Ann. occup. Hyg., Vol. 31, No. 2, pp. 249–254, 1987.
Printed in Great Britain.

0003–4878/87 \$3.00+0.00
Pergamon Journals Ltd.

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EFFICIENCY OF CONVENTIONAL GLOVES AGAINST VIBRATION

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Abstract—Different solutions have been proposed to reduce vibrations generated by tools like chipping hammers, grinders, etc. Among them are special gloves which are actually not used by the workers as they considerably reduce their handiness. The present study was undertaken to examine whether conventional gloves may provide any attenuation. It has shown that the hand–glove system behaves as a one-degree-of-freedom mass–spring system. This acts as an amplifier around its natural frequency which varies from 100 to 600 Hz, depending on the glove. As the most common tools are usually emitting vibrations at low frequencies, conventional gloves are not providing any protection and some of them are even slightly worsening the situation. However, they prevent cooling of the hands and will therefore reduce the occurrence of vibration-induced white finger attacks at work.

INTRODUCTION

IN MANY INDUSTRIAL situations, tools are used that can generate high levels of vibration. Repeated exposure to these vibrations is known to cause osteoarticular and/or vascular disorders (TAYLOR and PELMEAR, 1975; FAWER, 1976; BOVENZI *et al.*, 1980).

Several attempts have been made to eliminate or, at least, reduce vibrations generated by portable tools. For instance, mechanical filters have been incorporated in handles, providing attenuations of about 10 dB in all directions and even for low frequencies (MIWA, 1981). Layers of damping materials made of rubber and plastic foam have been placed directly on the handles (SUGGS and HANKS, 1981). One particular solution consists of gloves with an air-filled alveolar structure (INRS, 1983) or covered with a special material such as Sorbothane (CLARKE and DALBY, 1985).

While these devices can produce significant attenuations, some are, in practice, of limited interest as they reduce the handiness of the tool user. This is particularly the case for the special gloves which are consequently not used by the workers.

Therefore, in many situations, workers are provided with gloves designed for other purposes, in the expectation that, even if the vibration attenuation is lower, the overall protection will be greater, as these gloves are more likely to be worn continuously. The purpose of the present study is to test this hypothesis, that is, to determine whether such gloves may provide any reduction in the transmission of vibrations.

MATERIALS AND METHODS

The analysis was conducted on 11 pairs of gloves designed for different types of risks, such as cuts, chemical agents, abrasion or heat.

Table 1 gives for each of the gloves the type of material used, their weight (g), their thickness (mm) as well as a subjective appreciation of dexterity loss. This was made by the experimenters and based on the perceived rigidity and bulkiness of the gloves.

The transmission loss provided by a glove can be determined by the ratio between

TABLE 1. GLOVE CHARACTERISTICS

No.	Type of gloves	Materials	Weight (g)	Thickness (mm)	Dexterity loss
1	Moufle VDP–Thermox-TB	KEVLAR bouclé, nomex felt lining	38	10	Very high
2	Polysafe Multi	KEVLAR knitting, waterproof neoprene lining	115	6.5	Very high
3	Winter Monkey Grip 23-193	PVC, foam, cotton	95	5.5	High
4	Seams-Rite/H 20-105	PVC, felt	55	2.5	Low
5	Hycron/M Tric/H 27-600	Nitril rubber, cotton	50	2.5	Medium
6	Crusader 42-325L	Nitril rubber, felt bouclé	68	3	High
7	Therm-a-Grip 44-315M	PVC, felt	60	5	Medium
8	Terrytect Verrier	Bouclé + cotton knitting	75	3.5	Low
9	Worker Soudeur Top	Leather, felt	102	6	Very high
10	Safety Robusta Buffle	Leather, cotton	85	3	Medium
11	Cut-Grip Verrier	Natural rubber, cotton	82	3.5	High

accelerations measured at the level of the hand, with and without gloves. This was determined experimentally in the laboratory, using an electrodynamic shaker (B & K 4808) upon which a horizontal handle (Fig. 1) was mounted to simulate the handle of a tool.

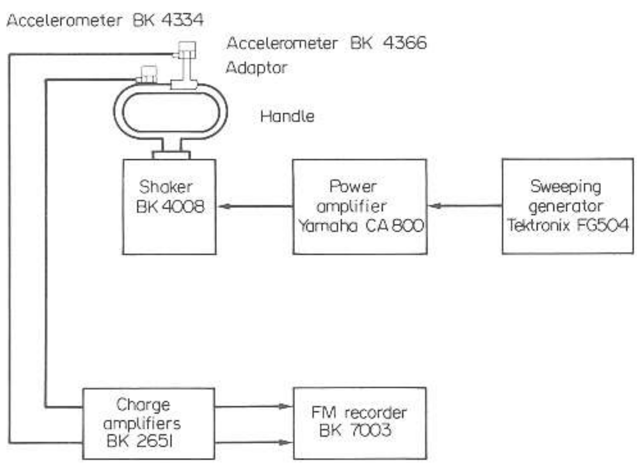

FIG. 1. Set-up used for testing gloves.

