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EARMUFF COMFORT

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ABSTRACT

In many industrial and military situations it is not practical or economical to reduce the noise to levels that do not present either a hazard to hearing or annoyance. In these situations, personal hearing protection devices are capable of reducing the noise by up to around 40 dB. Although the use of a hearing protector is recommended as a temporary solution until action is taken to control the noise, in practice, it ends up as a permanent solution in most cases. Therefore, hearing protectors must be both efficient in noise attenuation and comfortable to wear. Comfort in this case is related to the acceptance of the user to wear the hearing protector consistently and correctly at all times. The purpose of this paper is to review publications related to earmuff comfort, most of which are based on measurement of the total headband force and subjective evaluation using questionnaires. Most of the published results show a week correlation between total headband force and subjective evaluation. This paper presents new quantitative indices based on the comfort parameters, mainly measurements of the contact pressure distribution between the earmuff cushions and circumaural flesh of the human head. The comfort parameters were investigated and equations developed to calculate comfort indices. The calculated indices are correlated with subjective evaluations. Measurement results for the pressure distribution of ten earmuffs, show good correlation with subjective evaluation.

INTRODUCTION: EARMUFF COMFORT

When noise control at the source is not economically feasible in the short or medium term, hearing protectors are the only solution. Therefore, hearing protectors are the salvation of workers in noisy environment and should be given maximum attention for research and development to advance the technology required for high quality protectors which satisfy the noise protection requirements of the users and also the legislation. Hearing protectors should be used for 100% of the work shift, otherwise very little noise attenuation is gained, and they should be accepted by the users, so that they will be used consistently and correctly the whole time. This means that the hearing protector should be COMFORTABLE. All literature published on comfort, to our knowledge, has been based on the total force of the headband, or the average pressure (dividing total force by contact area) and evaluation based on the reaction of a group of jurors who subjectively evaluate the comfort. However, a large number of the studies published on earmuffs show that there is often a lack of correlation between comfort and headband total force or average pressure. Some published results, as shown later in this literature review, even show the contrary situation, that is, a strong headband force is more comfortable than a weak headband force. Pressure exerted by an HPD on the skin and underlying tissue and bone is probably one of the most common direct causes of discomfort. This paper presents quantitative indices based on the comfort parameters, mainly the measurement of the contact pressure and force distribution between the earmuff cushions and the circumaural flesh of the human head.

LITERATURE REVIEW

A large number of papers on hearing protector comfort are available in the literature. The following are some of the most important ones, particularly those by Casali, J. G., (1978), Pedro M. Arezes (2002) and Berger (1989). Berger's paper gives an overview of comfort and also shows the inaccuracy problem associated with applying the British Standard BS 6344 - Part 1, for the average pressure calculation. It also shows the weak correlation between comfort and some relevant parameters. Other related studies are reported in the rest of the references seem to report similar results. All of these papers show the lack of a true comfort index based on the physical characteristics of the earmuff and also week correlation between the total headband force or average pressure and subjective.

CACULATION OF COMFORT INDEX

A Specific Associated Measurement index 'SAM1' is developed for quantification of earmuff comfort. This index (SAM1) relates to the force distribution over the contact area. It is a single number index which describes the homogeneity of the force or pressure distribution. If the force distribution is homogenous and uniform over all contact surfaces, then the hearing protector is very comfortable and SAM1 equals unity in this case. If the pressure is very high in a concentrated area, then there is a lack of comfort and the value for SAM1 decreases.

This index can be measured on a flat surface with the cup-cushion separation distance fixed at a value of 145 mm, as in the standard for the measurement of the headband force (ANSI S12.6-1997). Also, it can be measured on a dummy artificial normalized head (ANSI S3.36-1985) to avoid the human variation parameter and decrease uncertainty, or it can be measured on a real human head, it is given by;

SAM1 = 1- {Modulus |(sum of deviation of each element force)| / (total force+(n-2) average force)}

Others indices can be considered too such as presented in (Gerges, 2010).

MEASUREMENTS ON A FLAT SURFACE, A NORMALIZED HEAD AD A REAL HUMAN HEAD.

