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Awareness of energy consumption in manufacturing processes

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Abstract

Several literature have reported on the low level of awareness for energy consumption in manufacturing processes. This paper presents results aimed at providing some evidence for this low level of awareness. The results of energy consumption as measured by various metering devices on different manufacturing equipment are presented. Predictive equations of energy consumption are also presented. The low awareness and meaningfulness of this results among a spectrum of students and manufacturing practitioners is reported to indicate the existence of a gap between the measured/predicted results and the human perception of energy consumption. Reasons for the gap between measurements/prediction and perception as well as methods for bridging the gap are proposed. The results are evidenced by experiments in turning, milling and rapid prototyping and have been conducted on manufacturing equipments which include manual desktop machine tool, desktop CNC machines and industrial scale manual and CNC machines

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1. Introduction

It is now widely accepted that the reduction of energy consumption in industry is a performance measure to be considered along with the traditional measures of cost, delivery time and quality. Various targets to reduce energy consumption have therefore been set and being constantly monitored at national, continental (e.g. in EU countries) and international levels. It has been reported that manufacturing accounts for over 30% of global CO₂ emissions and energy consumption [1], a trend that is growing, especially in emerging industrial economies like China, India and

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Brazil. The adverse impact of manufacturing activities on global sustainability means the manufacturing community need to be at the forefront of responding to the global sustainability challenge. This response is reflected in the various global sustainable manufacturing research activities and international standards (e.g. ISO 14000, ISO 50000, ISO 14955 series). With the vast amount of growing literature in the field of sustainable manufacturing, most of these were only conducted in an academic environment and those tested in industrial environments do not give indication of sustained adoption in those settings. This paper addresses this problem, with a focus on how academic results in measuring/predicting energy consumption in manufacturing processes could be used to raise energy awareness and auditing in industrial environments.

1.1. Aim and structure of paper

The paper reports a number of related investigation aimed at improving the energy awareness and adoption of energy efficiency measures in industry. Specifically the research question is: "What are the technical factors affecting a common-man understanding of energy consumption in manufacturing processes and what ways can be used to address this problem?"

After presenting the literature review in section 2, the paper considers the design research methodology employed in section 3. The background to the–research reported in this paper is the results (presented in section 4) of the laboratory-based investigations that measured and predicted energy consumption in various manufacturing operations in addition to an effort to disseminate it in industry. Section 5 then considers the set of investigations carried out to address the problem of making energy measurement industrially-relevant.

2. Review of the literature

From the pioneering works in the early 1990s, the literature on sustainable manufacturing is now vast and growing. The fragmentation have been identified by some researchers [2] and they suggested that the use of ontology may address this problem. Various literature review papers have made contributions in identifying some structure in the field, an example of which is a review paper by a group of researchers from the International academy of production research [3] which has identified the following 3 areas that the contributions in sustainable manufacturing can be classified into:

- Performance measures for sustainable manufacturing and their prediction/measurements;
- Improvement of performance of sustainable manufacturing through optimizing/improving the process parameters and
- Improvement of performance of sustainable manufacturing through designing new the process technologies/methods.

The key performance measures identified in literature that relates to energy consumption are power, energy consumed and energy consumed in processing unit volume of material (referred to as Specific Energy Consumption, SEC). Researchers such as Gutowski and collaborators at MIT [4] carried out some of the earliest comprehensive investigations, documenting these measures for a wide range of manufacturing processes. Various definitions of energy efficiency or Efficiency Ratios, ER, were addressed by researchers such as Rahimifard et al. [5]. Currently, there are over 50 performance measures and having these streamlined and in a form that can be transferable across industrial activities is still a challenge.

Factors that affect the adoption of energy efficient manufacturing have been considered by a number of researchers. Cagno and Trianni [6] identified a mixture of technical and non-technical factors which include: Technology-related, economic, organisational, behavioural, competence-related and awareness. The importance of information and how it is presented has been identified as being significant to raising awareness of energy efficiency issues. The technical factors that affect how practitioners understand energy consumption information is therefore considered important to address. It is however understood that this problem needs to be considered within a framework that promotes shared understanding so as to avoid the fragmentation developing in the field mentioned

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