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THE EFFECT OF DIESEL ENGINE ACCELERATION RATE ON NOISE LEVEL

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INTRODUCTION

Most vehicle exterior noise legislation is based on a drive-by test where the vehicle is accelerated at its maximum rate for the gear ratio selected past a stationary microphone position. The engine will be at a light load condition (constant vehicle speed) prior to the test. The engine speeds at the start and finish of the test will vary according to the test procedure, but maximum vehicle noise will usually be produced at somewhere between 80% and 105% of rated speed [1].

Engine noise at any given speed under transient conditions will usually be greater than that measured at a stabilised full load state [2,3]. Under steady state conditions bearing clearances and combustion chamber temperatures will be optimised, whereas under transient conditions high loads and fuelling are occurring at "cool" light load bearing clearances and combustion chamber temperatures. The effect is to increase engine mechanical noise (from increased clearances) and to increase combustion noise (from an increased delay period) [3]. This transient noise increase is usually greatest for turbocharged diesel engines due to turbocharger inertia.

In order to assess the likely engine noise increase during vehicle testing Ricardo practice is to carry out a 'free' transient acceleration at maximum speed demand from a low speed light load condition to governor run-out (in the case of a diesel engine). The engine accelerates the sum of its own and the dynamometer inertias. Such tests will produce a mean acceleration rate of the order of 25 rev/s^2, whereas vehicle acceleration rates (81/334/EEC tests) are typically 4 rev/s^2 for diesel trucks and 9 rev/s^2 for gasoline passenger cars.

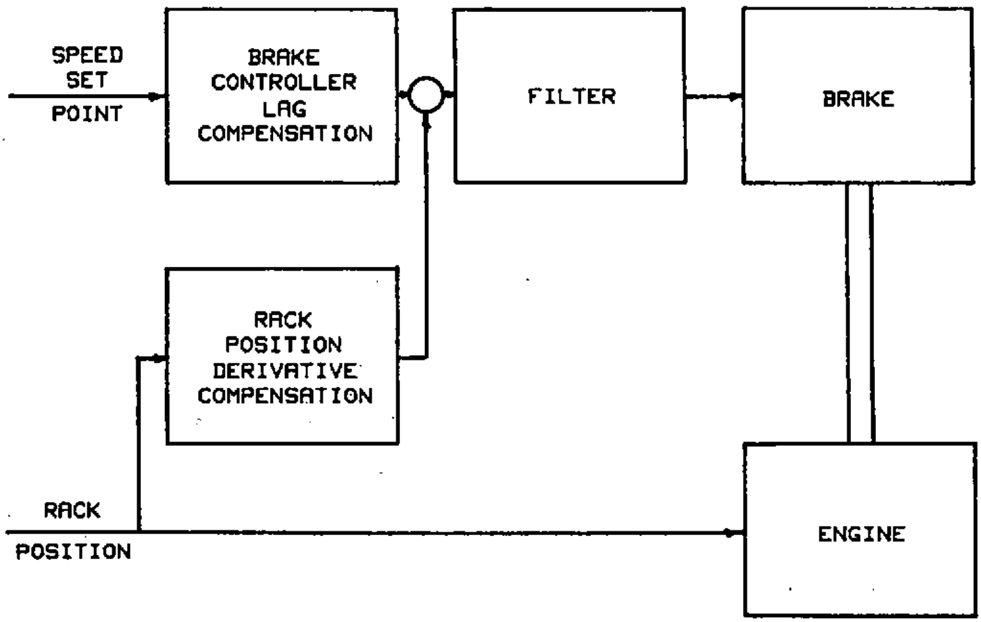
Whilst such 'free' transient acceleration tests are easy to carry out, because of the high engine acceleration rates they may not accurately reproduce the noise levels which might be produced by an engine during a legislative vehicle drive-by test. It was therefore decided to carry out an assessment of the effect on radiated noise of engine acceleration rates in the range 4 rev/s^2 to 25 rev/s^2.

