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NOISE LEVELS AND NOISE REDUCTION UNDER MOTORCYCLE HELMETS

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1. INTRODUCTION

Noise levels under a motorcyclist's helmet are high and increase rapidly with road speed. Many motorcyclists may suffer damaging noise exposures if they frequently travel at high speeds for long periods. For working riders, eg couriers or police motorcyclists, exposures may regularly exceed the Second Action Level of the Noise At Work Regulations 1989 [1]. Above 60 to 70 km/h (35 to 45 mph) aerodynamic noise from the airflow around the motorcycle and rider is the dominant source. This paper reports noise measurements in a wind tunnel and on the road to quantify noise levels, identify noise sources and paths, and to investigate the possibility of noise reduction.

2. MEASUREMENTS IN A WIND TUNNEL AND ON THE ROAD

Noise levels and spectra were measured in the 2.1 m x 1.7 m Wind Tunnel at Southampton with miniature microphones at the ears of a rider, a police driving instructor. Two motorcycles were used, a BMW K 100and a BMW K 1100 LT with engines not running. Measurements were made with several helmets at airspeeds of 22 to 32 m/s (80 to 113 km/h; 50 to 70 mph) as measured in the undisturbed flow upstream. Helmets were tested as supplied and with various treatments or modifications in an attempt to identify where and how the noise was generated and transmitted to the ear, and to reduce the noise at the ear by passive means. Windscreen heights were also varied. Airflow and turbulence were mapped at the rider's position, but without the rider, using a pitot tube and a hot-wire anemometer. Flow visualisation techniques included smoke and wool tufts.

Noise levels under unmodified roadworthy helmets were also measured on the road at speeds up to 193 km/h (120 mph).

3. FINDINGS FROM FIRST SERIES OF TRIALS

The first series of measurements have been described in more detail elsewhere [1], but the main findings are outlined below.

The levels of wind noise measured at the ear of a motorcycle rider in a wind tunnel at nominal air speeds between 22 and 32 m/s ranged from approximately 90 dB(A) to 109 dB(A), and depended upon the air speed, motorcycle and helmet. There were spreads of 7 - 10 dB approximately between different helmets tested at the same air speed on the same motorcycle.

An important factor determining noise levels at the rider's ear was the design of the motorcycle windscreen and its height and angle. Measurements of the mean air velocity and fluctuations in air speed using a pitot static tube and a hot-wire anemometer showed the edge the windscreen's wake to be highly turbulent.

Depending upon the height of the windscreen, the turbulent zone hits the rider between neck level and the top of the helmet. The turbulence acting on the helmet appears to be the dominant noise source.

With a very low windscreen the turbulence was directed towards the base of the helmet and the rider's neck and shoulders. Modifications to improve the sealing between neck and helmet reduced the noise at the ear. Changes to the visor, which was out of the turbulent zone, had little or no effect. Reductions of up to 6 dB were obtained from improved sealing around the neck at the helmet base.

With higher windscreens the turbulent flow was directed towards the face and, depending upon screen height, hit the visor and/or the helmet shell immediately above the visor. Modifications to the visor were then effective in reducing noise at the ear but changes to the base of the helmet, which was out of the turbulent zone, had no effect. Noise transmission through the visor, around the visor, and through the visor hinges to the helmet shell appeared to be the main limiting factors with higher windscreens. Effective noise reduction methods included using draught excluder to fill the gap between the top edge of the visor and the helmet, or replacing the visor hinges with small pads of foam then sealing around the visor. Reductions of 5 dB - 8 dB in A-weighted levels were achieved by these means.

Airflow over the helmet surface and the flow separation from the helmet were not found to be major sources of noise in comparison with the turbulence from the windscreen. The aerodynamics of the helmet could be modified by adding strips of draught excluder to the helmet surface. This appeared to reduce the drag experienced by the rider, but the noise levels at the ear were not affected.

Internal padding and damping materials applied to the inside of the helmet shell were not effective, except in one particular case where damping in the forehead region appeared to reduce noise when the airflow could be directed sufficiently high to clear the visor.

