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Attenuation of Noise by Motorcycle Safety Helmets

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For workers such as police motorcyclists or couriers, traffic and engine noise reaching the ears is an important factor contributing to the overall condition of their work. This noise can be reduced with motorcycle helmets. In this study, insertion loss of motorcycle helmets was measured with the microphone-in-real-ear technique and sound attenuation with the real-ear-at-threshold method. Results for 3 Nolan helmets show essentially no protection against external noise in the frequency range <250 Hz. In the frequency range >500 Hz, attenuation increases linearly at a rate of 8–9 dB per octave, to ~30 dB at 8 kHz. Lack of attenuation in the low-frequency range may cause annoying effects. In addition, high attenuation in the high-frequency range may decrease intelligibility of speech signals for a rider in a helmet. Attenuation measured in this study does not take into account noise generated by turbulent wind around the helmet. Thus, the measured values of attenuation represent a motorcycle rider's best conditions of hearing.

noise attenuation   measurements on subjects   motorcycle helmets
motorcyclist conditions of work

1. INTRODUCTION

There are several occupations including police officers, couriers and letter carriers, in which motorcycles are widely used. Motorcycle safety on a road involves several issues such as conspicuity of riders and their vigilance and alertness. Whereas conspicuity is a general problem related to the visibility of the motorcycle (including the motorcycle itself, the driver's uniform and the helmet), a driver's alertness may be affected by the limitations in the perception of signals associated with the road conditions as well as poor physiological conditions under the helmet. Among factors degrading physiological conditions under the helmet such as excessive concentration of carbon dioxide, excessive heat and humidity or limited vision, noise is another factor contributing to the conditions of riding the motorcycle [1], and thus the working conditions of the occupational groups just mentioned [2]. Motorcyclists at work, including policemen and letter carriers, are exposed to noise levels >100 dB(*A*) [3].

Sound reaching a motorcyclist's ear can be subdivided into components including noise generated by wind turbulences around the helmet

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and sounds generated on the road such as the motorcycle engine and tyre noise. Noise definitely impedes the conditions of driving and interferes with other sounds coming from the road that may contain useful information or are part of warning signals necessary in preventing accidents. Thus, the motorcycle helmet has to be treated as a device attenuating noise and useful signals generated on the road, and at the same time as a generator of turbulent noise. The latter becomes an important factor for driving speeds above ~50 km/h.

In this study, attenuation of outside sounds provided by motorcycle helmets was measured using methods similar to those commonly applied to hearing protectors. In terms of a measurement method, a motorcycle helmet was treated like a hearing protector that offers protection against road noise but unfortunately also attenuates signals bearing useful information on various road conditions.

For labelling purposes, sound attenuation of hearing protective devices such as earmuffs or earplugs is measured as a difference in level measured at the threshold of hearing when the protector is donned or doffed. This subjective measurement called real ear at threshold (REAT) is required by Standard No. EN 24869-1:1992 [4]. This procedure can be used for determining sound attenuation of a motorcycle helmet.

Measurement of insertion loss introduced by a helmet is an objective method alternative to the subjective method from Standard No. EN 24869-1:1992 [4]. It was previously used to determine the insertion loss of shotblasting helmets [5, 6]. In those studies, helmets were positioned on head-and-torso simulators or human subjects. Insertion loss was measured using a miniature microphone fixed in the concha. Results for shotblasting helmets showed that attenuation introduced by helmets was negligible for frequencies <500 Hz and gradually increased to ~20–25 dB at 8 000 Hz.

In this study, attenuation of noise provided by motorcycle helmets was determined using both insertion loss measurements and the subjective REAT method. Measurements were performed on human subjects. Insertion loss provided by three Nolan (Italy) motorcycle helmets was estimated. Subjective REAT measurements were performed for one helmet and compared to the insertion loss measurements done on the same helmet. Results of these measurements provided information on how motorcycle helmets attenuate external sounds.

