The effects of the mechanical properties on the attenuation of ear muffs

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ABSTRACT

The attenuation of ear muffs is dependent on their design and the materials used for construction. This work attempts to draw some generalised outcomes by presenting the results of an examination of the physical properties of 39 sets of ear muffs commonly available in Australia. The results indicate that attenuation increases with clamping force up to a limiting value of around 11 Newtons above which expected increases in attenuation are very small for large increases in clamping force. Likewise increasing the volume and mass of the hearing protector cup increases the attenuation but, as with clamping force a limit is reached where increased size and mass increases discomfort and wearing difficulty. While the physical and mechanical properties can be an indication of an ear muffs likely attenuation they are not an absolute predictor of performance.

INTRODUCTION

There is a limit to the amount of attenuation that can be offered by the use of hearing protectors (HP). This limit is the result of bone conduction and tends to be in the order of magnitude of around 35 to 40 dB (Sataloff & Sataloff: 1987) so no matter how well the HP is designed and constructed this limit will eventually be reached.

However, there appear to be some general trends that well designed HPs should follow in order to ensure that maximum attenuation can be achieved when desired. This paper summarises some work recently carried out at the National Acoustic Laboratories relating the physical/mechanical properties of HP against their acoustic performance.

METHOD

All mechanical and acoustic testing was carried out to the specifications required by combined Australian/New Zealand Standard AS/NZS 1270: 2002, Acoustics – Hearing protectors. In all a total of 39 earmuffs, both banded (26) and helmet mounted (13), from several suppliers were tested. All devices are readily available in Australia.

For simplicity attenuation is expressed in terms of the SLC rather than the more common SLC_{80} as expressed in AS/NZS 1270: 2002. This method for the calculation of the attenuation is the same as that provided in Appendix A of AS/NZS 1270 except that the standard deviation is not subtracted from each respective octave-band. Details of this calculation can be found in Williams (2005 and 2006). Basically the method considers the mean overall attenuation experienced by each subject during the testing and calculates the average attenuation and an associated standard deviation of all (16) subjects. This removes the variability (ie standard deviation) from the calculation and provides a separate, standard deviation. The resulting attenuation is expressed as the mean individual SLC (*mi*SLC) in dB. For simplicity in this paper this is the 'attenuation' referred to except as where otherwise noted.

RESULTS

Cup volume

In general, increasing the cup internal volume has the effect of increasing the octave-band attenuation. While attenuation at higher frequencies tends to be independent of volume, increasing the attenuation in the lower frequencies tends to raise the overall attenuation. This was not a consistent effect across all devices. *Figure 1* shows the results for three selected cup volumes. In general, most devices followed this trend.

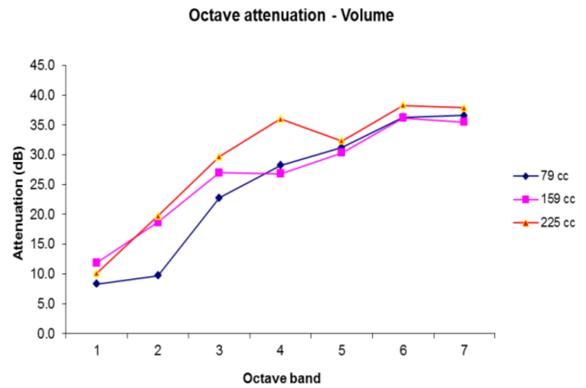

Figure 1: Attenuation (dB) at respective octave-bands

(1=125 Hz; 2=250 Hz; 3=500 Hz; 4=1 kHz; 5= 2k Hz; 6=4k Hz; 7=8k Hz)

For the individual devices the effect of increasing in the volume versus overall attenuation is shown in *Figure 2*. Interestingly a larger volume does not always increase the attenuation showing the mixed affects of other parameters. The lower volume boundary arises from requiring sufficient cup size to comfortably surround and enclose the pinna.