The shaker was excited by a sinusoidal signal sweeping from 0.5 to 1000 Hz emitted by a TEKTRONIX FG 504 generator and amplified by a YAMAHA CA 800 power amplifier. The acceleration amplitude was kept constant at 10 m s^{-2}. An accelerometer B & K 4334 was mounted rigidly on the handle in order to monitor continuously the excitation signal. A second accelerometer (B & K 4366) was fixed on a special adaptor to be held between the hand and the handle in order to record the acceleration amplitude at the hand level. This adaptor consisted of a rounded piece of metal held in the palm of the hand by means of a metal stem squeezed between the third and fourth fingers. The accelerometer was mounted on this stem at the level of the head of the third metacarpal bone. This adaptor was designed following the proposition made by RASMUSSEN (1981).

The two accelerometer signals were amplified by two charge amplifiers B & K 2651 and recorded on a FM recorder B & K 7003 (frequency response 0–1000 Hz).

Narrow-band analyses (2.5 Hz wide) of the recorded signals were made in the range of 0–1000 Hz with an FFT Nicolet 444A real-time spectrum analyser. The data were then treated using a MINC-DIGITAL 11/23 computer system.

The grip and the pressure forces exerted on the handle may modify the coupling between the hand and the source and thus influence the results (GRIFFIN, 1981). In order to minimize these factors, all the experiments were carried out by the same person and the forces applied were kept as constant as possible.

An attempt was made to measure these forces with four load cells, disposed in pairs on each side of the handle mounted on the shaker. The handgrip was exerted by means of a sleeve made of two half cylinders of a larger diameter and squeezed by the experimenter against the load cells and the handle. The sum of the four measured forces gave a measure of the grip force, while the difference between the indications of the two pairs of cells measured the magnitude of the pressure force. As the transmissibility of this system was very poor, the forces could not be measured during the experiments. Therefore, this set-up was only used to train the experimenter in exerting a steady grip force (40 N) and cancelling the pressure forces. In addition, each glove was tested three times consecutively in the same conditions.

RESULTS

The analysis was carried out in three successive steps to assess

- —the validity of the method: this was estimated from experiments made without gloves;
- —the reproducibility of the experiments;
- —the mean attenuation provided by the gloves.

Validity of the method

Experiments without gloves were conducted to verify whether acceleration levels in this condition were the same on the handle as on the hand adaptor.

Figure 2 illustrates the differences in dB between the two locations for the three experiments. The repeatability appeared to be very good, as the deviations between the three spectrum analyses were less than 0.5 dB. The absolute error was the largest at 1000 Hz but did not exceed 1 dB. The method can thus be considered reliable and reproducible without gloves.

Repeatability with gloves

The repeatability of the experiments with gloves was studied for each of the 11 gloves. The largest deviations observed between the three tests varied between 2 and 4 dB. Thus, the introduction of a glove between the hand and the handle disturbs somewhat the repeatability of the measure; this will have to be kept in mind when evaluating the actual efficiency of the gloves.

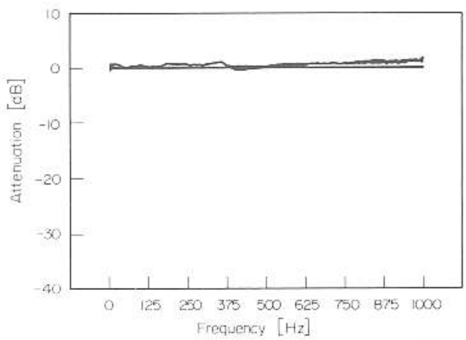

FIG. 2. Frequency–response curves for experiments without gloves.

Mean attenuation of each glove

The 11 gloves may be classified in four groups: Fig. 3 gives the attenuation curves observed for gloves Nos 3, 4, 8 and 11 whose attenuation characteristics are typical of these groups.

For gloves Nos 1, 2, 3, 6 and 10, the hand–glove system behaves as an amplifier below 400 or 500 Hz, depending on the glove. This amplification can reach 5 dB at some frequencies. For higher frequencies, the system acts as an attenuator, with a 15–20 dB decrease at 1000 Hz. Figure 3 illustrates this in the case of glove No. 3.

For gloves Nos 4, 5, 7 and 9, the amplification is not so pronounced at frequencies below 250 Hz. No attenuation is observed at higher frequencies up to 750 Hz; reduction in vibration transmission reaches only 5–10 dB at 1000 Hz (Fig. 3, glove No. 4).

Glove No. 8 (Fig. 3) exhibits a nearly neutral response below 250 Hz and amplifies vibration signals at all frequencies between 250 and 1000 Hz.

Finally, glove No. 11 (Fig. 3) amplifies somewhat the signal at frequencies below 130 Hz; beyond, the attenuation increases progressively to reach 25 dB at 1000 Hz.

DISCUSSION AND CONCLUSIONS

The shapes of the attenuation curves presented above correspond approximately to the frequency response of a one-degree-of-freedom mechanical model, where the spring and damper elements are constituted by the glove. Such a system acts as a transmitter at low frequencies, as an amplifier at frequencies around the natural frequency of the system and as a 12 dB per octave attenuator at higher frequencies. Transmissibility curves presented in Fig. 3 mainly differ regarding the position of the natural frequency defined by $f_0 = (1/2\,\pi)\,(k/m)^{1/2}$, where k is the stiffness coefficient of the glove and m the mass of both hand and glove.