2. MOTORCYCLE HELMETS TESTED

Noise attenuation was measured for three used but all in a good mechanical condition motorcycle helmets. One helmet had an open face design and was equipped with a panoramic visor (Figure 1). The other two helmets (Figures 2–3) were full-face ones, with the N70 XL helmet having an older design than Nolan N102 XL. In Nolan N102 XL, the protective section over the front of the chin was removable. In Nolan N70 XL chin protection was fixed.

Figure 1. A Diamond N41 XL helmet (Nolan, Italy).

Figure 2. An N102 XL helmet (Nolan, Italy).

Figure 3. An N70 XL helmet (Nolan, Italy).

3. MEASUREMENT SITE AND PROCEDURE

Measurements were performed in a test room originally designed for determining sound attenuation of hearing protectors (Figure 4). The

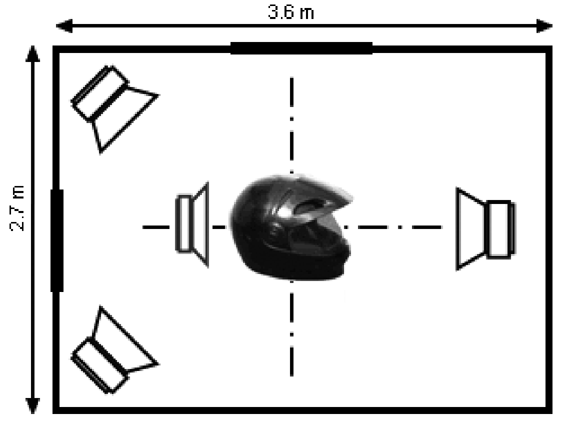

Figure 4. A subject in the measurement chamber.

diffused sound in the area of a subject's head position was produced with four JBL (USA) 4802 loudspeakers powered by two QUAD (UK) 520f power amplifiers. The test room and the diffused sound field met the requirements of Standard No. EN 24869-1:1992 [4]. Pink noise was generated with a Norsonic (Norway) type 828 system controlled with a PC. The wide band level of pink noise (frequency range 50–10 000 Hz) was set to 97 dB. The subjects were seated in the middle of test room. The average height of the entrance of the ear canal was 1.19 m above the floor.

3.1. Insertion Loss Measurements

For insertion loss measurements, the noise level was recorded with a miniature Knowles (USA) BL 1785 microphone. It was placed at the entrance of the subject's ear canal and was attached to the subject with medical tape to avoid any movements when the helmet was donned or doffed. Recorded signal was delivered to a Svan 948 spectrum analyser (Svantek, Poland) and analysed in third-octave bands. The measurement system was checked with a Brüel & Kjær (Denmark) type 4230 calibrator. Calibration was performed before and after each measurement session and every time when the microphone was removed from its position at the entrance of the ear canal.

A measurement session comprised two steps. First, the subject was seated, and the microphone was placed at the entrance to the right ear canal. The measurements in third-octave bands were conducted for an uncovered ear. In the second step, the levels were determined at the same position of the microphone at the ear canal entrance, but the ear was covered with a motorcycle helmet. Insertion loss measurements were made for each of the helmets tested, on 3, 5 and 8 subjects for Diamond N41 XL, N70 XL and N102 XL Nolan helmets, respectively. The subjects were 28–52 years old. Their age was not a critical parameter as the test was merely an acoustical measurement of the sound pressure level and the subjects did not perform any active role during the session.

For each condition, equivalent levels were determined using linear time averaging of the Svan 948 spectrum analyser over 30 s. Measurements were repeated 3 times for each condition. The subjects were given sufficient rest between measurements. Short averaging time and the measurement procedure ensured that subject were not exposed to over normative doses of noise. Insertion loss was calculated as a difference between third-octave levels measured at the entrance of an uncovered ear and levels measured under the helmet.

