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Improving thermal properties of industrial safety helmets

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Abstract

This paper presents the redesign of an industrial safety helmet shell to improve its thermal properties. First an experiment was established to simulate the conditions of a head wearing a helmet. The average temperature beneath the helmet shell, the speed of heat dissipation through convection, and the temperature contour beneath the helmet shell were used to describe the thermal properties of a helmet. Helmets of different types and makes were tested, and various design concepts were examined. Design suggestions for improving thermal properties of industrial safety helmets were made. According to these design suggestions, a new design prototype was developed, tested, and further modified. The thermal properties of our final helmet shell design have improved over the commercially available helmets we tested. It also passed the weight, impact, and penetration tests of the Chinese National Standards. Finally a subjective human evaluation showed that the new helmet design has significantly better thermal properties than existing commercial helmets.

Relevance to industry

Industrial safety helmets provide head protection for industrial workers. Thermal discomfort is one of the major reasons that industrial workers do not like to wear safety helmets. This paper presents and verifies ways on improving thermal properties of industrial safety helmets.

Keywords: Industrial safety helmet; Thermal properties

1. Introduction

Industrial safety helmets provide head protection against small falling objects striking the top of the shell in industrial environments. Most of the tests in the standards (CNS, 1992; ANSI, 1986; ISO, 1977; BSI, 1987) that apply to industrial safety helmets are to measure whether a helmet can provide effective protection to the wearers. Considerable amount of research has also been done on the performance in impact and shock absorbing ability of the safety helmet (Mills and Gilchrist, 1987,1993; Rowland et al., 1988; Rowland, 1987). However, many workers are not willing to wear helmets simply because they are not comfortable. The "comfort performance", which may often be overlooked, is obviously another important issue for industrial safety helmet design.

Hickling (1986) discussed 12 factors that affect the acceptability of head protection at work: weather protection, thermal properties, tactile properties, absorptivity/permeability, mass distribution, degree of fit, size and shape, retention performance and fit, helmet volume, visual factors, speech and sound factors, and helmet compatibility.

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Among these 12 factors, the one of importance for the workers in a tropical or subtropical climate, such as that of Taiwan, are the thermal properties of industrial safety helmets. Liu and Holmer (1995) evaluated experimentally the evaporative heat transfer characteristics of industrial safety helmets. The effects of ambient humidity, solar radiation, and wind on heat loss were investigated.

This paper presents a project on how to redesign the shell of the industrial safety helmet to improve its thermal properties. In this project, first an experiment was established to simulate the conditions of a head wearing a helmet. Helmets of different types and makes were then tested. The average temperature beneath the helmet shell, the speed of heat dissipation through convection, and the temperature contour beneath the helmet shell were used to describe the thermal properties of a helmet. Various design concepts, e.g., adding ventilation holes, increasing clearance between the helmet shell and the head, covering the shell with reflective materials, were also tested. Finally, some design suggestions for improving the thermal properties of industrial safety helmet shells were made.

According to these design suggestions, a new design prototype was developed, tested, and further modified. At this stage, attentions were also paid to structural safety, appearance, manufacturability, and other practical issues. Finally, we developed our final helmet shell design. The thermal properties of this final design have significantly improved over other commercially available helmets we tested. It also passed the weight, impact, and penetration tests of the Chinese National Standards (CNS). A human description evaluation showed that the new helmet design has significantly better thermal properties than existing commercial helmets.

2. An experiment to measure the thermal properties of a helmet

Heat may be gained or lost from the head wearing a helmet by conduction, convection, and radiation. Conduction to the air is typically low, while convection and radiant heat transfer can be impeded by the presence of the helmet. There can be three heat sources that affect the temperature beneath the helmet shell: radiation from the sun, body heat from the wearer's head, and heat exchange with the surrounding air through convection.

Fig. 1 shows an experiment designed to simulate the conditions of a head wearing a helmet. The helmet being tested was resting on a headform. The headform was made of rubber and covered with hair. A set of four halogen lamps were positioned above the headform, so as to evenly distribute their radiant heat over the whole test region. A heat source (a light bulb) was put inside the headform to simulate body heat from the head. The temperature of the headform was controlled to maintain at body temperature 37.6°C.

The test environment was surrounded by electric heating coils for controlling the temperature of the surrounding air. According to the Central Weather Bureau of Taiwan, the average temperatures of Taiwan during summer months range from 26.8°C to 28.3°C, and the highest temperatures of the summer months range from 31.5°C to 33.3°C. Therefore, the temperature of the test region was set at 30.0°C. The halogen lamps and electric heating coils were controlled through a temperature controller, so that the temperature of the test environment was maintained at 30.0°C. Also according to the Central Weather Bureau of Taiwan, the average wind speed in Taiwan is about 2.0–2.5 m/s. An electrical fan was adjusted to provide a constant airflow at 2.5 m/s. The room temperature outside the test region was kept at about 25°C.

In summary, the standard test conditions of our experiment simulated a worker wearing a helmet in a 30.0°C sunny day, with wind blowing at 2.5 m/s.

3. Describing thermal properties of a helmet

To the extent of the authors' knowledge, there has not been a universally agreed index that formally defines the thermal properties of industrial safety helmets. Roszkowski (1980) compared the thermal properties of 10 industrial helmets on a resting subject. The results obtained were expressed in terms of dry bulb temperature and relative humidity beneath the helmet. Liu and Holmer (1995) measured the heat loss from a