Available online at www.sciencedirect.com
ScienceDirect
International Journal of Industrial Ergonomics 37 (2007) 267–275
International Journal of
INDUSTRIAL ERGONOMICS
www.elsevier.com/locate/ergon

Using ergonomic software in non-repetitive manufacturing processes: A case study

Javier Santos*, Jose M. Sarriegi, Nicolás Serrano, Jose M. Torres

Tecnun—University of Navarra; P° Manuel Lardizabal 13, 20018 San Sebastian, Gipuzkoa, Spain

Received 2 June 2006; received in revised form 11 October 2006; accepted 31 October 2006
Available online 24 January 2007

Abstract

Thanks to simulation software, ergonomic analysis has ceased being the complex and time-consuming task that it once was. However, the majority of Small and Medium Enterprises (SMEs) are still unaware of these tools. This paper uncovers, by means of a case study based on a real process, the advantages and the practical barriers involved in the implementation of 3D simulation tools in SMEs. The chosen case study is based on a non-repetitive manufacturing process, the most common within this size of companies.

Relevance to industry

Modeling and simulation tools could help to improve ergonomics in Small and Medium Enterprises. Many companies deal with non-repetitive manufacturing processes that could be hazardous for employees.

Keywords: Simulation; Ergonomics; Modeling software; Case study; OWAS

1. Introduction

Any decision-making process significantly benefits from the use of information systems. Developments in computer science have allowed ergonomic applications that were once limited to large computers to now be set up in personal computers, drastically broadening their access and availability.

However, many businesses have not taken full advantage of these information systems. They have generally downplayed the importance of ergonomics simulation packages and, as a consequence, this type of application has yet to become widely implemented. To make matters worse, the cost of software licensing is still high compared to other business applications.

This situation is most evident in Small and Medium Enterprises (SMEs), the majority of which do not even have a department dedicated to the ergonomic study of the workspace. However, the risk of ergonomic problems is the same for all companies, regardless of their size.

In order to analyze the possible uses of these ergonomic tools in SMEs, a practical case study was developed using a commercial tool, simulating a real working process in a company. Another objective of the project was to analyze the potential of these tools in a non-repetitive manufacturing process, that is, in a process where the working cycle is not fixed and the processed parts are not identical.

2. Theoretical foundations

Ensuring the health and safety of employees has historically been the responsibility of company managers. Staying true to this goal, the study of ergonomics helps to pinpoint which positions are most hazardous to the health of workers. The objective of these types of studies tends to focus on reducing Cumulative Trauma Disorder (Armstrong, 1986; Maizlish et al., 1995). However, ergonomic analysis can also simultaneously include improvements in productivity (Resnick and Zanotti, 1997).

*Corresponding author. Tel.: +34 943 21 98 77; fax: +34 943 31 14 42.
E-mail address: jsantos@tecnun.es (J. Santos).

0169-8141/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.ergon.2006.10.022

Most of these ergonomics analyses take place in assembly plants in order to evaluate how the bending or twisting of the trunk (Punnett et al., 1991), upper limb soft tissue (English et al., 1995) or shoulder disorders affect workers health (Punnett et al., 2000). Some studies are even more specific, such as focusing on reducing the strain of a lowering action carried out by female workers (Ciriello, 2005).

Ergonomic studies are mainly done by interview or questionnaire and both methodologies yield similar results (Wiktorin et al., 1999). In addition, several traditional models evaluate the individual's receptiveness to change (Prochaska and DiClemente, 1982). This model (the Stage of Change model) has been applied and adapted in various locations, including a pre-fabricated buildings factory (Barret et al., 2005).

On occasion, a participatory team analyzes and solves the ergonomic issue at hand. This method has proven the effectiveness of a participatory and structured approach to ergonomic problems (Moore, 1994; Adler et al., 1997).

