International Journal of Industrial Ergonomics 41 (2011) 268–279

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Sensitivity analysis of important parameters affecting contact pressure between a respirator and a headform

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A R T I C L E I N F O

Article history:
Received 4 April 2010
Received in revised form
9 September 2010
Accepted 20 January 2011
Available online 18 February 2011

Keywords:
Respirator
Headform
Comfort and fit
Contact pressure
Finite element model
Friction

A B S T R A C T

Respirator comfort and fit are two important parameters for respirator design, usage, and standard development. The contact pressure (as measured between a respirator and the wearer) plays an important role in comfort and fit. This work attempts to investigate the contact mechanism and factors that affect the contact pressure. This paper focuses on mechanical factors such as strap tension, strap orientation, strap location, friction, and seal material. A finite element (FE) model-based method was developed to assess the contact pressure. The FE models for both the headform and the respirator have multiple layers. The headform is a medium size headform developed by the National Institute for Occupational Safety and Health (NIOSH) and the respirator is an MSA Affinity Ultra respirator. The results show that the positive Z directional force of strap tension that forces the respirator to move towards the headform is the most important parameter for measuring pressure distribution. Other factors such as strap orientation, friction, strap location, and softness of the seal material were found to affect the contact pressure distribution in this study. Strap orientation and friction coefficient have no significant effect on maximum pressure and maximum shear stress. The dispersive strap location increased the contact pressure on the nose-bridge area of the wearer, while concentrated location had no considerable effect on contact pressure. A softer seal material causes larger deformations and transfers the location of the maximum pressure from the nose-bridge to the tip of the nose.

Relevance to industry: This study investigates the effect of important parameters on contact pressure between a respirator and a headform. The sensitivity analysis can provide insights of the interaction between a respirator and a headform. The findings are critical to respirator designers, users, and standard developers to ensure maximal respirator fit and comfort.

1. Introduction

American workers rely on respirators and other personal protective equipment to reduce the likelihood of disease, injury, and death at work (Zhuang and Bradtmiller, 2005). Respirator fit and comfort are two important performance characteristics that respirator designers, users, and standards developers care about. Respirator designers strive to ensure that the designed respirators satisfy fit and comfort requirements while endeavoring to reduce the development cost, and shorten production time. Healthcare workers use respirators to reduce their exposure to biological agents when they are in close contact with patients with infectious diseases. Workers in industrial settings such as manufacturing and construction use respirator masks day after day for protection against workplace aerosols.

A number of research activities have been carried out to determine the factors that affect respirator fit and comfort (Manninen et al., 1988; Shimozaki et al., 1988; Damascene et al., 1988; White, 1989; Snook et al., 1966; Akbar-Khanzadeh et al., 1995; Piccione and Moyer, 1997, and Mols et al., 2000). The majority of the research done to address concerns related to fit has been experimentally-based approaches. For example, respirator fit is typically studied by using monitoring equipment to measure the concentration difference of certain particles inside and outside of the respirator. Experimental approach also needs to be used a validation tool for model-based method. Experimental approach can answer “what”, but it can’t answer “where the leakage is”. That means the experimental approach can evaluate respirator fit, but it is difficult to show where the leakage is. Additional limitations of this approach are that it cannot predict respirator fit for any new respirators, requires physical prototypes for testing, tends to be time consuming, and is expensive. Even if the respirator fit is acceptable for one subject, we do not know if this respirator fit is

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0169-8141/$ – see front matter
doi:10.1016/j.ergon.2011.01.007