Proceedings of The Institute of Acoustics

NOISE EMISSION FROM INDIVIDUAL VEHICLES

R.R.K. JONES, D.C. HOTHERSALL
SCHOOL OF CIVIL AND STRUCTURAL ENGINEERING,
UNIVERSITY OF BRADFORD.

A noise survey has been carried out on manoeuvring vehicles operating on public roads in order to establish the form of relationship which exists between instantaneous sound pressure level due to an individual vehicle, and its velocity and acceleration. Measurements were taken at ten different positions, spread over seven sites which were level and open, and close enough to some form of restriction in traffic flow to ensure that vehicles would tend to be accelerating or decelerating. Mean velocity and acceleration were measured over a 4m section of road using a pair of commercially available remote sensing devices, each of which operated by measuring the time taken by a vehicle in traversing a 2m length of the road bounded by co-axial cables stretched across its surface, perpendicular to the direction of travel. The sound was detected by a microphone placed at a height of 1.5m above the ground, and 7.5m from the judged centre of flow of passing traffic half way along the measurement section, enabling a tape recording of the noise signature of passing vehicles to be made.

The passage of a vehicle was recorded only if it appeared likely that there was no acoustic interference from other vehicles, and a simultaneous commentary was made on the second channel of the tape recorder specifying the vehicle type, and the point when its front wheels were at the centre of the measurement section, as well as the readings in seconds x 10^{-4} from the remote velocity and acceleration devices. Recordings were played back through an octave filter set and level recorder to give the sound pressure level in each octave band between 63Hz and 8kHz when the vehicle was at the central position. Any trace which showed acoustic interference from other vehicles was eliminated ensuring that all results applied to vehicles operating in isolation. The octave band levels were corrected for the frequency response of the record/ playback system, and then weighted and summed to give the instantaneous sound pressure level in dBA.

In order to determine the functional form of the relationship between sound pressure level in dBA and velocity and acceleration, multiple regression techniques were applied. 1045 results were available and these were divided into the usual two categories of light and heavy vehicles containing 874 and 171 vehicles respectively. Functions of increasing complexity were fitted to the data, which tended to increase the multiple correlation coefficient, until the standard error of estimate was not significantly reduced by further complexity. This led to the choice of a function in log V,A,A^2, and A log V. V is velocity in km/h and A is acceleration in m/s^2. The A log V term accounts for the expected velocity dependence of the effect of acceleration on noise. The sound pressure levels in each octave band were then analysed using the same form of equation, and the full set of results is shown in Table 1. The mean velocity and standard deviation for light vehicles were 53.3 km/h and 19.6 km/h respectively, and the corresponding values for heavy vehicles were 53.6 km/h and 16.5 km/h. Mean acceleration and standard deviation for light vehicles was $-.2 m/s^2$ and $1.5 m/s^2$, respectively and for heavy vehicles these were $-.1 m/s^2$ and $1.7 m/s^2$. A three dimensional representation of the 'A' weighted results is shown in Figure 1.

The relatively high values of standard error of estimate indicated in Table 1 reflect the large amount of scatter of the results. This is to be expected due to the wide range of vehicle type, condition, and driver behaviour encountered in real situations. It was hoped, however, that analysis of a large amount of data, spread over several sites would cause the effects of these variables to be averaged out, and the reasonably high values of the multiple correlation coefficient can be taken as an indication that this approach was justified. To assess whether combination of data from all measurement positions was a valid approach, regression analyses, using the same form of equation, were carried out for each set of data. The combined standard error for all positions analysed individually was reduced from 4.1dBA (all positions combined) to 2.9dBA for light vehicles and from 3.5dBA to 3.1dBA for heavy vehicles. The value for heavy vehicles of 3.5dBA for all positions combined was obtained by re-analysis of all the data, less those values from sites yielding numbers of results too small for the individual site analysis to be carried out. The improvement in standard error of 1.2dBA for light vehicles and .4dBA for heavy vehicles was considered small enough to justify retention of the equations derived from all data combined in the light of fact that the data displayed a great deal of scatter, and that a general expression valid over a wide range of velocity and acceleration was preferable to a number of expressions for small ranges.

The factors which affect sound pressure level emission from individual vehicles can be divided into two main groups, these being firstly the vehicle's construction, design and tyre type, and secondly the operational variables of engine speed, engine load, road speed, vehicle loading, road type and gradient. Variations between identical vehicles will also occur due to inconsistencies in the manufacturing process, and these variations can increase with the age of the vehicles as maintenance histories will differ. The effect of the operational variables on emission is dependent on driver behaviour especially when gear changing is involved.