Because the turbulent air hits different parts of the helmet and rider depending on the windscreen height, the site of the noise generation and the transmission paths to the ear vary. The strengths and weaknesses of different helmets are exposed by different motorcycles and at different windscreen heights. One helmet which was the 'quietest' of a set on a motorcycle with a low windscreen in fact became the 'noisiest' with a higher windscreen. Rank ordering of helmets according to their noise level was not possible since the order varies from motorcycle to motorcycle and from windscreen to windscreen. A single number noise rating for comparing helmets would therefore be misleading.

The windscreen height preferred by many police motorcyclists is a few centimetres below eye level so that they may easily look above the optically poor windscreen. At this windscreen height, the turbulent zone of air is directed towards the top of the visor. A rider looking just above the windscreen was at or near a position of maximum noise. Raising the head by a few centimetres reduced noise levels by 4 - 5 dB, or lowering the head so it was more in the lee of the windscreen reduced noise levels at the ear by 8 - 9 dB with some helmets. The windscreen height which is optimum for keeping airflow off the rider's body and which allows a good view of the road ahead above the windscreen is poor in terms of noise levels at the ear.

Noise levels measured under helmets with each motorcycle driven on the open road ranged from 78 - 90 dB(A) at 13 m/s (30 mph, 48 km/h) to 114-116 dB(A) at 54 m/s (120 mph, 193 km/h) depending upon the helmet, road speed, and motorcycle and wind screen. The average rate of increase in noise levels during the road trials was 15.5 dB per doubling of speed, for speeds above approximately 25 m/s (55 mph). The noise levels measured on the road were similar to those in the wind tunnel for the same helmets and motorcycles when the air velocity in the wind tunnel was corrected to allow for the blockage caused by the motorcycle and rider.

4. FURTHER TRIALS

The first series of measurements showed that the greatest reduction in A weighted level which could be achieved from relatively simple treatments or modifications to the helmet was of the order of 8 dB. Subsequently further trials were carried out in the wind tunnel the scope of work was extended to include hearing protection in the form of earplugs and active noise reduction in earmuffs under a helmet.

Earplugs The earplugs tested were E.A.R. foam earplugs worn under three different helmets. A small hole was punched through a plug to accept a polythene probe tube fitted to a miniature microphone [3]. Noise levels were measured in two locations: in the ear approximately 5 mm beyond the earplug using the probe-tube microphone, and between the earplug and the helmet using a second miniature microphone.

The noise levels under the plug were between 8 dB and 16 dB below the levels at the ear between helmet and plug. In the best cases, noise levels were as low as 74 dB (A) at 22 m/s and 80 dB (A) at 32 m/s nominal air speed.

Active Noise Reduction A flying helmet containing earmuffs with an active noise reduction system was fitted to the rider. The ANR earmuffs replaced the original, light-weight earmuffs supplied with the helmet. Muffs were held against the rider's ear by webbing straps. Again tests were at nominal air speeds of 22 m/s to 32 m/s and the height of the motorcycle windscreen was varied. With the original earmuffs noise levels at the ear were between 91 and 107 dB(A) depending on speed and windscreen height. With the new earmuffs, but with the ANR switched off, noise levels were between 83 dB(A) and 100 dB(A) at the ear. With the ANR switched on, noise levels were reduced to between 70 dB(A) and 87 dB(A). The active noise reduction consistently reduced A-weighted levels by 12 to 13.5 dB. This demonstrates in principle that ANR systems could be fitted effectively in motorcycle helmets. However, when the ANR system and muffs were fitted in a conventional motorcycle helmet very little active noise reduction was obtained. Indications from the trials were that the earmuffs need to be well isolated from contact with the helmet shell in order to be effective.

5. CONCLUSIONS

The main noise source was the turbulent flow from the top of the windscreen. The turbulence hits the helmet at a position somewhere between the neck or the top of the visor depending upon the windscreen's height. This position determines whether improvements to the sealing round the neck or improvements to the visor and its sealing and hinges will be more effective at reducing noise. Noise reductions up to 8 dB were achieved by simple helmet modifications or treatments. The lowest levels at the ear were obtained under earplugs and under a flying helmet containing earmuffs with active noise reduction

6. REFERENCES

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