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Procedia CIRP 17 (2014) 422 – 427

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Variety Management in Manufacturing. Proceedings of the 47th CIRP Conference on Manufacturing Systems

Assessment methodology to design an ergonomic and sustainable order picking system using motion capturing systems

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Abstract

This paper focuses on a preventive approach for an ergonomic assessment methodology applicable in order picking systems with little effort. The approach intends to support logistic planners to ensure a sustainable physical stress on operator's body while handling a various number of complex products during order picking processes. The developed assessment methodology is based on an ergonomically recognised screening method (Multiple Loads Tool) and serves as a combined overall ergonomic risk estimation of various types of manual handling tasks by observing body postures during order picking. Implementing and using motion capturing systems provide an automatic and on-going capture of the operator's body postures while handling loads.

Selection and peer-review under responsibility of the International Scientific Committee of "The 47th CIRP Conference on Manufacturing Systems" in the person of the Conference Chair Professor Hoda ElMaraghy"

Keywords: variety management, logistics, order picking, motion capturing systems, ergonomics, physical stress, sustainability, demographic change

1. Introduction

International expanding markets, new technologies as well as continuous development of new customer-oriented products lead to shortened product lifecycles resulting in increasing process variety and complexity. According to current challenges, manufacturing companies and logistic service providers have to enhance process flexibility and adaptability to remain sustainably competitive [1-3]. Therefore, continuous waste elimination and implementing lean production principles to gain highly efficient production and logistic processes are common goals of many companies [4].

Despite the increasing trend towards automation and hybrid work systems, order picking processes are the most labor-intensive operations in logistic systems and approximately represent 50% of the total warehouse costs. Furthermore, any underperformance in order picking leads to unsatisfactory service and high operational costs in warehouses and consequently in the whole supply chain. For these reasons order picking processes are of outstanding importance and are considered as a high priority area for productivity improvements [5-6].

Manual material handling is one of the most physically demanding operations during order picking and is characterized by a high load weight, high repeatability and unfavorable body postures. These features increase the stress on the operator's body significantly and may cause occupational diseases as well as long-term injuries concerning the musculoskeletal system [7-8]. However, to achieve an ergonomic, sustainable order picking system, an on-going analysis and assessment of physical stress on the operator's body is indispensable.

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doi:10.1016/j.procir.2014.01.046

This paper presents an assessment methodology to evaluate each body posture occurring during material handling, taking into account resulting loads on the musculoskeletal system, time duration and/ or covered distance. Moreover, applying the assessment methodology enables the identification of cause-effect-relations between order picking systems' characteristics (e. g. unloading height, product weight) and physical stress specific factors (e. g. load weight, body posture). As a result musculoskeletal disorders in order picking systems may be reduced sustainably.

2. State of the art in assessment methodologies

Musculoskeletal disorders are responsible for more than one third of the total sick leave in the European Union and cause high costs for manufacturing companies, logistic service providers and national economies in common [9]. Therefore, manual material handling, that is one of the most physically demanding activities in production and logistic processes, has been a major field of research in the last 30 years [10-11].

The retrospective validation as well as the prospective and sustainable planning of order picking systems requires comprehensive knowledge about the actual existing biomechanical load in every manual material handling process. Based on biomechanical, physiological or psychological criteria or a combination of these a large number of various assessment methodologies have been developed to reduce health related disorders and to gain highly efficient work systems [10]. Depending on the evaluation type, existing assessment approaches and tools can be differentiated in methodologies defining recommended weight limits (e.g. NIOSH) or long-term dosage limits and methodologies classifying the level of risk for injuries in the musculoskeletal system (e.g. OWAS, KIM) [12]. Hereinafter, individual assessment methodologies are presented.

In 1981 the National Institute of Occupational Safety and Health (NIOSH) published an equation to identify the recommended weight limit for different manual lifting processes. It is based on biomechanical, psychophysical and energetic criteria. Because of the fact that the application of the developed equation was limited to sagittal lifting tasks the equation has been revised in 1991. The expanded version enables practitioners to evaluate asymmetrical lifting tasks, objects with less than optimal hand-container couples and guarantees the assessment of a larger range of work time duration and higher lifting frequencies [13] Using the NIOSH equation it is possible to reduce and eliminate not only disorders of the low back but also lifting-related health risks concerning the shoulder or arm [14].

A significant point of criticism of the uni-sex and uni-age NIOSH equation is the insufficient consideration of individual worker's characteristics. In addition, using the NIOSH equation does not enable the combined assessment of different manual material handling processes characterized by variable load weights and body postures. However, evaluating physical stress on the operator's body while performing manual material handling processes, the calculation of a uniform recommended weight limit is not reasonable and appropriate.

In contrast to the above mentioned NIOSH equation, the risks assessment using the Ovoko Work Analysis System (OWAS) is implemented by observing and classifying body postures occurring during manual material handling processes [15]. The assessment methodology has been invented to investigate the exposure of operator risk factors associated to musculoskeletal disorders. The OWAS methodology uses a large number of different diagrams of body postures and scoring tables to assess the adopted body posture during process execution. In addition to the evaluation of different leg, arm and back postures, the carried load can be analyzed by three given load dimensions. Finally, the selected body posture code is represented by a color code divided into four categories which classify the level of risk for musculoskeletal disorders. Moreover, the color code indicates the necessity and urgency of corrective structural and/ or design measures regarding the operator's work place.

Analogous to the NIOSH equation the OWAS methodology does not include operator specific characteristics like age and sex. Significant parameters for evaluating physical stress caused by manual material handling like load application point or dynamic effects, are not taken into account either.

Current assessment methodologies discussed in literature are developed for specific application like assembly systems or automative industry. Neither the combined assessment of various manual material handling processes characterized by different body postures and a heterogeneous load spectrum nor order picking systems' characteristics are considered adequately. For this reason these methodologies are not appropriate to evaluate the operator's physical stress in warehouse systems.

3. Multiple Loads Tool

For combined assessment of multiple and mixed types of manual material handling, the EXCEL based Multiple Loads Tool (MultipLa) was published in 2010. This approach is based on the Key Indicator Method (KIM) which was developed by the German Federal Institute for Occupational Safety and Health (BAuA) and uses standardized risk classes to evaluate physical stress concerning a heterogeneous load spectrum and various body postures [16]. KIM includes the evaluation of manual material handling - repositioning, holding and carrying - and in addition, the evaluation of pushing and pulling tasks [17].

MultipLa as well as KIM uses different criteria for the evaluation of manual material processes [18-19]

- body postures
- load weight
- positioning accurance
- pulling of loads
- lifting frequency