EQUIPMENT AND EXPERIMENTAL TECHNIQUE

The tests were to be carried out on a naturally aspirated 14 litre direct injection diesel engine (a typical "premium" truck engine) installed in an anechoic cell. The installation followed standard Ricardo practice except that the manual rack control was replaced by a Kinetrol Type EP pneumatic actuator. This actuator was controlled by a Ricardo Speed and Torque Controller which also controlled the Schenck type W400 eddy current dynamometer (positioned outside the cell).

The Speed and Torque Controller was pre-programmed to achieve the desired engine acceleration rates during the full rack (maximum speed demand) transient tests. The control scheme is shown diagrammatically in figure 1.

FIGURE 1 TRANSIENT SIMULATION CONTROL SCHEME: CONTROLLER



The initial conditions were nominally 20 rev/s at 8% of rated torque. The engine was accelerated to governor run-out (40 rev/s nominal). It was initially intended to carry out some tests with a relatively high initial speed (circa 75% of rated speed), but due to the nature of the eddy current dynamometer this did not prove possible. Typical control signals and responses are shown in figure 2.

Noise measurements were made using B & K 4165 microphones at the standard Ricardo side positions (1m horizontally from cylinder head gasket at the engine centre). Engine cylinder pressure was measured

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using a flush mounted Kistler 6121 transducer in No.2 line.

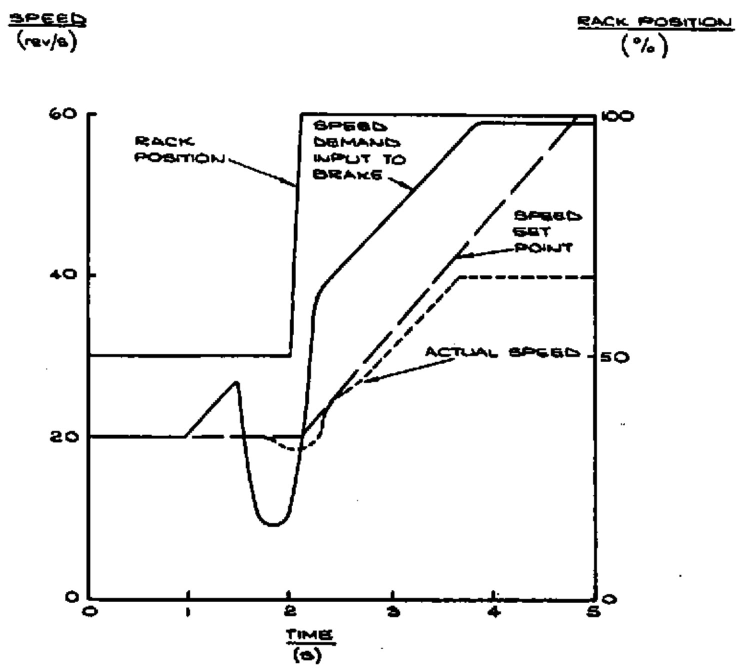
The following data was recorded on a Racal Store 7D FM tape recorder during the transient tests:

1) Noise - RHS
2) Noise - LHS
3) Cylinder Pressure
4) Cylinder Pressure - high pass filtered at 250Hz
5) Engine Speed - 60 tooth wheel signal
6) Injector Needle Lift
7) Degree Timing Markers

The engine acceleration rate was measured by recording the engine speed on a Rikadenki chart recorder and then determining the mean slope of the resulting trace.

Maximum noise levels ('A' weighted "Fast") were obtained by replaying the recorded data into a B & K 2203 Sound Level Meter. Noise versus engine speed plots were obtained by replaying the data via a B & K 2607 amplifier into a Bryans X-Y recorder.

FIGURE 2 TRANSIENT SIMULATION CONTROL SCHEME: TYPICAL CONTROL SIGNALS AND RESPONSE



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In order to study the effect of acceleration rate on engine combustion several cylinder pressure time histories were analysed using a Hewlett Packard Type 5451C Fourier Analyser. The Analogue to Digital Converter of this analyser was locked to 512 samples per engine revolution so that each data block of 1024 samples contained information from one engine cycle.

