

DESIGN OF ANTIVIBRATION GLOVES

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1. INTRODUCTION

Repetitive trauma associated with excessive vibration directed into the hands and arms is a significant health problem in U.S. industry. It is estimated that between two to four million workers are exposed to on-the-job hand-arm vibration in the U.S. and that around 50% of these workers either have or will develop symptoms associated with hand-arm vibration syndrome (HAVS). HAVS is associated with the destruction of the small blood vessels and with nerve damage in the fingers. HAVS is caused by excessive vibration directed into the hands from vibrating hand tools and vibration-intensive work processes. Symptoms associated with HAVS usually show up as a combination of finger blanching, particularly in response to cold, and progressive finger numbness.⁽¹⁾ In advanced stages, HAVS can result in the loss of tactile discrimination and manipulative dexterity.⁽¹⁾ When the level of vibration exposure to the hands is excessively high, symptoms associated with HAVS can appear within as little as one year's time.⁽²⁾

One method of reducing vibration energy into the hand and arm is to use protective clothing, in particular antivibration gloves. NIOSH publication 89-106 states that strategies for reducing hand-arm vibration in the U.S. shall be supplemented by the "use of antivibration clothing, mittens, gloves, and equipment."⁽⁴⁾ The NIOSH publication further states that the vibration-damping material in an antivibration glove must:

"provide adequate damping with minimal thickness so that the dexterity required for safe and efficient tool operation will not be reduced, and

have adequate damping characteristics over the vibration frequency spectrum associated with HAVS."

The International Organization for Standardization adopted ISO Standard 10819 to define the performance criteria and related test procedures that must be met and used to classify a glove as an antivibration glove.⁽⁵⁾ An antivibration glove must:

have an average ISO weighted transmissibility of less than 1, $TR_M < 1$, in the mid frequency range from 16-400 Hz and of less than 0.6, $TR_H < 0.6$, in the high frequency range from 100-1,600 Hz;

be a full-fingered glove that has the same vibration protection in the palm and fingers.

2. ERGONOMIC REQUIREMENTS FOR GLOVE DESIGN

The ergonomic effects of a tool on the hand include hand posture, grip strength, push force, tactile feedback, and temperature. The design of an antivibration glove must address these issues. Five ergonomic factors must be considered in the design of an antivibration glove. Paying proper attention to these factors increases the effectiveness of the glove in reducing vibration while making the glove comfortable to wear.

The thickness of the vibration-damping material placed in a glove to reduce vibration must be relatively thin. Placing vibration-damping material in the palm and the finger and thumb stalls of a glove increases the effective diameter of a tool handle when clasped while wearing the glove. Placing a material with too great a thickness in a glove can make the glove feel bulky and uncomfortable when clasping a hand tool or work piece. This can also make proper control of a tool difficult to maintain. A larger diameter handle requires a greater grip force to clasp the handle with the same grip effort, as compared to a smaller diameter handle. This increases muscle fatigue and the intracompartment pressure in the carpal tunnel in the wrist.⁽⁶⁾ Increased muscle fatigue and intracompartment pressure in the carpal tunnel raises the risk of developing carpal tunnel syndrome.⁽⁷⁾ Both HAVS and carpal tunnel syndrome must be considered when designing an antivibration glove. Increasing the thickness of the vibration-damping material in a glove usually increases the effectiveness of the glove in reducing vibration. However, thicker material can cause a glove to feel bulky and be uncomfortable. It can also increase the risk of developing carpal tunnel syndrome when using the glove over an extended time period. Material placed in the finger and thumb stalls of a glove should have a thickness less than 4.6 mm (0.18 in.) and in the palm area less than 6.4 mm (0.25 in.).

Vibration-damping materials placed in a glove should be flexible and pliable, and they should not interfere with tactile feedback. These materials should easily conform to the natural flex-lines in the palm and fingers. This allows the worker to easily maintain control of his tool or work piece. Vibration-damping materials should minimize the reduction in tactile feedback associated with their use. To properly perform work operations, an oper-

ator must be able to feel his tool and/or work piece.

The vibration-damping material must cover the full palm area and all of the digits of the fingers and thumb.

Vibration from a tool or work piece enters the hand at the palm, fingers and thumb. The primary damage associated with HAVS occurs in the fingers and thumb. Thus, to protect the fingers and thumb, all of the digits of the fingers and thumb must be isolated from the tool or work piece.

An antivibration glove must have an opposed thumb. A wing thumb is often used in a glove because it simplifies the manufacturing of the glove. When a glove that contains vibration-damping material and that has a wing thumb is used to clasp a tool handle, the material in the thumb stall rotates to the outside surface of the thumb. This places the thumb in direct contact with the tool handle, exposing it to vibration. Using an opposed thumb will prevent this. When a glove with an opposed thumb is used to clasp a tool handle, the vibration-damping material always stays properly positioned between the thumb and handle.

An antivibration glove should be loose fitting. Vibration-damping material that is placed in an antivibration glove can make the glove feel tight and stiff, particularly in the finger and thumb stalls. This usually reduces manipulative dexterity. Over-sizing a glove to accommodate vibration-damping material will increase manipulative dexterity. It is particularly important to over-size the finger and thumb stalls

3. GLOVE WITH AN AIR BLADDER VIBRATION-DAMPING ELEMENT

A thin layer of air placed between a vibrating handle or work piece and the hand is the most efficient means of attenuating vibration into the hand. A thin layer of air can be achieved with an air bladder that is made by welding two layers of thin-film thermoplastic material together with a quilted pattern of weld points and with weld lines that correspond to the natural flex-lines of the hand. An air bladder made by this process is thin, pliable, and flexible. This allows the bladder to naturally conform to the palm and fingers when clasping a handle or work piece. The air bladder for each hand has a bulb inflator. The inflator is connected to the air bladder by means of a flexible tube that allows the inflator to be placed on the backside of the glove. The air bladder is placed in a pocket in the glove between the palm of the hand, fingers and thumb and the outside shell of the glove. A thin cotton or Lycra material is placed between the air bladder and the hand to prevent the hand from sweating. The outside shell of the glove can be leather, Kevlar, or any other durable material.

A worker who wears a glove with an air bladder can easily maintain control of his tool or work piece. Tactile feedback is received through the air bladder while it provides

good vibration protection. A worker who wears a glove with an air bladder can always feel what he is doing. Gloves with an air bladder are made with an opposed thumb. This allows the thumb portion of the bladder to remain between the thumb and tool handle when the handle is clasped by the hand.

Compared to other glove vibration-damping materials, air is essentially massless. Thus, a glove with an air bladder is light and comfortable to wear. To provide the same vibration protection as an air bladder, every other glove vibration-damping material will require a material thickness that will make the glove uncomfortable to wear and use. Also, gloves with a thicker layer of vibration damping material will increase the potential for developing carpal tunnel syndrome with prolonged use.

4. REFERENCES

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