Figure 1 shows the general trend for both heavy and light vehicles that at low velocities increasing the acceleration rate has a marked positive effect on sound pressure level, with this effect reducing as velocity increases, until at very high velocities there is a small negative effect. This is probably due to the fact that high speed decelerations will tend to involve the use of engine braking in a lower gear, and hence a higher engine speed. The fact that high acceleration rates do not often occur in normal vehicles at high road speeds results in a lack of data for this case, biasing the result toward the deceleration effect.

Above a speed of about 55km/h most vehicles are in top gear, and their road speed is therefore related directly to their engine speed. Below this speed gear changing means that such a direct relationship does not occur, especially as the manner in which gears are selected is dependent on vehicle type and driver behaviour. At low road speeds a high acceleration probably occurs in a lower gear than a low acceleration, and therefore the increase in level is affected not only by increased load on the engine, but also by the higher engine speed. When a vehicle is in top gear at high road speed, the engine is subjected to a considerable load purely to maintain the speed. It is unlikely, therefore, that the extra load caused by acceleration will greatly increase total load and therefore the small augmentation in levels

	Frequency band Hz	Regression Coefficients					r	σ dB
		Constant	log V	A	A^2	A log V		
	dBA	33.2	23.8	10.6	-.08	-5.73	.76	4.1
	63	80.9	-1.7	6.7	-.33	-3.79	.22	6.4
	125	51.1	14.3	14.9	-.21	-8.34	.47	6.7
Light	250	39.0	18.3	10.8	-.07	-5.78	.59	5.2
874	500	27.1	24.4	9.4	-.05	-4.94	.73	4.5
vehicles	1K	21.8	27.8	9.4	-.07	-5.11	.82	3.8
	2K	20.5	26.1	10.0	-.13	-5.64	.78	4.1
	4K	20.0	23.9	10.2	-.05	-5.57	.72	4.6
	8K	17.1	22.9	11.4	-.09	-6.22	.63	5.8
	dBA	48.5	18.9	7.5	-.11	-4.29	.63	3.9
	63	76.2	3.4	9.8	-.28	-5.59	.20	6.6
	125	56.4	14.2	7.2	-.25	-4.56	.45	5.8
Heavy	250	42.5	20.4	7.4	-.18	-4.37	.61	4.6
171	500	39.6	20.7	7.1	-.17	-4.04	.60	4.6
vehicles	1K	41.9	19.7	7.1	-.05	-4.01	.63	4.1
	2K	41.3	18.6	7.8	-.08	-4.57	.59	4.5
	4K	30.8	22.0	5.6	-.10	-3.16	.58	5.2
	8K	25.1	22.2	6.3	+.01	-3.46	.52	6.1

Table 1. Regression results for sound pressure level in each octave band, and in dBA.

caused by acceleration at high speeds as indicated by the regression curves is to be expected, especially as levels will already be high due to high engine speed.

The equations relating instantaneous sound pressure level in dBA to vehicle velocity and acceleration have been incorporated in a digital computer simulation of traffic noise in restricted situations, where the effects of vehicle manoeuvring on individual vehicle noise emission are significant.

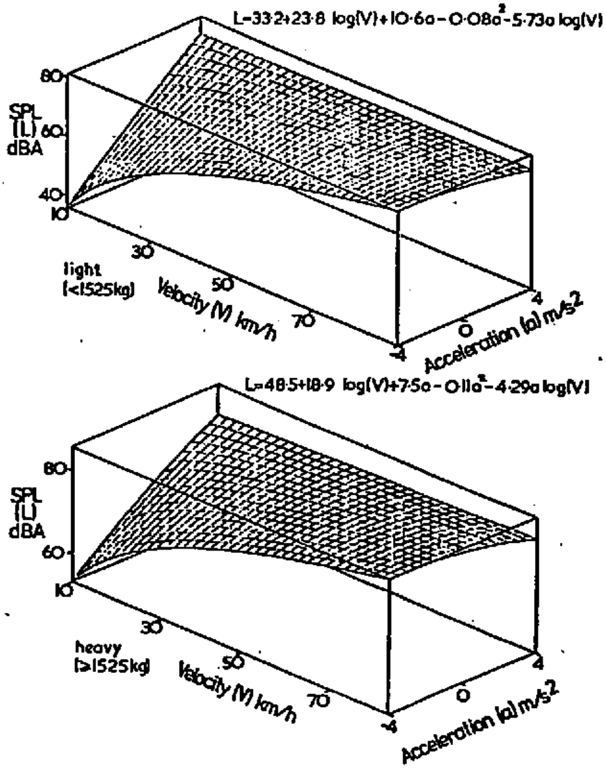

Figure 1. Instantaneous S.P.L. at 7.5m from vehicle centre line as a function of velocity and acceleration.