a necessity for the realisation of digital manufacturing.

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

Keywords: Digitalisation, Manufacturing, Maintenance, Tools, Methods

1. Introduction

The manufacturing industry is currently undergoing changes that will shape its future. The reason is digitalisation. Within 20 years, the implementation of the Internet of Things will realise the digitalisation of the manufacturing industry, which is spurring governmental initiatives all over the world. In Germany, this initiative is referred to as "Industrie 4.0", and the American equivalent is known as "Industrial Internet Consortium". The production systems in the digital factories of the future are envisioned as highly automated, flexible, and efficient. Expectations are clearly high, but there is a fundamental prerequisite for the realisation of such systems: the highly complex and automated equipment must deliver high performance. Naturally, maintenance organisations play a key role in fulfilling this prerequisite.

Although digitalisation is a common goal for the manufacturing industry, companies are struggling with low equipment performance. In order to measure equipment performance, Overall Equipment Effectiveness (OEE) has been widely used in industry [1], and OEE figures of 85% are often considered world-class [2]. However, low OEE figures of around 40-60% have been consistently reported during the past two decades [3,4]. Ljungberg [5] presents extensive OEE data with an average of 55%; refers to other studies with similar results, and comments that it "does not seem unusual to have low OEE" (p. 505). Likewise, more recent publications argue that OEE figures are commonly 15-25% below the targeted level, thus constituting one of the largest problems in industry today [6]. Clearly, this situation is incompatible with the prerequisite of high equipment performance in future digital production systems.

To achieve high enough equipment performance in future systems, working towards reduction of all types of equipment losses is essential in every life-cycle stage. However, this work requires engineering approaches within maintenance organisations. One indicator of such approaches is the use of engineering tools and methods, but there is unfortunately a

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2016.11.096

lack of studies showing the actual use of them in industry.

Engineering tools and methods in this paper are interpreted in a wider sense. Tools are understood as means to accomplish certain objectives, which include for example Failure Mode and Effects Analysis (FMEA) [7] and Fault Tree Analysis [8]. Methods are understood as systematic procedures to accomplish certain objectives, and include for example preventive maintenance planning (e.g. [7]) and maintenance prevention [9].

The aim of this paper is to identify the current state of the use of engineering tools and methods in maintenance organisations. The study intends to answer the following two questions:

(1) To what extent are engineering tools and methods used?
(2) To what extent are engineers performing work related to engineering tools and methods?

To answer the two questions, a web-based survey study in the Swedish manufacturing industry is used, where empirical data are collected from over 70 companies. Increasing the use of engineering tools and methods within maintenance could be a first step towards achieving equipment performance levels sufficient for the realisation of future digital factories. Tools and methods can act as an important link between the operational and design and development phases, where increased knowledge of the factors affecting equipment performance can be used to improve both existing and future production systems.

2. Literature review

In this section, various engineering tools and methods applicable in maintenance organisations are presented, which are considered useful for the work towards improved equipment performance.

2.1 Models of maintenance management

In literature, numerous models for maintenance management have been proposed. When reviewing the published literature on this topic, Fraser et al. [10] found that the three most popular models are Total Productive Maintenance (TPM), Condition-Based Maintenance (CBM), and Reliability-Centered Maintenance (RCM) (note that TPM is a more holistic company-wide model, while RCM and CBM can be used as integrated parts in a company's maintenance model. For further review of these three models, see [11]) However, Fraser et al. [10] observe that out of several thousand articles published on TPM, RCM, and CBM, only 82 papers provided empirical evidence or links to practice. Therefore, a gap between theory and practice in regard to these models is proposed, where the authors conclude that "maintenance theory, in many respects, is de-coupled from practical applications." (p. 655).

2.1 Engineering tools and methods

Within the three most popular maintenance models, as well as in other maintenance literature, the use of various engineering tools and methods are emphasised. These tools and methods aid in identifying, analysing, and evaluating various types of risk, and thus contribute to improved decision-making for reduction of equipment losses.

To identify hazards and risks, suitable qualitative tools are e.g. Hazard and Operability studies (HAZOP) and FMEA, whilst FTA and Event Tree Analysis (ETA) are quantitative alternatives [8]. Decision Tree Analysis (DTA) can be used for maintenance policy selection [12], and Variation Mode Effects Analysis (VMEA) is useful for finding critical areas in terms of the effects of unwanted variation [13]. Further, Root Cause Analysis (RCA), which is normally supported by Fishbone Diagrams, is important for analysing problems down to their root causes instead of merely addressing their symptoms [14]. These tools can be used for many different purposes, e.g. FMEA which is useful for hazard and risk identification [8], deterioration and failure analysis [15], and preventive maintenance planning [7].

For a manufacturing company, the occurrence of equipment failures and their consequences are fundamental to manage. However, reliability analysis not only deals with failure modes (i.e. *how* equipment fail using e.g. FMEA) but also with failure rates (i.e. the *frequency* in which it fails, using e.g. Weibull analysis [16]). Furthermore, engineering tools are vital for a proactive approach to safety risks [17], and managing safety risks in essential in maintenance. Production disturbances often results in direct accident risk for maintenance workers [18], and the European Agency for Safety and Health at Work (EU-OSHA) [19] reports that 10-15% of all fatal accidents within the 'working process' area are related to maintenance. Lind and Nenonen [20] describe several risk-increasing factors for maintenance workers such as operating under the pressure of time, performing independent maintenance work during night shifts, as well as poor work practices, work guidance, and risk analysis. To review job procedures and practices, identify hazards, and determine risk-reducing measures, Job Safety Analysis (JSA) is a suitable tool [21]. Further, even simple and quick tools can provide useful information, where one example is What-if analysis (for a discussion of situations where such simple tools are justified, see [22]).

Academic research within the field has focused on enhancing the capabilities of individual tools [23]. Authors have proposed both developed versions of individual tools, e.g. cost-based FMEA [24], as well as combinations of several tools, e.g. combining RCA, FMEA and Fuzzy Methodology [25] or FMEA-aided LCC [26]. However, some engineering tools are academic and therefore seldom used by maintenance practitioners [23]. Moreover, many tools are deemed time-consuming. For instance, Takata et al. [15] claims that FMEA is not extensively used in industry, and argues that this due to its high requirement in terms of expertise and time. To reduce the time-consumption and thus improve the usefulness of tools, computer supported versions have been proposed (e.g. Computer-Aided FMEA [27] or Automatic Generation of FMEA [28]). In fact, Zio [29] advocates for the development of user-friendly software to implement reliability engineering methods in the future.

2.2 Engineering tools and methods in design and development

The cost of failures can be avoided if their consequences are addressed early [13]. Therefore, addressing reliability and maintainability during the design and development phase is