DESIGN OF A HAND-MOUNTED PALM AND FINGER ADAPTER SYSTEM TO MEASURE VIBRATION EXPOSURES AND PALM AND FINGER FORCES

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Introduction

A hand-held adapter approach is one of the most common and most convenient methods for quantifying vibration exposure at the hand-tool and hand-handle interfaces[1]. While most of the commercially available adapters are capable of reliable quantification of the acceleration magnitudes, the need for grip force monitoring is being overlooked, especially since it is well known that grip force is an influential factor in vibration exposure[2]. When exposed to vibration, the hand-arm system provides different biodynamic responses at the fingers when compared to the palm[3] suggesting that differentiation between the finger and palmar acceleration measurements is crucial for vibration monitoring and understanding exposure-response relationships. Peterson et al.[2] introduced a palm adapter as part of a Vibration Exposure Monitor (VEM) system that was capable of recording uniaxial acceleration and palm force using a force sensing resistor (FSR) on one hand. In order to investigate day-long two-handed tool couplings and exposures, this paper presents a palm and finger adapter system that was designed for use with a second-generation VEM system[4] that is capable of recording 16 channels of raw waveforms at up to 5,000 Hz for more than eight hours.

Methods

All adapter components for the palm and finger were manufactured out of polylactic acid (PLA) using fused deposition modeling (FDM) 3D printing. The palm adapter assembly has an upper, a lower, and a FSR component, where the upper and lower components join to house a tri-axial accelerometer (356A24, PCB Piezotronics Inc.) as well as to secure an elastic strap for mounting the adapter to the palm. The upper component has a curved surface to promote a comfortable fit with the topology of the palm, especially when gripping tool handles. Two FRS sensors are embedded in the FSR component, which is a plate mounted to the bottom of the lower component of the adapter. The overall size of the device is 4x1.5x1.6cm and weighs about 16g with all the sensors included. The finger adapter also consists of an upper and a lower component, where the lower component houses a uniaxial accelerometer (352C23, PCB Piezotronics Inc.) and an elastic strap for finger mounting is sandwiched between the upper and lower components. The FSR on the finger adapter is held in place on the bottom side of the lower component using two pressed-fit aluminum tabs that also act as electronic connections. The overall size of the finger adapter is about 1.6x1.1x0.68cm and weighs about 5g with all the sensors included. Both adapters use thin sheets of rubber for mechanical filtering, in order to protect the accelerometers from extreme vibration and, for consistency, each FSR is slightly modified to distribute the applied force over the active sensing area[2]. Based on previous related work presented by Tornifoglio and Peterson[5], a target of four FSR sensors was desired but, due to space limitations, only three FSR sensors per hand are incorporated.

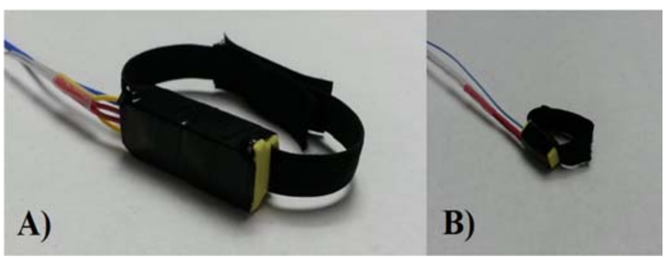

Figure 1 Adapters for measurement of vibration and force at the A) palm and the B) finger

The palm and finger adapters were tested for transmissibility performance up to 5,000 Hz using a random vibration signal of 20 m/s^2 total RMS and involved mounting the adapters on a bare hand and gripping the vibrating handle of a ISO 10819 glove testing system. The FSR sensors follow a specific calibration procedure[2] and were each observed to be capable of measuring forces up to 60 lbs.

Results

The averaged (n=15) palm adapter frequency response was ±2 dB between 16 and 2,500 Hz, while the averaged (n=15) finger adapter response was 1 to -2 dB between 16 to 2,500 Hz. Results of the bare hand test for the palm and finger adapters can be seen in Figure 2 and it can be seen that the performance of the mechanical filtering was observed to be more than -10 dB at 5,000 Hz.

