SHORT ORIGINAL PAPER

Design of ergonomic manufacturing equipment by a human-centered methodology

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Abstract
Even in the era of the fourth industrial revolution, companies should necessarily deal with human sustainability, with the aim of improving workers' health and safety and enhancing their skills. Several studies have faced this issue by proposing approaches or framework to boost the consideration of human factors in the workstation design and support ergonomic evaluations. However, the need arises for a methodology that collects and systematizes existing methods and tools in order to create workplaces that fit to human needs. For this aim, this paper proposes a structured methodology that supports the design and engineering of manufacturing equipment in order to improve workstations in terms of ergonomics and efficiency. It allows identifying a problem, solving it and carrying out a complete and objective evaluation from different perspectives. The methodology has been experimented in a real case study in collaboration with a global manufacturer of agriculture and industrial vehicles. Significant benefits in terms of productivity, process standardization and human factors have been achieved.

Keywords Human-centered manufacturing · Equipment design · Ergonomics · World class manufacturing · Workplace organization pillar

1 Introduction

In the socio-technical transformation towards the factory of the future, human continues to play a key role [1]. The importance of ergonomics principles in work and workplace design and the benefits related to the adoption of human-centered approaches are amply argued in literature [2]. Battini et al. [3] proposed a concurrent engineering approach for improving assembly system design considering ergonomic aspects. Djapan et al. [4] described an innovative methodology for risk assessment concerning human, organizational and technical/technological factors and proposed a tool for manufacturing sector to increase workplace safety.

On the other hand, the analysis of anthropocentric perspectives within Industry 4.0 highlights how the digital transformation in manufacturing production system is changing the role of the human operator and offers new opportunities to support him from a physical and cognitive point of view [5]. In this regard, Caputo et al. [6] presented a framework that uses digital twins of workstations with the aim of reducing the time used to design an assembly line. Alkan et al. [7] developed a software solution based on digital human models that uses operator position and workload data for virtual manufacturing process planning.

The abovementioned studies represent an important enhancement in preventing ergonomic issues from the design phase of a production process. However, the need arises for a methodology that collects and systematizes existing methods and tools in order to design ergonomic workstations.

Existing approaches rarely support the qualitative and quantitative definition of the problem or include the solution validation by an objective ergonomics analysis. This paper aims to overcome this lack by proposing a structured methodology to support the human-centered design of manu-

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