The measurement system used in this study is TEKSCAN I - Scan Lite *Enhanced* system, type 5101 with 1936 pressure resistive sensors (see Figure 1). The sensors are inside a plastic semi-hard sheet which cannot bend on the top of the ear, and therefore the ear area was cut out and some area of the pressure map was lost (see Figure 1-B). Also, we developed software to transform the color map pictures into numerical values to calculate the indices. Attempts to use other sensors, like capacitive sensors with flexible surfaces, did not give good results, since the lowest pressure which can be measured is only around 600 Pa. We need to go as low a zero Pa to be able to detect leakage and non contact areas.

Figure 1 – A

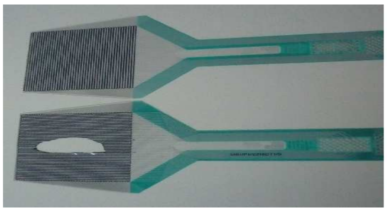

Figure 1 – B

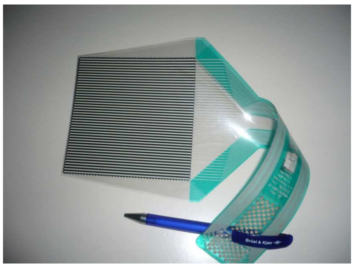

Figure 1 – C

Figure 1: TEKSCAN measurement system with (A) sensors onete to notebook, (B) sensors ith a hole for the ear position, and (C) showing the rigidit of the sensors.

Measurements were taken for ten differet earmuffs (see figure 2) in three differet situations; on a flat surfae, on a dummy standartied head (ANSI S3.36-1985) and on a real human head.

Figure 2: The ten earmuffs used i this study

Measurements on a flat surfae

Measurement of the pressure distribution is carried out on a flat surface. This surface is the same as that of the headband force measurement apparatus (ANSI S3.19-1974] with 140 mm width, as shown in Figure 3. The total force reading on the headband apparatus is the same as that calculated by TEKSCAN system. The TEKSCAN system is suitable for taking measurements on a flat surface. For each earmuff measurements were carried out in triplicate. Tpical measured results for the pressure map are shown in Figure 4. The headband force varies slowly with time, and therefore the measurement was carried out for a period of 15 minutes. Figure 8 shows the results obtained for the force distribution index SAM1. The values for this index were 0.86 for the best protector down to 0.68 for the poorest.

Figure 3: Measurement on a flat surface

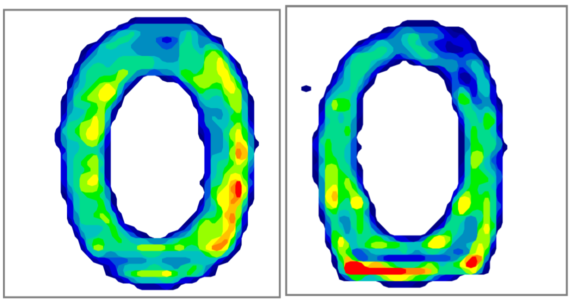

Figure 4: Typical contact pressure map for an earmuff

Measurements on Standardized Dummy Head

Due to the great variation between subjects an artificial normalized head (ANSI S 3.36 - 1985) is used to determine the values for the index for the different earmuffs. Figure 5 shows the standardized dummy head used which is a close replica of a real human head. The values for the force distribution index calculated using the colored map are shown in Figure 8.

Figure 5: Dummy Head Measurements

Measurements on Human Head

The measurements obtained using a real human head (see Figure 6) were taken for comparison with those of the flat surface and normalized dummy head measurements. However, the subjective comfort parameter values usually exhibits large inter-subject and inter-laboratory variation, which makes it difficult to compare and select hearing protectors. Typical force distributions are shown in Figure 7 measured using a single subject only. The values for the force distribution index SAM1 are shown in Figure 8. It is very interested to note that one of the hearing protectors which has a specified left/right muff shows a lower index value on the flat surface measurement than for the dummy head measurements, as expected, because of its non-symmetry characteristic. Figure 8 shows the results for the flat surface, dummy (normalized) head and human head measurements.

Figure 6: Human Head Measurements.