RESULTS

Figure 3 shows two typical engine speed time histories, figure 3 a) being close to the maximum acceleration rate achieved whilst figure 3 b) represents the minimum acceleration rate.

FIGURE 3 TYPICAL ENGINE SPEED TIME HISTORIES

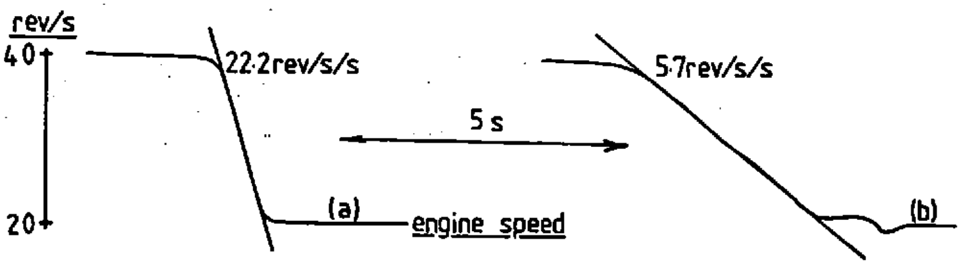

FIGURE 4 TYPICAL ENGINE NOISE v SPEED PLOTS AT HIGH AND LOW ACCELERATION RATES

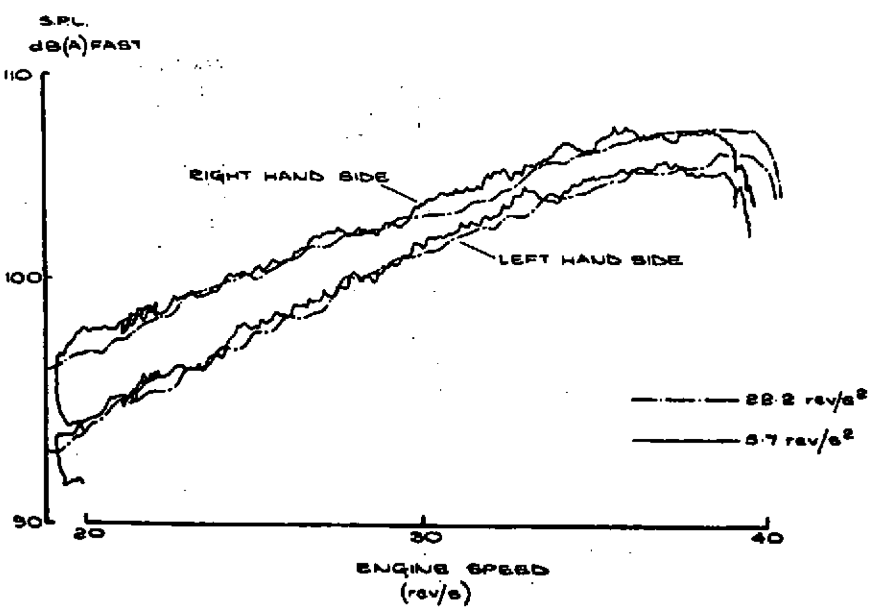

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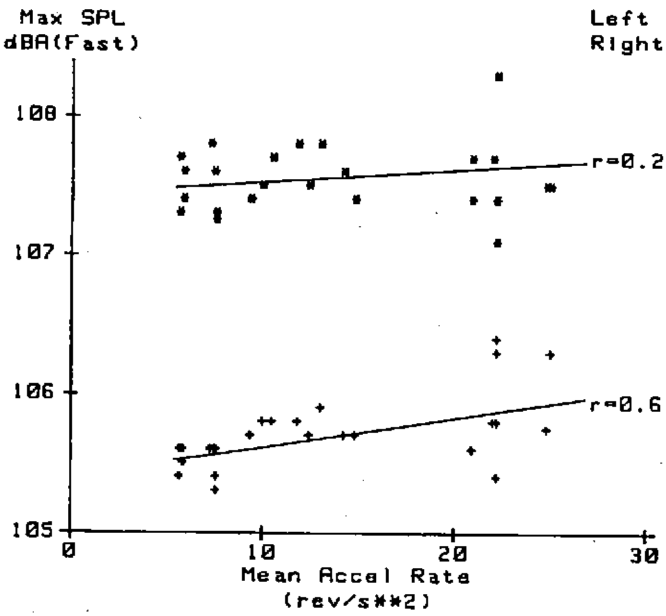
Figure 4 shows two typical engine noise versus speed plots for high and low acceleration rates.