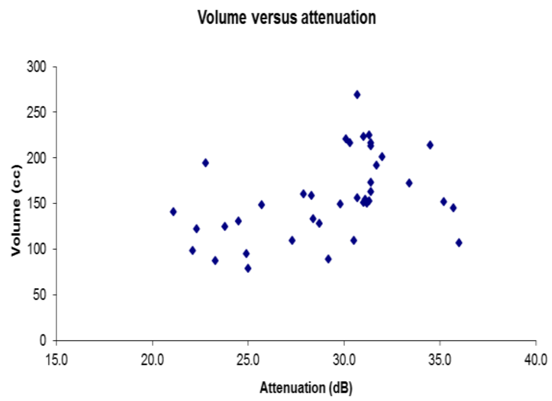

Figure 2: The relationship of cup volume (cc) to attenuation (dB) showing only a very small trend to increase overall attenuation with increased volume.

Cup mass

The mass here refers only to the mass of the complete ear-muff cup (cup, cushion, internal absorbers, etc) and does not include the mass of the headband or the helmet, if helmet mounted. The results are presented in *Figure 3*. The mass will be a function of the materials used in construction and while increased mass generally increases the attenuation this is not the rule. Better absorption and attenuation may be obtained by the use of lighter materials with better acoustic properties.

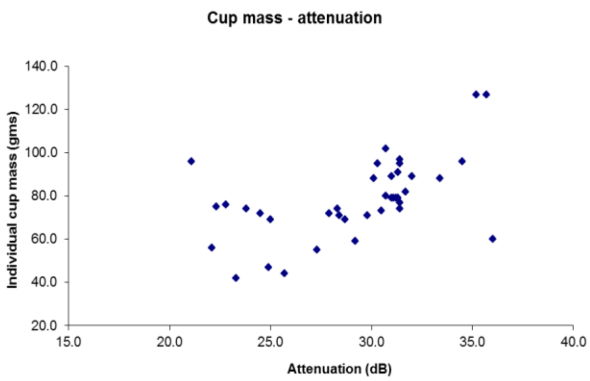

Figure 3: The relation between cup mass (gms) and overall attenuation (dB). Generaly greater mass implies larger attenuation but this is not always the case.

Clamping force and pressure

The clamping force is the main mechanical parameter measured and reported during HP physical tests. It is frequently the first port of call for HP manufacturers who wish to increase the the attenuation of the device.

The spread of the measured values of clamping force with respect to overall attenuation are presented in *Figure 4*. As can be observed simply increasing the clamping force does not necessarily mean larger attenuation - a limiting value seems to lie in the 10 to 12 N range. *Note: A more comprehensive analysis and evaluation of attenuation and clamping force can be found in Williams, Seeto & Dillon: 2012*

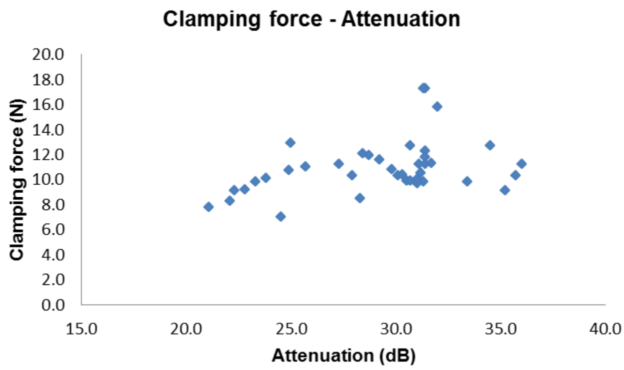

Figure 4: The relation between measured band clamping force (N) and overall attenuation (dB).

In terms of comfort the clamping pressure is probably more important than the clamping force. Pressure is the clamping force divided by the cushion area. For the same clamping force a device with a larger surface area of the cushion will exert less pressure on the side of the head.

The calculated pressure in relation to attenuation data is presented in Figure 5.