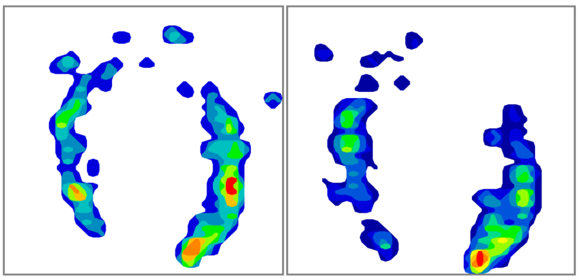

Figure 7: Typical pressure map measur on Human Head

Subjective evaluation

Subjective evaluation was carried out for a short test period, since Ivergrad (1976) showed that short-term (2 to 3 minutes) tests were a valid basis for long term user assessments. The 10 earmuffs were tested by 20 subjects randomly chosen from the postgraduate students at UFSC - Acoustics and Vibration Laboratory, Brazil. Ages ranged from 20 to 35 and the time which each subject spent on the experiment was between 8 to 30 minutes (average 16.45 minutes and Standard Deviation 6.62 minutes). The subjects were asked to rank the 10 earmuffs from only the comfort point of view and each subject was permitted to attempt the assessment as many times as he/she wished. There was no time limit established. Each subject arranged the earmuffs on the table from worst to best in terms of comfort and was then asked to give them a grade from zero (worst comfort) to one (best comfort), using unit steps. Figure 8 show the measurement results compared with those of the measured evaluation.

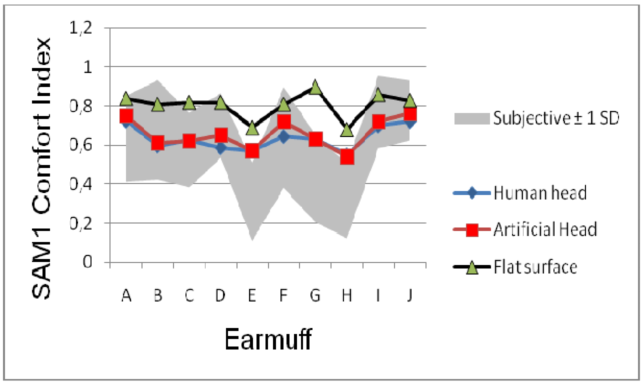

Figure 8:SAM1 Comfort index for earmuffs: Comparison between subjective and measurements.

DISCUSSION

The TEKSCAN measuring system gives very good results for the flat surface measurement only. The correlation results shown in Figure 8 show that measurements taken on a flat surface are not a good indicator of the force distribution on a real human head and for this reason they cannot be used even for relative comparisons. Furthermore, some hearing protector earmuffs may have different left and right earmuffs to fit the respective human ears. Poor correlations were obtained between the flat surface measurements and the subjective evaluations. The subjective evaluation gives higher comfort levels than the flat surface results in most cases. Although the measurements of the force distribution index SAM1 on the normalized head and human head are not very accurate; the correlation with the subjective evaluation appears to be good. Most of the measurements are within the range of the average subjective results plus or minus one standard deviation. Only the human head results of the earmuffs E, G and H are outside the area by a small values. This is a good correlation, considering that subjective evaluation is usually difficult to quantify. It seems that The TEKSCAN measurement system did not make good contact with the surface when used on the artificial head or human head due to its rigidity.

CONCLUSIOS

The results obtained in this study for the measurements of the contact pressure and force distribution between the earmuff cushions and circumaural flesh of the human head can explain the contradiction between the measurement of total force and subjective evaluation in many studies reported in the literature which show that a higher headband force is more comfortable than a lower force. This study reveals that this is due to the details of the pressure distribution. A more uniformed distribution gives more comfort even for a higher total force. Therefore, the design of the headband's point of attachment and flexibility of the cushions is very important.

The results obtained in this study show that some available pressure contact measurement system, for example, TEKCSCAN (resistive-type sensor), can give good results only when measured on flat surfaces (not on the human ear or artificial head). Resistive sensors are probably better than capacitive sensors since they go down to near zero pressure values. Flat surface measurements are not good indicators of comfort, since the results obtained in this study show poor correlation with those of the subjective measurements. Also, flat surface measurements do not represent the real situation of the human head with its curved surfaces, especially for the new hearing protectors with specified left and right earmuffs. Unfortunately, to the best of my knowledge, there is no system available in the market to carry out accurate measurements on a real human head.

In spite of the low accuracy of measurement on the normalized head and human heads using the TEKCSCAN system, and also the limited statistics using only one human subject, the results show good agreement with the subjective evaluation.

The author is currently developing a measurement pressure contact system for the earmuff on the human head made from smart materials.

Acknowledgements

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