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TYPICAL DRIVING PATTERNS OF CARS AND TRUCKS AND HOW THEY COINCIDE WITH DRIVING ACCORDING TO NOISE MEAURING STANDARDS

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1. INTRODUCTION

Since 1970, noise emissions from powered vehicles have been subject to uniform limits throughout the European Union. These limits have meanwhile been reduced several times, often substantially. The real reduction in noise emissions from road traffic has, however, been much smaller. This is due partly to the fact that the acceleration events on which noise measurement in the homologation test is based are not generally mirrored by the operational modes of the engine in real traffic. This emerges clearly from the results of studies of driving behaviour for cars and lorries in real traffic which FIGE has carried out or is now carrying out on behalf of the German Federal Environmental Agency.

2. DATABASE

The data on driving behaviour in lorries are taken from a study aimed at improving the measuring method for pollutant emissions from diesel engines in heavy goods vehicles and at obtaining driving cycles which could be used to calculate emission factors [1]. In this project, driving behaviour was determined in practical operations for a total of 30 lorries and local transport buses from 5.6 t to 40 t total permitted weight. In addition, data from an analogous Swiss study involving four further vehicles are available. The field measurements were carried out in 1992 and registered road speed, engine speed and torque (on the transmission shaft). The data volume ranges from 8 to 24 h, depending on the vehicle; were sampled at one-second intervals.

In the case of cars, driving behaviour studies were performed on 10 different types of vehicle varying considerably in terms of their technical design attributes (see Table 1). The measurements were made on a predefined circular route in the Aachen area, selected to represent all road categories from a residential street to a feeder road (constructed to semi-motorway standards and with a speed limit of 100 km/h). Three different driving modes were adopted for each vehicle:

- avoid unnecessarily high engine speeds and vehicle acceleration
- behave like most of the others in traffic fleet
- try to minimize driving time

vehicle no.	engine	capacity cm³	rated power kW	rated speed min^-1	idling speed min^-1	gearbox	number of gears
1	4R	1999	110	6000	950	manual	5
2	4R	1799	90	5500	800	manual	5
3	6B	3600	200	6100	750	manual	6
4	4R, Diesel	1900	66	4000	900	manual	5
5	4R, Diesel	1900	66	4000	900	automatic	4
6	V8	4000	210	5800	700	automatic	5
7	V8	4000	210	5800	650	manual	6
8	5R, Diesel		90	3800	650	manual	5
9	4R	1239	40	5300	750	manual	5
10	4R	1242	44	5500		automatic	continuous

Table 1: Technical data of the test vehicles (cars)

The results (road speed, engine speed, drive torque) were sampled at 100 ms.

3. EVALUATION AND INITIAL RESULTS

The vehicle acceleration and engine power were determined from the measured values. The conversion factors used to calculate engine power were found by matching the full-load curve (manufacturer's data) to the generating curve for the measured data. This permits determination of the time components for full load and various sub-load levels. The main indicators used for evaluation were two-dimensional distributions of road speed and acceleration, normalized engine speed and normalized engine power. Normalization of the engine speed was based on the formula

$$n_{norm} = \frac{n - n_{idle}}{s - n_{idle}}$$

(s = rated engine speed, n_{idle} = idling speed)

The normalized engine power values are referred to the full-load power for the appropriate engine speed in each case.

In addition, time curves for the above-mentioned variables are analyzed as a function of the road type, for example in order to filter out typical acceleration events.

Cars

Fig. 1 shows an example of a two-dimensional frequency distribution for normalized engine speed and normalized engine power for a medium-sized car (maximum speed 190 km/h). The car is driven mainly in the range of normalized engine speeds from 20 to 50 % (corresponding to 1700 to 3100 r.p.m.) and in the sub-load range. Full-load modes are of subordinate importance. Fig. 2 depicts the normalized engine speeds versus the road speed for the example shown in Fig. 1, but only for positive accelerations. This indicates the ranges within the individual gear stages which are used in real operation and makes it possible to compare them with the operating modes used for noise measurements in the homologation test. In the homologation test, the vehicle is accelerated at full power in second and third gear from a speed of 50 km/h. It is evident from Fig. 2 that only the acceleration event in third gear corresponds to real operating behaviour. Fig. 3 shows the influence of vehicle size or, more precisely, engine power. For the small cars in the study (maximum speed 150 km/h), even the acceleration event from 50 km/h in third gear is of only limited practical relevance.

There is an entirely different situation in the case of lorries.