Figure 5 shows the maximum 'A' weighted "Fast" noise levels at the two microphone positions plotted against acceleration rate. Data from tests on three different days is shown together with least squares fit lines for both data sets.

FIGURE 5 MAXIMUM RMS FAST 'A' WEIGHTED NOISE LEVELS AT SIDE MICROPHONES



Cylinder pressure development is shown in figures 6 and 7 for acceleration rates of 22.2 rev/s^2 and 5.7 rev/s^2 respectively. The maximum cylinder pressure spectra from the tests shown in figures 6 and 7 are given in figure 8 (spectra from the 250Hz high pass filtered signal).

DISCUSSION

The slowest acceleration rate achieved was 5.7 rev/s^2 (figure 5) and this is slightly higher than the typical mean value of 4 rev/s^2 for diesel trucks. However, the trends shown in both left hand and right hand noise levels indicate no significant change between 4 rev/s^2 and 5.7 rev/s^2.

At the maximum rate of acceleration the measured 'A' weighted noise levels are 3.5 dB and 3 dB higher than the rated speed and load steady state levels for the left and right side positions respect-

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ively. The arithmetic mean increase in decibel noise levels (transient compared with steady state) from seven truck DI diesel engines (3 TC, 4 NA) tested by Ricardo is 4.2 dB (standard deviation 2.4 dB), so the noise level variation with acceleration rate seen in figures 2 and 3 is negligible. This must be due to the slowest measured acceleration rate still being "fast" in comparison with the time required for the engine temperatures to stabilise after the transition from light to full load, as shown by Watanabe et al [3].