3.2. REAT Measurements

Attenuation of helmets with the REAT procedure was done according to Standard No. EN 24869-1:1992 [4], except for the number of subjects. Two subjects, a man (32 years old, subject 1) and a woman (28 years old, subject 2) participated in the measurements. Their audiometric thresholds complied with the requirements in the standard. Centre frequencies of one-third octave band-pass noise were spaced in octaves from 63 to 8 000 Hz. Threshold estimates were made for the helmet donned and doffed interchangeably, and sound attenuation was determined as the difference in thresholds between those two measurement conditions. All other testing conditions such as details of the procedure for determining the threshold and noise floor levels in the testing room followed Standard No. EN 24869-1:1992. The measurements were performed for the Nolan N70 XL helmet.

4. RESULTS

Figure 5 illustrates the insertion loss of three motorcycle helmets defined as the difference in signal levels in third-octave bands measured with helmets doffed and donned. Regardless of the details of the construction of the helmets, there was essentially no attenuation of the outer noise level for frequencies <500 Hz. Attenuation gradually increased to ~30–35 dB in the 500–8 000 Hz frequency range. Despite the low number of subjects tested, it is apparent that the spread in individual results was smaller for the open helmet than for the two full-face helmets. For the open helmet it was 2–3 dB up to the centre frequency of 4 kHz, and ~10 dB above that frequency. This spread was ~5 dB below the 4-kHz centre-frequency band and almost 20 dB at 8 000 Hz for the Nolan102 XL helmet.

Figure 6 shows insertion loss of the three helmets averaged over the subjects. It is clear that the overall change in attenuation was similar for all subjects. There was no attenuation in the frequency range <250 Hz. In the 250–500 Hz frequency range, there was attenuation of ~3 dB for the full-face Nolan102 XL helmet only. Above 1 kHz, attenuation of the helmets increased at a rate of about 8–9 dB per octave. Attenuation provided by Nolan102 XL was ~3–5 dB higher than attenuation of Nolan Diamond N41 XL and Nolan N70 XL. The difference in attenuation between the latter two was negligible.

Figure 7 shows the results of REAT measurements. In the high frequency range at 1 000 Hz and above, there was a good agreement between attenuation determined with REAT and insertion loss measured with MIRE especially for subject 2. Data obtained for subject 1 displayed attenuation lower by ~9 and 4 dB with threshold measurements at 2 and 4 kHz, the reason being unknown. In contrast, in the low-frequency range, data from REAT of subject 1 showed attenuation values close to the insertion loss measurement. The REAT data of subject 2 provided attenuation of ~10 dB for frequencies <500 Hz. This was a measurement artefact, which clearly resembled the real conditions of helmet use. Subject 2 could not avoid blowing the exhausted air against the chin protector, which generated extra noise elevating the hearing threshold measured with the helmet donned. Despite being the artefact for the present measurements this situation resembled real conditions of helmet use. If breathing causes extra noise generated inside the helmet, that noise will cause additional masking of all external signals.