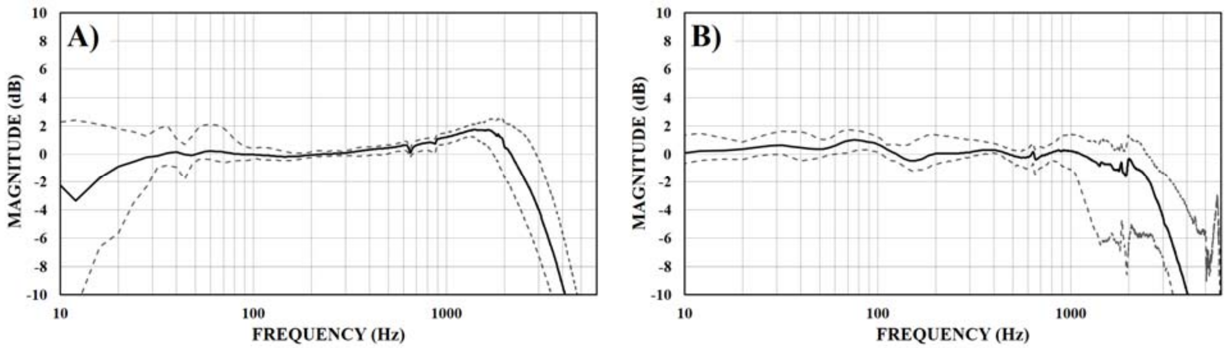

Figure 2 Frequency response of the palm (A) and finger (B) adapters

Discussion

Additive manufacturing methods (3D printing) can be utilized to cheaply, conveniently, and rapidly manufacture complex palm and finger adapter designs that are capable of exhibiting fairly flat frequency responses within a frequency range suitable for hand-arm vibration assessments. The addition of a finger adapter will allow for the characterization of vibration and force exposures at the fingers, especially since the fingers play a key role in understanding exposure-response relationships and long duration finger measurements have not yet been reported. Furthermore, simultaneous measurements taken on both hands will allow for the investigation of complex hand-tool coupling and two-handed calculations of A(8) from ISO 5349[6].

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Forward – Welcome Address

On behalf of my conference co-chairs, I am pleased to welcome you to Guelph, Ontario, Canada for the 5th American Conference on Human Vibration. The 5th ACHV is being co-hosted by the University of Guelph, Laurentian University, Western University and the University of Toronto. We are honored to be hosting this biennial conference on the University of Guelph campus. As the premier North American conference for human exposure to vibration, the conference provides a unique and convenient opportunity for researchers, engineers, medical professionals and industry representatives to exchange information on all aspects of vibration control and human responses to hand-transmitted vibration and whole-body vibration. The theme for this year's meeting is "Human Vibration - From Theory to Industrial and Clinical Applications".

Founded in 1827, Guelph was named after the British Monarch King George IV, who was from the House of Hanover. Selected as the headquarters of a British development firm called "The Canada Company", Guelph was designed by John Galt, who was a Scottish Novelist. The town was designed to resemble a European city center comprised of squares, wide main streets and narrow side streets. Guelph was home to Lieutenant Colonel John McCrae, the author of "In Flanders Fields". Its references to the red poppies that grew over the graves of fallen soldiers resulted in the remembrance poppy becoming one of the world's most recognized memorial symbols for fallen soldiers. Guelph was also the home of North America's first cable TV system. Fredrick T. Metcalf created MacLean Hunter Television (now part of Rogers Communications) and their first broadcast was of current monarch Queen Elizabeth II's Coronation in 1953. With a population of over 120,000, Guelph is part of a technology triangle which is comprised of the cities of Guelph, Kitchener, Cambridge and Waterloo. Guelph is consistently rated as one of Canada's best places to live because of its low crime rate, clean environment, high standard of living and low unemployment rate. Almost one quarter of Guelph employment is provided through the manufacturing sector with over 10% provided through Educational services. The City of Guelph has identified life science, agri-food and biotechnology, environmental management and technology companies as industries on which to focus future economic development activities.

Many thanks to Elyse Dubé from Conference Services at the University of Guelph for all of her hard work in helping to plan and sort through the conference logistics. We'd also like to thank Guelph Engineering students Gregor Scott and Dan Leto as well as School of Engineering technician Carly Fennell for their help in setting up the laboratory tours. We hope that your visit to the 5th ACHV and Guelph will be both educational and enjoyable.

Sincerely,

Michele Oliver, Jim Dickey, Tammy Eger and Aaron Thompson