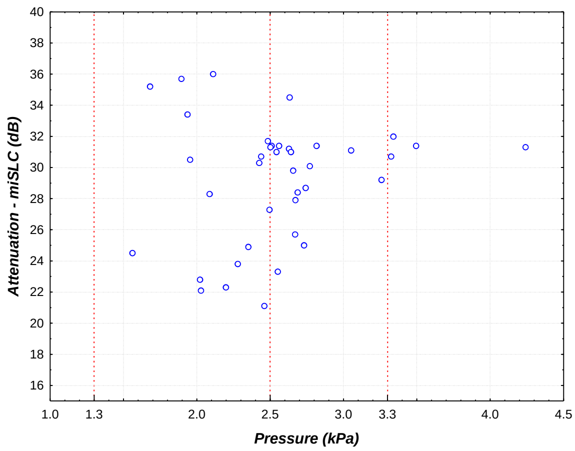

Figure 5: The distribution of attenuation versus hearing protector clamping pressure. The mean clamping pressure is indicated by the line at 2.5 kPa (SD = 0.5) while the lines at 3.3 and 1.3 kPa show the mean capillary blood pressure at the arterial (inlet) and venous (outlet) sides respectively.

Also included in *Figure 5* are the mean clamping pressure (2.5 kPa) and the typical inlet (arterial) and outlet (venous) capillary blood pressure of 3.3 kPa and 1.3 kPa respectively. Some of the devices measured had the clamping pressure greater than the inlet blood pressure while all had values greater than the outlet pressure. A more detailed analysis of these results can be found in Williams (2007).

This means that the majority of wearers will have the blood flow in the skin area around their ears disrupted in some way and will at some stage experience discomfort. Time to discomfort will vary between individuals. The implication from these results is that if hearing protectors are considered a mandatory part of the job process at some stage time must be allowed for the wearer to remove their protectors, in a quiet place, so that equilibrium (blood flow) can be restored.

Also of note are the results presented in *Figure 6* demonstrating that there is a very poor correlation between the standard deviation of the attenuation with respect to the clamping pressure. This implies that the variation in performance as measured by standard deviation cannot necessarily be decreased by increasing the clamping pressure/force.

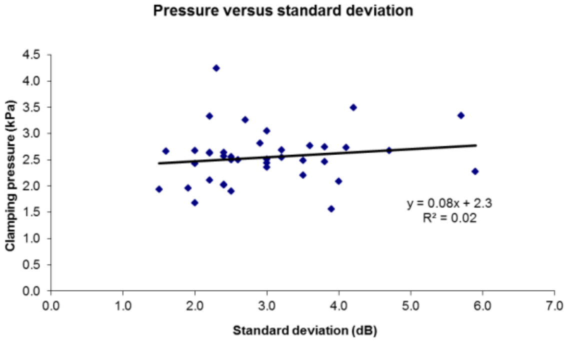

Figure 6: The standard deviation of the attenuation (dB) of the earmuffs versus the clamping pressure (kPa).

GENERAL DISCUSSION

From the above results it can be seen that while the mechanical properties of an ear muff can provide an indication of expected performance, performance cannot be predicted in the individual case.

The design and the 'quality' of the devices appear to have a very important influence on performance. While quality may be difficult to define it is usually quickly assessed by the experienced eye but remains difficult to explain and quantify in measurable terms.

The best hearing protector is the one that is worn for the duration of the noise exposure almost irrespective of the rated attenuation – even the highest rated ear muff will only provide an exposure reduction of 3 dB if worn for half of the time exposed.

Comfort of fit is a difficult parameter to specify or measure and while it must somehow include clamping force/pressure many factors are involved (Bhattacharya et al: 1993; Broughton: 1995; Edwards: 2003; Hsu et al: 2004). Certainly during attenuation testing test subjects could be asked to assess comfort but this would necessarily be for a relatively short wear time compared to a whole work shift for example.

CONCLUSIONS

While it is difficult to say with precision exactly how specific parameters affect the attenuation of a particular hearing protector some overall generalisations can be made.

Generalisations such as:

- the larger the volume the greater the overall attenuation and the greater the individual octave-band attenuation;

- the larger the cup mass the greater the attenuation;

- increasing the clamping force will increase attenuation but is limiting above 11 Newtons;

- the circum-aural cushion pressure will cause discomfort due to capillary blood flow disruption; and

- simply increasing the clamping force will not necessarily improve the performance (attenuation) of the device as measured by the standard deviation.

These generalisations can be made but they will not be true in all cases.

FURTHER ANALYSIS

If further and a much more comprehensive analysis of the mechanical data presented in this paper is required it can be found in Williams, Seeto & Dillon (2012).

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