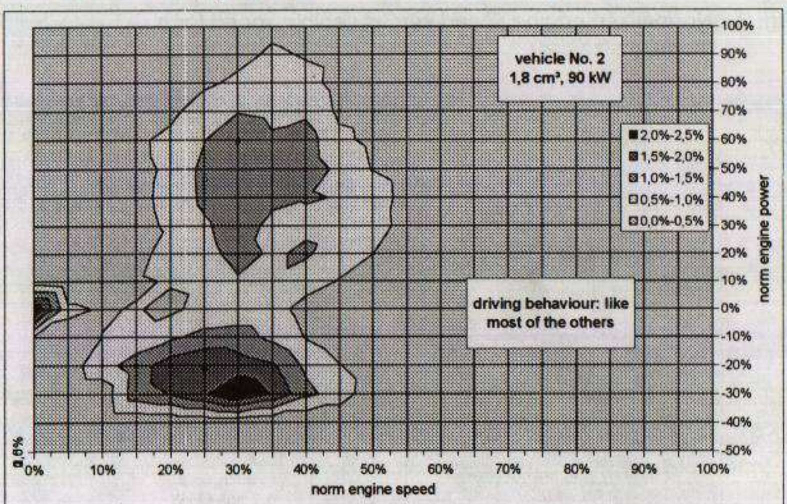

Fig. 1. Joint frequency distribution of normalized engine speed and power for a car

Lorries

Like Fig. 1, Fig. 4 shows the two-dimensional frequency distribution for the normalized engine speed and normalized engine power of a 40 t articulated lorry with a rated power of 277 kW. Unlike car engine speeds, lorry engine speeds in real operations rise as high as the rated engine

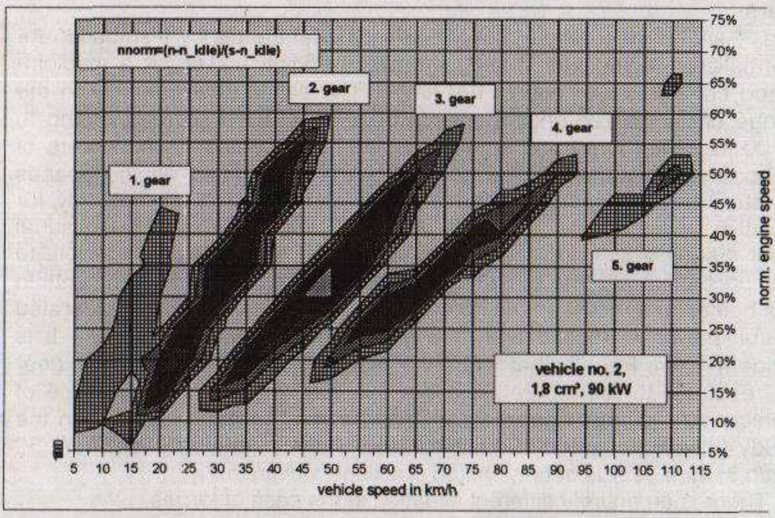

Fig. 2. Normalized engine speed versus vehicle speed for a medium size car

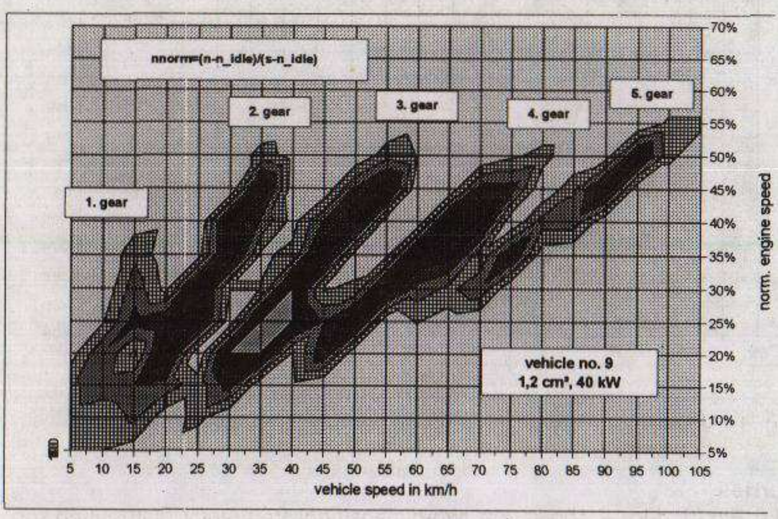

Fig. 3. Normalized engine speed versus vehicle speed for a small car

speed, although this is not often reached. The most common operating modes are full load, thrust and the sub-load range with normalized engine speeds from 45 % to 55 % (corresponding to 1100—1250 r.p.m.) The latter occurs mainly in free-flowing traffic. Typical acceleration events take place from a normalized engine speed of 50 % and rise to some 85 %. In the homologation test, this vehicle is accelerated from 28 % normalized engine speed to the governed speed, without a trailer. This means that the engine speeds used in real traffic are within the engine speed range covered by the homologation test. However, the noise value determined in the homologation test corresponds to engine speeds in the vicinity of the rated engine speed. Figures 5 and 6 summarize the differences between cars and lorries for the case of uni-dimensional distributions of normalized engine speed and engine load in road traffic and indicate the differences between different lorry power classes. The car curve is averaged from 9 vehicles.

