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Eco-effective changeovers; changing a burden into a manufacturing capability

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Abstract

Changeovers stand as a critical operation in the manufacturing companies, however in their current state with significant economic and environmental impacts they are more of a burden then a capability. Market pressures and sustainability requirements soon will push companies even harder to convert this burden into a manufacturing capability. Purpose of this paper to investigate the value definition of changeovers, type of impacts and possible improvement opportunities from an industrial perspective. Due to the lack of data availability on changeover impacts in the current literature, a case-study was conducted through interviews and onsite observations. Current findings indicate that, changeovers may be considered as value adding in some cases. Moreover, from an environmental perspective water consumption, wastewater treatment, energy use, chemical use and product loss were the type of impacts that were frequently brought up, whereas loss of production time was highlighted as the main economic impact. Additionally, companies believe that both design and operational changes can provide improvements for their current systems. Current findings represent the issues within the type of industries included in this early stage of the study and therefore may change in the later stages of the project. This paper highlights important aspects of changeover operations that are commonly neglected in industrial practice while improvements towards these aspects could provide substantial economic benefits while improving companies' environmental performance.

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Keywords: Changeovers; eco-effective changeovers; setup operations; cleaning operations; sustainable manufacturing; setup time reduction

1. Introduction

Manufacturing firms are facing serious challenges while competing in highly dynamic markets. Increasing trends towards mass customization is pushing companies from one side towards enriching their product range through innovation while at the same, global sustainability trends is pushing from the other side towards reducing the impacts on environment and society without compromising the economic profitability.

Within this complex environment changeovers stand as a crucial component of manufacturing firms at the process level. We define changeovers as the set of necessary but non-value adding activities while switching from one product to another, which starts with planning and preparation, before a process ends and lasts until the first quality product is produced as it can also be seen from Figure-1. Changeovers carry a crucial importance especially for multi-product companies where there is a constant demand for agility, flexibility, and quality.

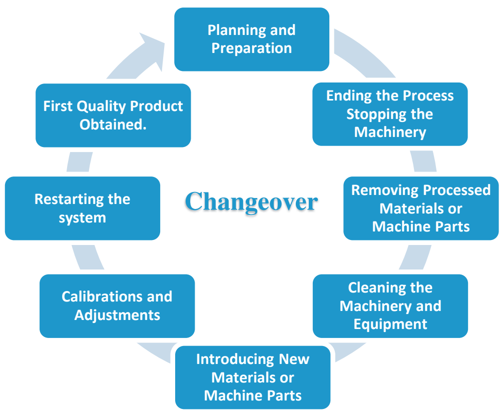

Figure 1- Changeover Mechanism

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Changeovers have a vital impact on all of these requirements as well as the economic and environmental performance of the system with the impacts created such as; product losses, water and energy consumptions and chemical use. Therefore with the current design and practice changeover operations conflict with the requirements of sustainable industrial systems.

When looked from this comprehensive perspective, changeovers are critical for a wide range of industries, however, the academic literature covering the environmental and economic impacts of changeover operations has yet to be established. Current literature streams are clustered around setup time reduction and cleaning operations separately. However, considering the complexity of the problem more balanced decisions need to be made considering the both aspects. Therefore the literature review has focused on these two areas. Additionally manufacturing strategies most related to changeover activities have been investigated. Moreover, communication with the industry has showed that there is lack of attention to the topic within industry as well. Even though, companies are quite keen to obtain this information and have ideas on how they may use it, they have not taken the necessary steps to develop the mechanisms that can capture this data.

The aim of this research is to provide the necessary mechanisms for companies to calculate the economic and environmental impact of their changeover operations and provide guidelines on improving changeover operations towards previously introduced eco-effective changeovers concept. This paper presents the findings from a preliminary case study along with a literature and practice review section to illustrate the type and magnitude of the impacts that may occur as a result of changeover operations, value proposition of changeovers and where the improvement opportunities may be.

2. Background

2.1. Practice Review

Changeover impacts are believed to be bringing an important cost stream to the company and an impact stream to the environment, and therefore conflicting with sustainable manufacturing targets. In order to support this claim, the practice from the literature has been reviewed. Although, a comprehensive evaluation was not available, supporting information from different sources indicate that setup and cleaning operations in the body of changeovers can cause additional costs to the company through resource, energy and time losses, wastewater production and other environmental impacts.

As a part of changeovers, cleaning systems are frequently overdesigned to ensure the cleanliness of the system, product safety and protect brand reputation (Fryer & Asteriadou, 2009). Fryer et al. inform that cleaning operations can take up to 25% of the operational time, especially in industries such as food and drink where intensive fouling results in frequent disruption of the production system (Fryer et al., 2011). Others reported that cleaning times in dairy industry may reach up to 15% of the total production time, but this can be reduced by reducing the fouling with surface modifications up to 76 per cent in specific situations (Mauermann et al., 2009). In another study, researchers managed to reduce the cleaning time more than 50% by using hydraulically generated flow pulses (Gillham et al., 2000). Mileham et al. indicated in their study that the loss in productivity can sum up to 8% annually, even with the low number of changeovers (10-15 annually) with long durations (Mileham et al., 1997).

Grundermann et al. have looked at the conversion of macro batch production plants to micro continuous manufacturing in an ink factory that was creating 4 m^3 of wastewater per tonne of ink produced. With this method they argue that it is possible to reduce the detergent and water use by up to 95%. (Grundemann et al., 2012). They also suggest that while switching between products with similar properties (e.g. different colours of ink), a continuous flow without any changeovers (product to product push) may be considered, during which the blend as a result of two mixing ink could be discarded as waste or could be sold as a lower quality by-product (Grundemann et al., 2012).In another investigation a milk factory was found to be consuming 3.25 L of water per litre of milk processed (Canut et al., 2007). They also report that the dairy industry average is around 1-5 L of water consumed per kg of milk produced and in well managed installations this amount could go down to 1-2 L/kg of milk. (Canut et al., 2007).

Several researchers have investigated the cost of heat exchanger fouling at the industrial level; Steinhagen et al. estimated that total cost of fouling for the New Zealand industry as being between $31 - $46 million dollars. In their distribution of fouling costs, the biggest portion, 72.4% is associated with maintenance and cleaning operations and rest are 14.1% Energy losses, 6.4% additional installation costs, 4.3% overdesign and 2.8% lost production (Steinhagen et al. 1993). Similar results were obtained in previous studies which estimated the total cost of fouling for UK industry as £300 - £500 million in 1978 (Pritchard, 1987 & Thackery, 1980) and between $8 -$10 billion in 1984 for the U.S. industry (Garrett-Price, 1985). However in these studies environmental impacts and associated costs weren't taken into consideration.

A new instrument was introduced by Friedrich to be used in the Active Pharmaceutical Ingredient (API) Industry as an alternative cleaning system. He claims that with this new equipment it is possible to achieve $522,924 total revenue savings, by reducing the annual water consumption from 653 m^3 to 47 m^3, saving 640 m^3 of cleaning agent and reducing the cleaning time by 72% (Friedrich, 2009). In another study, researchers have looked at the cleaner production opportunities for a milk processing facility and identified that 50% of the service water used, 9.3% of wastewater, 65.36% of the chemical use, a chemical oxygen demand (COD) discharge of 181.9 kg/day and 20.7 kg/day of total suspended solids (TSS) discharge could be eliminated by using cleaner production techniques (Özbay & Demirer, 2007). Perka et al. argue that the amount of waste from cleaning operations would still be