Altogether, the efficiency of the gloves in attenuating vibrations is poor and, in some cases, the exposure conditions appear to be worsened, as low frequencies are actually amplified. Also, it is well known that common tools like drilling or chipping hammers mainly produce vibrations at these frequencies, Fig. 4, (a). At higher frequencies, the attenuation provided by the gloves is of limited interest, as the

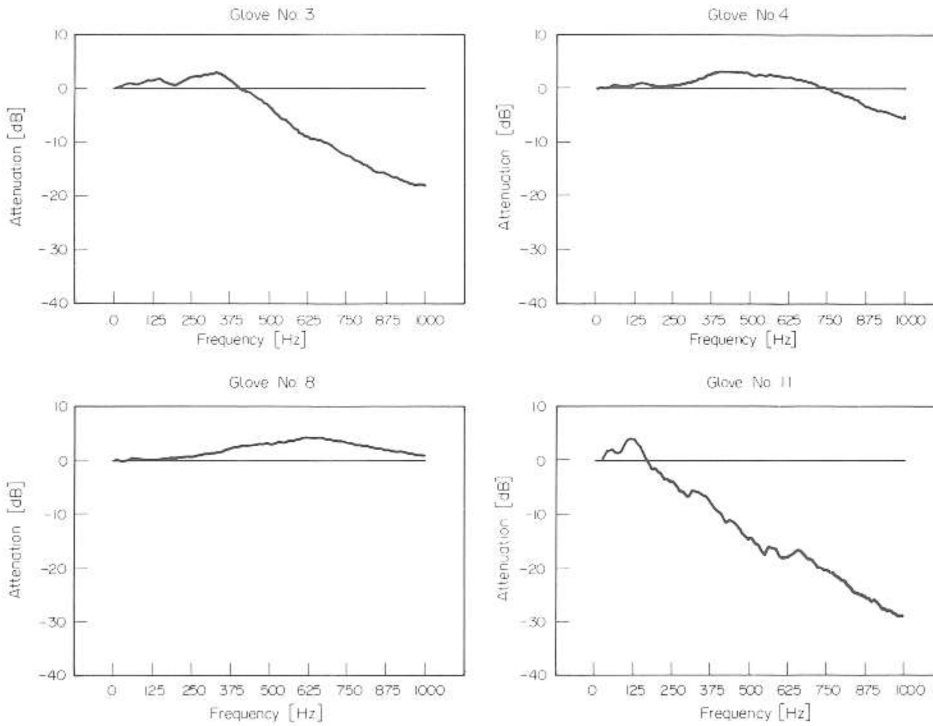

FIG. 3. Attenuation provided by gloves Nos 3, 4, 8 and 11 as a function of frequency.

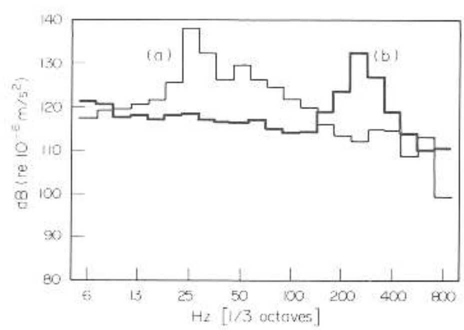

FIG. 4. One third octave band weighted spectra according to ISO 5349. (a) Chipping hammer and (b) pneumatic grinder.

fundamental frequency for the tools with the highest rotating speeds usually does not exceed 300 Hz; this is the case, for instance, for a 18 000 rpm pneumatic grinder, as illustrated in Fig. 4, (b).

Considering glove No. 11 which provides the best performances at high frequencies, the attenuation reaches only 6 dB at 300 Hz. In addition, account must be taken of the reproducibility error at which the order of magnitude is 4 dB, as seen previously.

While such gloves clearly can provide only marginal attenuation, their use could at least contribute to a reduction of vibration-induced white finger (VWF) attacks at the work place. Indeed, VWF attacks are usually triggered by exposure to cold (WASSERMAN, 1985) and most of the pneumatic tools perform by adiabatic expansion of compressed air, resulting in the cooling of the body of the tool and in the exhaust of cold air. Gloves may then be useful to avoid direct contact with these cold sources.

For that purpose, gloves Nos 4, 5, 7, 8 and 9 should preferably be selected for tools giving low frequency vibrations (below 200 Hz), as their use would at least not result in an amplification of the signal in this frequency range. For frequencies higher than 200 Hz, only glove No. 11 could be recommended. However, the loss of dexterity associated with this glove is quite significant.

In conclusion, the attenuation provided by the gloves which were tested must be considered as negligible at low frequencies. Therefore, the choice of gloves for a given task should not be based on vibration protection but should take into account the loss of dexterity, which might raise safety problems, and subjective comfort, which is ultimately the criterion determining whether and how long they will be used.

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