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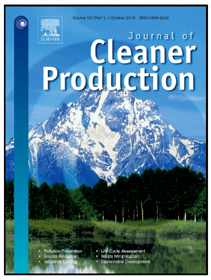

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An Internet of Things based energy efficiency monitoring and management system for machining workshop

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Abstract: Machining workshop is a widely distributed manufacturing system that consumes massive energy in a low efficiency. In recent years, the increasing pressure from energy price and environmental directive have forced machinery manufacturers to address energy efficiency monitoring and managing to improve economic benefits and environmental performance. However, due to the complicated energy flow and dynamic energy changes of the machining workshop, machinery manufacturers still lack an effective method to monitor and manage the energy efficiency in a practical manner. To this end, this paper proposes an energy efficiency monitoring and management system with the support of the newly emerging Internet of Things (IoT) technology. Firstly, the energy characteristics and energy efficiency indicators of the machining workshop are analyzed and defined. Then the framework of the IoT based energy efficiency monitoring and management system is proposed. The key approaches for energy efficiency monitoring and managing are then illustrated. Finally, an industrial application is demonstrated to validate the effectiveness and benefits of the proposed system. With the application of the proposed system, potential opportunities for energy consumption decrement and energy efficiency improvement can be identified. Machinery manufacturers can easily reduce energy consumption and energy cost by managing the machining process.

Keywords: Energy efficiency; Internet of Things; Monitoring; Machining workshop

1. Introduction

In recent years, the increasing global energy crisis has become one of the biggest challenges faced by manufacturing. Taking China as an example, statistical data shows that the industry sector is extremely energy-intensive and accounts for nearly 70% of the total energy consumption (Tao et al., 2016). Particularly, among the energy consumed by industry sector, machining industry accounts for almost a quarter of the total. However, although machining industry accounts for a significant portion of the industry sector's energy consumption, its energy efficiency is quite low. Numerous surveys indicate that the energy efficiency of the machining process is very low and usually less than 30% (Cai et al., 2016). In the work presented by Gutowski et al. (2006), the energy efficiency of a typical milling process is only 14.8%. Hence, it is important and imperative to improve energy efficiency and reduce energy consumption of the machining process.

However, as reported by Palasciano et al. (2016), the energy consumption of the machining process has a series of characteristics, such as a large number of energy consumers and dynamic energy flows. These characteristics make a challenge for energy reduction and energy efficiency improvement. To address this challenge, many researchers have been engaged in energy analysis and modelling of the machining process. As a result, many practicable energy models were proposed based on machine-specific characteristics or process-related features. For example, Gutowski et al. (2006) classified the energy consumption of the machine tools into two categories. One was the constant energy consumption that was independent on cutting load, while the other one was the variable energy consumption that depended on it. Li et al. (2011) explored the fixed energy consumption of machine tools and decomposed it into auxiliary, lubrication, and other energy units. Balogun

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