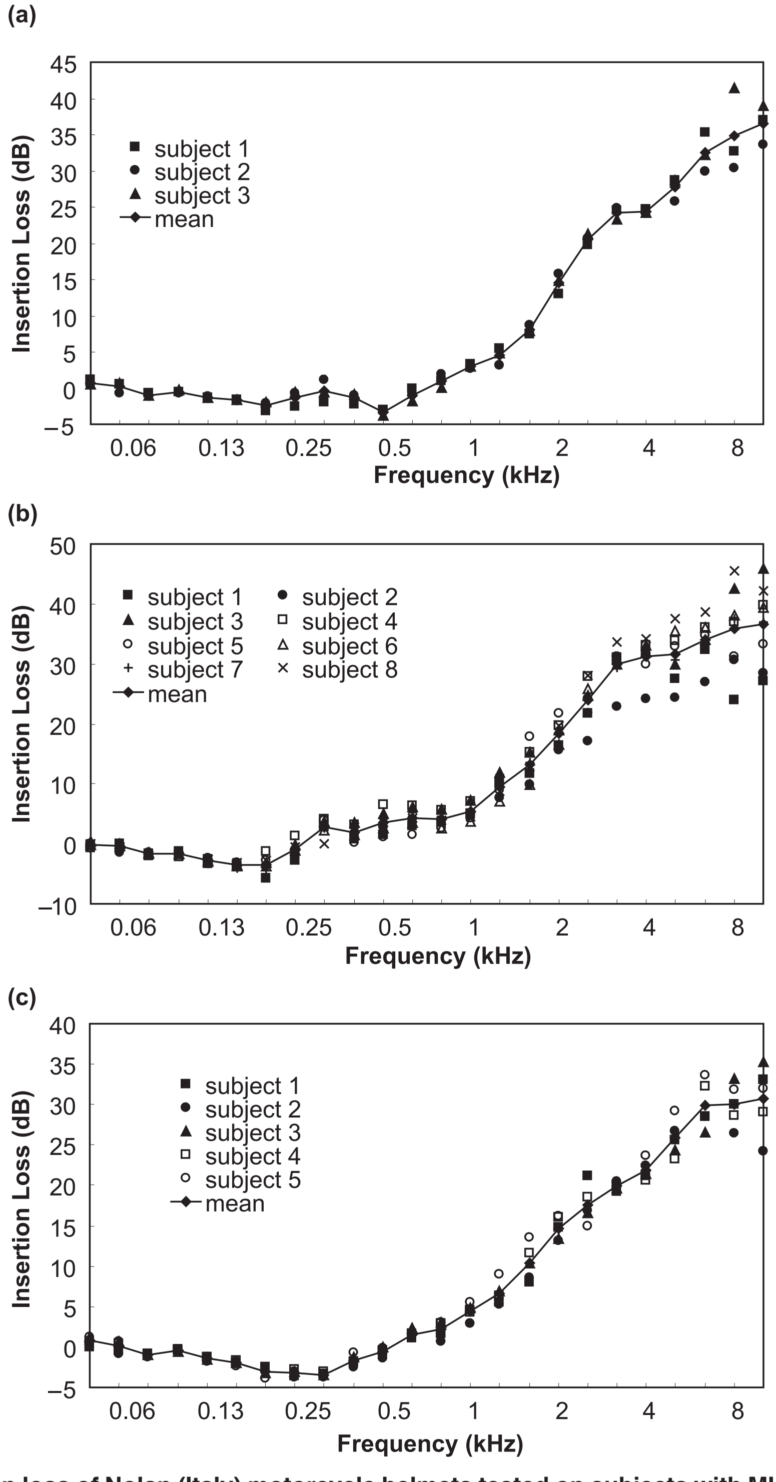

Figure 5. Insertion loss of Nolan (Italy) motorcycle helmets tested on subjects with MIRE (microphone in real ear); (a) Diamond N41 XL, (b) N102 XL, (c) N70 XL. *Notes.* Various symbols represent the spread of individual results. Solid line represents average insertion loss.

