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The benefits of human-centred design in industrial practices: re-design of workstations in pipe industry

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Abstract

Sustainable Manufacturing (SM) traditionally focused on optimization of environmental and economic aspects, by neglecting the human performance. However, the industrial plant's costs, productivity and process quality highly depend on the individual human performance (e.g., comfort perceived, physical and mental workload, simplicity of actions, personal satisfaction) and how much hazardous positions and uncomfortable tasks finally cost to the company. The present paper defines a human-centred virtual simulation environment to optimize physical ergonomics in workstation design and demonstrates its benefits on an industrial case study in pipe industry. The proposed environment aims at overcoming traditional approaches, where analysis are carried out at the shop-floor when the plant is already created, by providing a virtual environment to easily test and verify different design solutions to optimize physical, cognitive and organizational ergonomics.

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1. Introduction

Sustainable manufacturing aims at creating sustainable manufacturing processes, reducing the impact of the three sustainability areas: environment, economy, and society [1]. While a lot of attention has been paid during the recent years to environmental impact reduction and cost optimization [2], the social dimension is still vague considered. However, the importance of the social impact on the modern processes has been recently pointed out by several

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sources all around the world. The fourth industrial revolution is starting to transform not only the modern companies, but also the way people interact with products and processes due to the change in product smartness as well as the work environments through 2025 and beyond [3]. This fact will have significant implications on the nature of product and process design, and will drive the so-called human-centred evolution in the design and usage of manufacturing sites and production systems [4]. However, real benefits can be achieved only when sustainability assessment is introduced during the early design stages, and sustainability becomes a design driver that serves to optimize the sustainability performance before product creation and process definition, to reduce production times, and to avoid late optimization loops [5]. In order to promote sustainability, different validation and verification assessment models are diffusing in industry. The interest of manufacturing companies to the human-related aspects optimization is arising for two main reasons: regulations and costs. On one hand companies have to care about workers' health and avoid work-related musculoskeletal disorder (MSD) as regulated by laws in different countries and sectors. On the other hand, the great economic impact of MSD connected to unnatural positions and dangerous actions executed by workers for both industry and society has been demonstrated in numerous cases. More specifically, bad workplace ergonomics has also extremely negative impact on company productivity, product quality, safety and production costs as analysed in different industrial sectors [6]. However, the actual practices are based on ex-post analyses to monitor the existing conditions by ad-hoc simulations created on monitoring the real processes. As a consequence, actions are usually taken after the design stage, when products and/or processes are already developed.

In this context, digital mock-ups are commonly used throughout the design phase, starting from the conceptual design phase to digital mock-ups validation in the advanced stages of the design process. Design tasks can be successfully reviewed by full-scale stereoscopic visualization within an immersive virtual environment [7]. These tools provide a virtual representation of workers in a simulated working environment and support the identification of ergonomic problems. However, such simulations have some limits in reliability, robustness and completeness of simulation. Indeed, the majority of tools use static scenes of single working postures and analyse only physical aspects without considering the cognitive aspects as well as the mental workload. However, actual tools difficultly allow the evaluation of both physical and cognitive ergonomic aspects, are not able to include the subjective impressions of workers, and do not consider to the workers' needs, skills, capabilities, and resilience (the so-called human factors).

The paper aims at demonstrating the benefits of a virtual simulation by the use of an immersive simulation environment adopting virtual reality (VR) technologies and mixed prototyping, merging real and virtual objects, to optimize physical ergonomics in workstation design. The study has been developed in collaboration with a leader company in energy industry for the optimization of the social sustainability of its workstations. The immersive virtual simulation was proved to support re-design actions by anticipating the human factors assessment during the design stage by involving real users, validating the plant layout, and improving the overall process quality.

2. The research background

Human factors have been recognized as a fundamental aspect in industrial engineering, so that ergonomics is always more often considered in industrial products and systems design. The analysis of human factors is focused on the analysis of the effectiveness and the efficiency with which activities and tasks are carried out, related to both physical and cognitive workloads [8]. As far as industrial operations, in different contexts it has been demonstrated that human factors highly affect the global efficiency of industrial processes [9][10]. Low attention to human factors brings to unnatural positions and dangerous actions executed by workers during their jobs, with consequent lower performances, higher production time, greater absence from work, and a general increase of Musculoskeletal Disorders (MSDs) with a consequence impact on national economies, in Europe as well as in other countries [11]. Such evidences are pushing companies to pay increasing attention to the evaluation of ergonomic performances based on different methods: from NIOSH equation [12] to the Ovako Working posture Analysis System (OWAS) [13], from the Occupational Repetitive Actions (OCRA) analysis [14] to the Rapid Upper Limb Analysis (RULA) [15], the Rapid Entire Body Assessment (REBA) [16] or Workplace Ergonomic Risk Assessment (WERA) [17]. In order to carry out proactive ergonomic assessment, digital simulation tools allow reproducing the human actions by digital human models (DHMs) and simulating the interaction with objects in a virtual environment. Different