FIGURE 6 CYLINDER PRESSURE DEVELOPMENT AT 5.7 REV/S/S ACCELERATION RATE

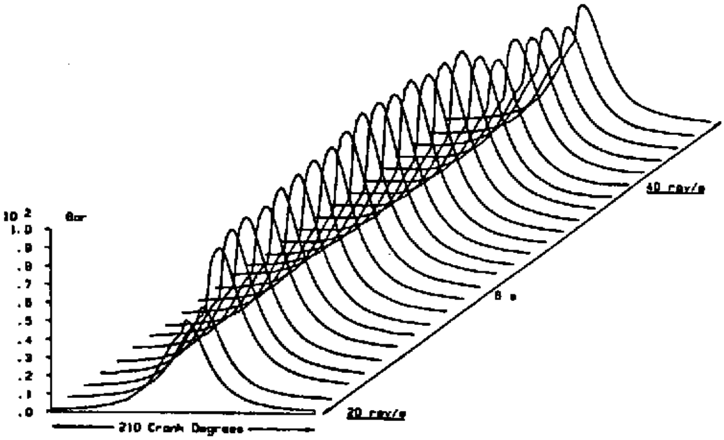


FIGURE 7 CYLINDER PRESSURE DEVELOPMENT AT 22.2 REV/S/S ACCELERATION RATE

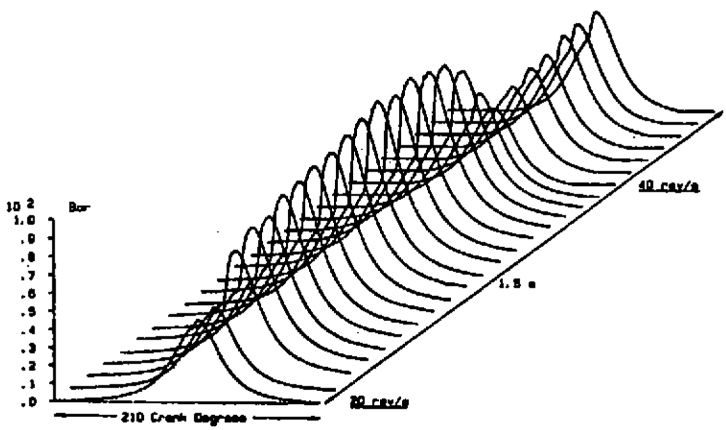
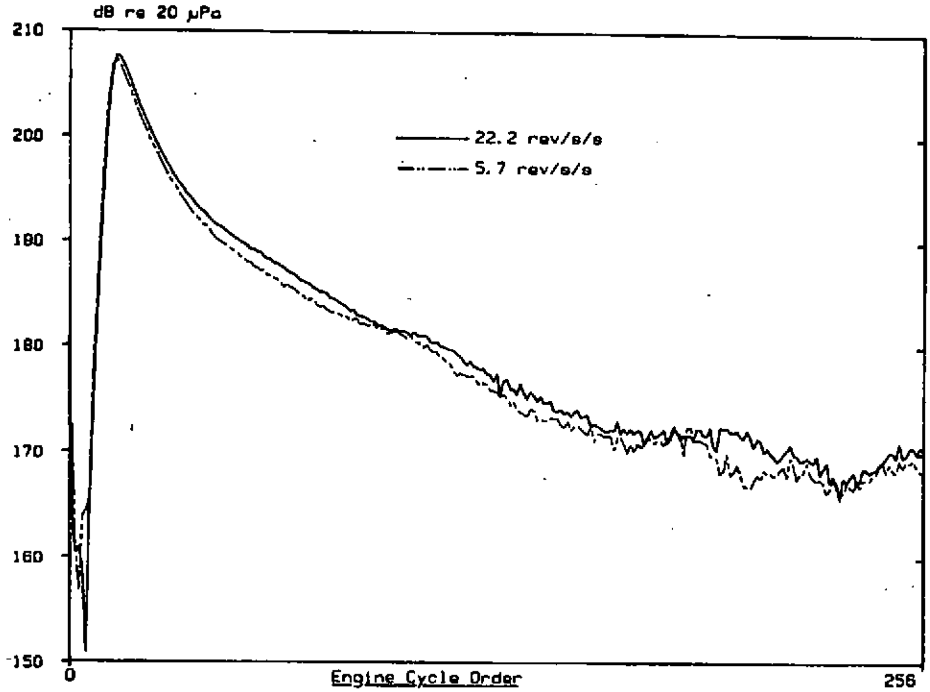


FIGURE 8 COMPARISON OF MAXIMUM CYLINDER PRESSURE SPECTRA (HIGH PASS FILTERED AT 250Hz)



This is confirmed in figures 6, 7 and 8 where, even during the 5.7 rev/s^2 transient, figure 7, the cylinder pressure diagram shows a very rapid pressure rise at the start of combustion and the maximum cylinder pressure spectrum is very similar to that recorded during the 22.2 rev/s^2 transient figure 8 .

The inability of the controller/dynamometer combination to simulate the normal drive-by test engine starting speed (circa 75% of rated speed) was a disappointment, but previous work using the 'free' transient type of test with varying starting speeds has shown no change in the maximum noise level so it is unlikely that higher starting speeds would have a significant effect on the tests carried out in this investigation.

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CONCLUSION

The maximum 'A' weighted "fast" noise level to the sides of a 14 litre naturally aspirated diesel engine has been shown to be virtually independent of acceleration rate in the range 6 rev/s^2 to 25 rev/s^2 when the acceleration transient is preceded by light load running. This is due to the engine being required to run at full load whilst at light load temperatures. The time taken to achieve full load steady state temperature is considerably longer than the time taken at even the slowest acceleration rate measured.

From the data obtained in this investigation it is confirmed that the practice of simulating engine conditions during vehicle drive-by tests with a 'free' acceleration at full rack from an initial light load and low speed condition is valid.

ACKNOWLEDGEMENTS

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