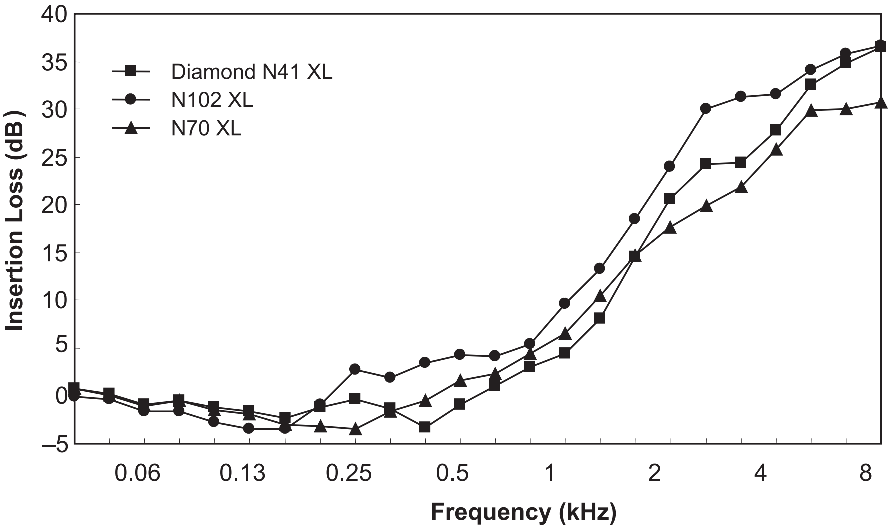

Figure 6. Insertion loss (mean values) of 3 Nolan (Italy) motorcycle helmets tested on subjects with MIRE (microphone in real ear).

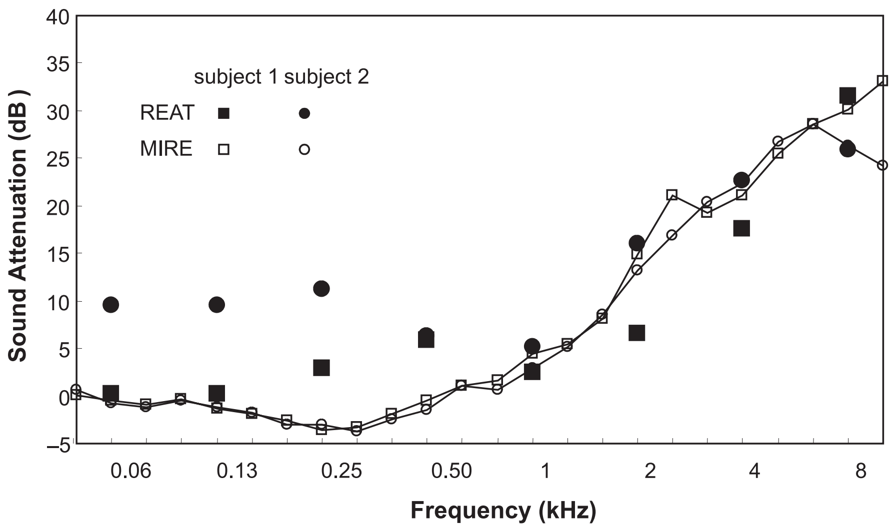

Figure 7. Sound attenuation measured on 2 subjects with REAT method (Nolan N70 XL). *Notes.* Solid lines show insertion loss measurements on the same subjects; REAT—real ear at threshold, MIRE—microphone in real ear.

7. CONCLUSIONS

External noise attenuation provided by the motorcycle helmets is largely frequency dependable. In the low-frequency range (up to ~250 Hz), helmets provide essentially no protection against external noise. In the frequency range >500 Hz, attenuation increases linearly at a rate of 8–9 dB per octave, to ~30 dB at a frequency of 8 kHz. This attenuation characteristic is similar regardless of detailed differences in the design of the helmets, and is similar to the attenuation of shotblasting helmets [6]. The pattern of motorcycle helmet attenuation obtained in this study suggests two unfavourable effects related to helmet use. Poor attenuation in the low-frequency range results in a negligible decrease in low-frequency annoying sounds that may cause riders' fatigue and low alertness. High attenuation in the high-frequency range may seriously impede riders' understanding and comprehension of speech.

Sound attenuation measured with the REAT method is generally similar to attenuation determined as insertion loss. Nevertheless, there are certain effects related to breathing that affect measurement results. This additional noise caused by breathing may occur during a normal use of a helmet. Therefore, elevated attenuation in the low-frequency range observed for one subject may be related to additional masking of useful external signals during actual helmet use.

Attenuation measured in this study does not take into account noise generated in the helmet by turbulent wind during a motorcycle ride at a sufficiently high speed. This noise will cause additional masking of useful warning signals and speech coming from external sources. Therefore, measured attenuation represents best riders' conditions of hearing during a ride when the helmet is worn.

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