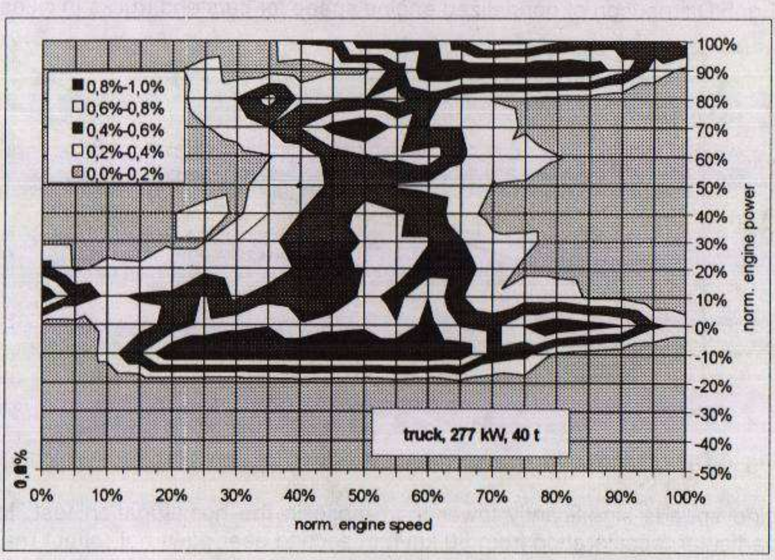

Fig. 4. Joint frequency distribution of normalized engine speed and power for a 40 t semi-trailer truck

4. SUMMARY

Driving behaviour for cars and lorries in real operation was determined by measuring road speed, engine speed and torque. In practice, most cars are driven at much lower engine speeds and engine loads than lorries. In the case of cars, acceleration events in real operations take place at en-

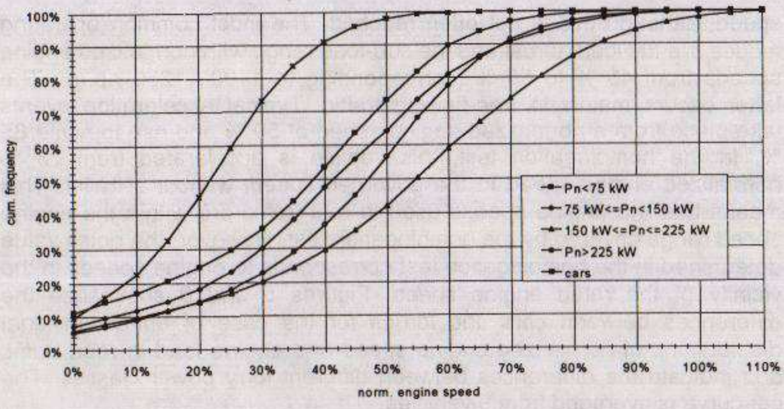

Fig. 5. Distribution of normalized engine speed for cars and trucks in cities

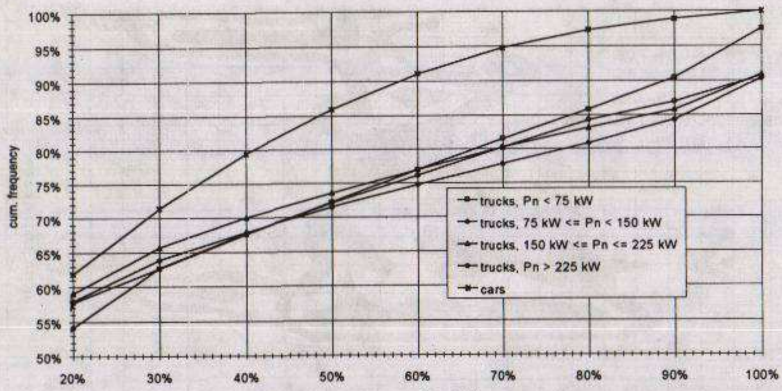

Fig. 6. Distribution of normalized engine power for cars and trucks in cities

gine speeds significantly lower than those in the homologation test. In particular, acceleration from 50 km/h in second gear does not reflect real operating practice. In the case of lorries, the spectrum of engine speeds covered by the homologation test is usually much wider than that for real acceleration events. The measured noise value in the homologation test roughly corresponds to rated engine speed, which is rarely attained in practice.

Literature

[1] H. Steven, Engine Torque and Speed Distributions of Commercial Vehicles in real traffic and its Consideration in Emission Measurement According to EC Directive 88/77/EEC or ECE Regulation R 49