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Energy efficiency in assembly systems

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Abstract

In order to provide flexibility in manufacturing many tasks are still executed manually. Tasks like assembly, cleaning, and packaging thus imply the use of workstations. Here we show the development of a method to assess energy consumption at different levels of a factory system. Exemplarily manual workstations are assessed using flexible measurement concepts. Conducting the assessment in the environment of a learning factory, energy saving potentials of up to 65 percent were identified. Besides, the findings were transferred into an interactive learning concept and a prototype workstation used in production processes for products made from CFRP was developed. We anticipate that an energy-efficient design of workstations is an example of how energy transparency in manufacturing can be increased, especially in industries that are characterized by costumer-specific, low-volume production and a high share of manual operations.

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Keywords: Assembly Systems; Manual Workstation; Energy Efficiency; Resource Efficiency; Learning Factory; CFRP

1. Introduction

Optimization measures for energy efficiency have focused on reducing the ecological impact of manufacturing operations since the late 60s. Ever since the rational use of energy and material has become an important factor for competitiveness, especially in highly developed manufacturing environments of the western world [1, 2]. Though the widespread requests in industries for short payback period’s favors the realization of energy efficiency measures in large scale machinery and production equipment [2, 3].

Yet, for instance Galitsky and Worrel identified possibilities to improve energy efficiency in the vehicle assembly industry [4]. Nevertheless workstations used in set-up, assembly, rework, cleaning, commissioning and packaging tasks have not been considered since their total energy saving potentials appear to be minor [5]. However this study presents results that show that in terms of relative saving potentials it is worth addressing aspects of energy efficiency in the design and operation of assembly systems. Moreover we show how these learnings can be transferred to other areas of manufacturing systems in the context of a learning factory on resource efficiency [6].

2. Methodology

The work is intended to contribute to the current strife for transparency in manufacturing considering energy consumption. Therefore, Fig. 1 categorizes manufacturing operations according to their contribution to energy transparency in production facilities encompassing different levels of a factory system according to systematic described in [7]. It illustrates the efforts that need to be undertaken (e.g. complexity of individual measurement concepts) in order to augment energy transparency in manufacturing operations. Fig. 1 subdivides a factory system in different levels encompassing building location, building shell, building services, auxiliary processes, machinery and processes. It shows how complexity increases alongside with the aggregated level of information. Different levels of a factory require different measurement concepts. Besides, from an economical

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perspective energy transparency needs to be contrasted with investment costs for the installation and current costs for operation and maintenance of energy monitoring systems. Energy consumption transparency in manual assembly therefore is one specific approach on how to increase the aggregate level energy transparency.

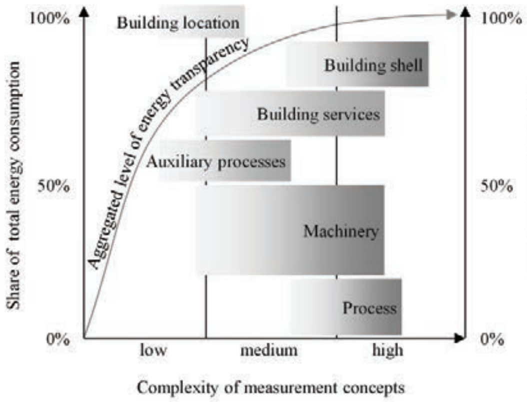

Fig. 1 Level of Complexity and Energy Transparency

Looking at the market development, the share of manufacturing facilities being specialized on final assembly is increasing in countries with high energy costs, e.g. Germany. Target Key Performance Indicators (KPIs) to be quantified in assembly planning projects are usually lead time, overall equipment efficiency or stock. In addition to that, energy demand and energy efficiency need to be considered. Therefore this paper firstly assesses an approach on how energy efficiency can be systematically assessed an optimized.

3. Development of Reference Scenarios

The analysis of assembly systems in this paper specifically addresses energy consumption. Besides aspects of work design, ergonomics and occupational safety were considered since they imply the use of operating resources such as lighting and extraction systems. Since workstations for manual activities are frequently used in assembly operations, different assembly tools are compared for their energy consumption during reference operations. In order to acquire comparable results reference scenarios were develop. Subsequently good- and bad practice solutions are compared and measurement results are presented.

3.1. Lighting (Constant vs. presence- and daylight based control)

Speed, accuracy and reliability of visual tasks are significantly influenced by lighting levels.

The maximum lighting for the task area and the immediate surrounding can be derived from the requirements described in DIN EN 12464-1. According to the norm, the maintenance value $\bar{E}_m$ for indoor workplaces depends on the conducted working operation. Commonly encountered requirements in a manufacturing environment are listed in Table 1.

Table 1. Lighting requirements (exerpt from DIN EN 12464-1) [8]

Conducted working operations	$\bar{E}_m$
Quality control	1,000
Assembly tasks (very precise)	750
Fine machine works Tolerance: < 0.1 mm	500
Rough and average machining Tolerance: ≥ 0.1 mm	300

Good practice solution for the lighting of workstations encompasses the use of presence- and daylight based control system, which turn of the light (or reduce it to a minimum lighting level required for orientation) during times of inactivity e.g. breaks or shift changes. Besides daylight control adjusts the illuminance according to daylight availability (ref. Fig. 2).

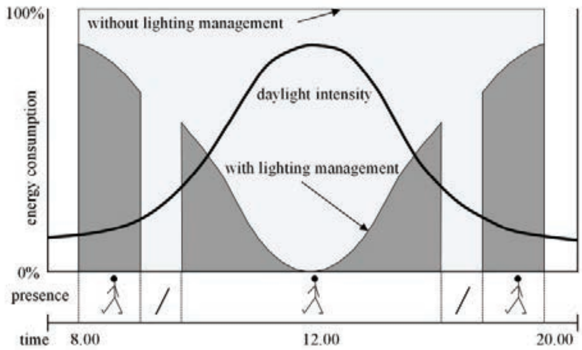

Fig. 2: Static scenario for presence and daylight based control

Given the before mentioned, a static scenario for the presence and daylight based control was implemented. Therefore a digital luxmeter was used to measure horizontal illuminance in the task area of an 850 mm high workplace surface (ref. Fig. 3). The reference workstation itself is situated in a representative working environment 10 m away from a window area that faces north with a heights of 12 m.

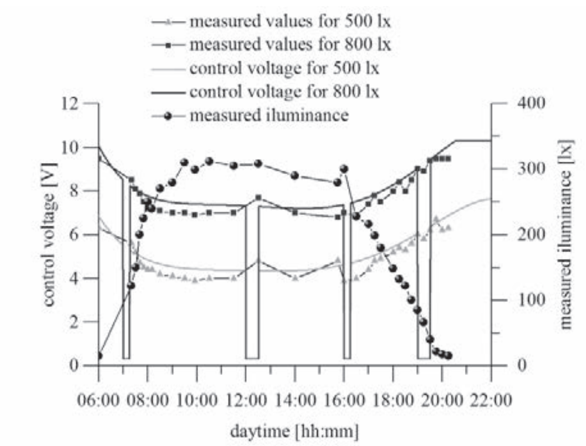

Fig. 3 Control voltage for the adjustment of illuminance