The computer applications dedicated to ergonomic study are numerous and have evolved from basic numeric programs to ones based on virtual reality. One of the first reviews of these applications (Clark, 1981) compared two numeric examples accepted and used in industry at that time (4M Data System and ADAM).

During the 1990s many researchers developed virtual models to work with CAD systems. Some examples of these programs (CYBERMAN, COMBIMAN, CREW CHIEF, JACK, SAMMIE and MANNEQUIN) were analyzed to help the user select the right program according to workstation design (Das and Sengupta, 1995). In 2000, a book was published featuring a total of 27 papers (Landau, 2000), including 13 with descriptions of human models and applications in product and workplace design (Smith, 2002).

In the past, only a handful of studies lauded the potential value of virtual environments for ergonomic studies (Wilson, 1997). Nowadays, the most expansive ergonomic applications include a CAD module to build a virtual workplace and allow the integration of CAD software such as AutoCAD or ProEngineer. All these applications can now be run on a windows-based computer.

Most of the currently used applications were recently cited in a paper (Feyen et al., 2000) which merely dealt with the development of an interface to join AutoCAD with a specific simulation software program (3DSSPP—3D Static Strength Prediction Program). The 3DSSPP software was developed by the University of Michigan's Center for Ergonomics and includes a biomechanical model (Chaffin, 1997). This software has been used, for instance, to study the risk factors in the manual handling of material in an automotive parts distribution company (Ulin and Keyserling, 2004).

A number of ergonomic applications have similar functionalities: Deneb/ERGO (Nayar, 1995), Jack (Badler et al., 1995), MTM-Ergo (Schaub et al., 2004) or eM-Workplace (Rooks, 2000). The project presented in this paper has been developed with the eM-Workplace application (created by Tecnomatix). The choice to use this tool was based on the fact that the University of Navarra has a research license for this package.

Traditionally, ergonomic analysis software has been applied to repetitive production processes. Sherif, for example, used computer animation to evaluate and to improve the sawing process in a poultry-processing plant (Sherif and Sistler, 1999).

Computers notably facilitate the realization of this kinds of studies. In fact, in some cases they are vital in testing situations that are difficult to carry out in the workplace or even in a prototype laboratory. For example, a case study of the chassis assembly process in a bus manufacturing company was analyzed using Jack software to build a computer model of selected operations (Sundin et al., 2004).

Virtual humans are also used for testing ergonomic designs. These models allow one to test, for example, the external visibility of a car (Colombo and Cugini, 2005), postural comfort on a motorcycle (Barone and Curcio, 2004) or the biomechanical concerns of a car's interior design (Kuo and Chu, 2005).

Ergonomic simulation software is based on traditional Method-Time studies. The possible ranges of ergonomic and Method-Time studies are limited by software functionality. The most complete programs allow for the following studies:

- *MTM study*: The MTM system (Maynard et al., 1948) is based on the division of a process into a limited number of basic tasks and its analysis uses tables with predetermined times. These predetermined times correspond to 25 generic movements (Niebel and Freivalds, 2003). This method has also been used to predict the biomechanical load on an operator performing a new task, combining it with a developed tool called ErgoSAM (Laring et al., 2002). The used software applies MTM-1 movements for standard movement development.
- *OWAS study*: The Ovako Working Posture Analysing System (OWAS) method carries out a qualitative analysis of the worker's movements during a working process. The postures of the worker's body are classified depending on the effort exerted (Karhu et al., 1977). Traditionally, the OWAS method can be quite time consuming because it requires direct observation (Hagberg, 1992). This method has been used, for example, to study construction workers' hammering (Mattila et al., 1993) or in the development of a perchery system in the poultry industry (Scott and Lambe, 1996).
- *Lift Analysis*: Lift Analysis includes four ergonomic methods used for the measurement of effort that affect the elevation of a weight and its transportation towards another point. The Lift Analysis includes four methods: NIOSH81, NIOSH91, Burandt–Schultetus and GARG.