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SIX DECADES OF VEHICLE NOISE ABATEMENT - BUT WHAT HAPPENED TO THE TYRES?

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INTRODUCTION

The industrialization and technical development has claimed several sacrifices in the environment, one of them being the silence. Here road traffic noise is the major offender since several decades. However, traffic noise disturbed already the old Romans, as their chariots and delivery vehicles rolled through the streets causing a lot of noise. As ref 1 reports, the Roman author Martial wrote that "the noise on the streets at night sounded as if the whole of Rome was travelling through my bedroom".

Unfortunately there are no dB(A) values reported from that activity. However, the introduction of the air inflated rubber tyre, patented 1888 by the Irish J.B. Dunlop, must have meant an improvement in the traffic noise environment on the cobbled streets. But the benefit of this was soon - if not immediately - compensated by the increasing density of engine-powered vehicles. Backed by the force of public opinion a departmental committee on "Noise in the operation of Mechanically-Propelled Vehicles" was established in the U.K. in 1934 (ref 2). There was a corresponding development in Germany; already in 1938 there was a vehicle noise regulation in that country. When one looks back on these activities, one is surprised by the extensive work made in those years in the absence of practical measurement equipment.

The vehicle industry was not insensitive to the complaints on noise. Especially the driver's noise exposure was the goal of reduction and this had benefits also for the external environment. But what help is the improved quality if the quantity is increasing virtually without limitations, as was the case for the number of vehicles and the speed at which they were driven during the past three decades?

BACKGROUND FOR THE NOISE MEASUREMENTS ON OLD CARS

In order to take the proper action against the future noise problem, knowledge about past and present trends is essential. How much more quiet have the vehicles become during the past decades, i e have the regulations and public concern had any effect, and how much more quiet have the tyres become? These were some of the questions which we sought answers to without finding any useful comparable measurements. So, we decided to make an experimental study which also included some concern for the influence of tyre design on the tyre/road noise. There are, namely, some hypotheses concerning this influence which needed to be tested using a great variety of tyre dimensions.

Despite the scientific value of such an experiment, it was decided to perform the main part privately, without any public sponsorship. Otherwise, one could imagine problems with the press if they found some researchers playing around with veteran cars on government money.

PURPOSE AND OUTLINE OF THE PROJECT

The purpose of the experimental program was threefold:

- o To obtain information concerning vehicle noise from some cars from the past 60 years.
- o To obtain information concerning how tyre/road noise might have changed during 60 years of tyre development.
- o To see if any influence of tyre dimensions on noise can be detected.

The ambition was not to detect minor trends but to see if changes of the order of 5-10 dB(A) occurred through the years.

Two-three vehicles from each decade 1920-1980 were selected and the external noise of these was measured when the vehicles were accelerating, cruising and coasting by a microphone at the road-side. The measured overall noise levels, frequency spectra and some selected directional characteristics were studied.

MEASUREMENT OBJECTS

From the very early British measurements it could be seen that most cars emitted very similar noise levels (ref 2). Most of them fell within a 4 phon (loudness) range, a result which is comparable with today's quite small noise differences between cars. The small differences can make a limited sample quite representative. In this study the cars presented in fig 1 were chosen. The selection was based on the availability, condition and representativity (in proportion to the former Swedish market) of the cars. They were all in excellent, and in essential parts original, condition as is usual for such personal treasures. In addition to the cars in fig 1, seven cars from 1977-78 were included as a basis of reference. They were 1-2 years old at the time of measurement.

A wide range of tyre dimensions and type was obtained as can be seen in fig 2. These tyres were in reasonable original condition with the exception of the rubber properties. To have any control of the rubber the shore hardness was measured.

MEASUREMENT METHODOLOGY

In the applicable parts the requirements of the ISO 362 method were fulfilled, which e.g. meant that all measurements were made utilizing a microphone located 7.5 m from the center of the vehicle running track and 1.2 m above the ground. The measurements were recorded for later laboratory analyses. If nothing else is stated the presented data are A-weighted maximum levels; time constant "fast" or 0.25 s.

Five driving conditions were used:

1. Full throttle acceleration on 2nd gear from 50 km/h
2. Cruising at 40 km/h in second highest gear (cars with only two gears were tested in top gear)
3. Coasting with the engine switched-off at 70 km/h (or max speed if this is lower)
4. Coasting at 50 km/h. Coasting is assumed to give only tyre/road noise
5. Coasting at 30 km/h

The road surface was a smooth asphalt concrete. Its macrotexture profile between 2 and 100 mm wavelengths was about 0.2 mm rms, approx equivalent to 0.3 mm sand patch texture depth. In other tests it has been shown to give a tyre/road noise level quite typical of worn bituminous roads in Sweden.

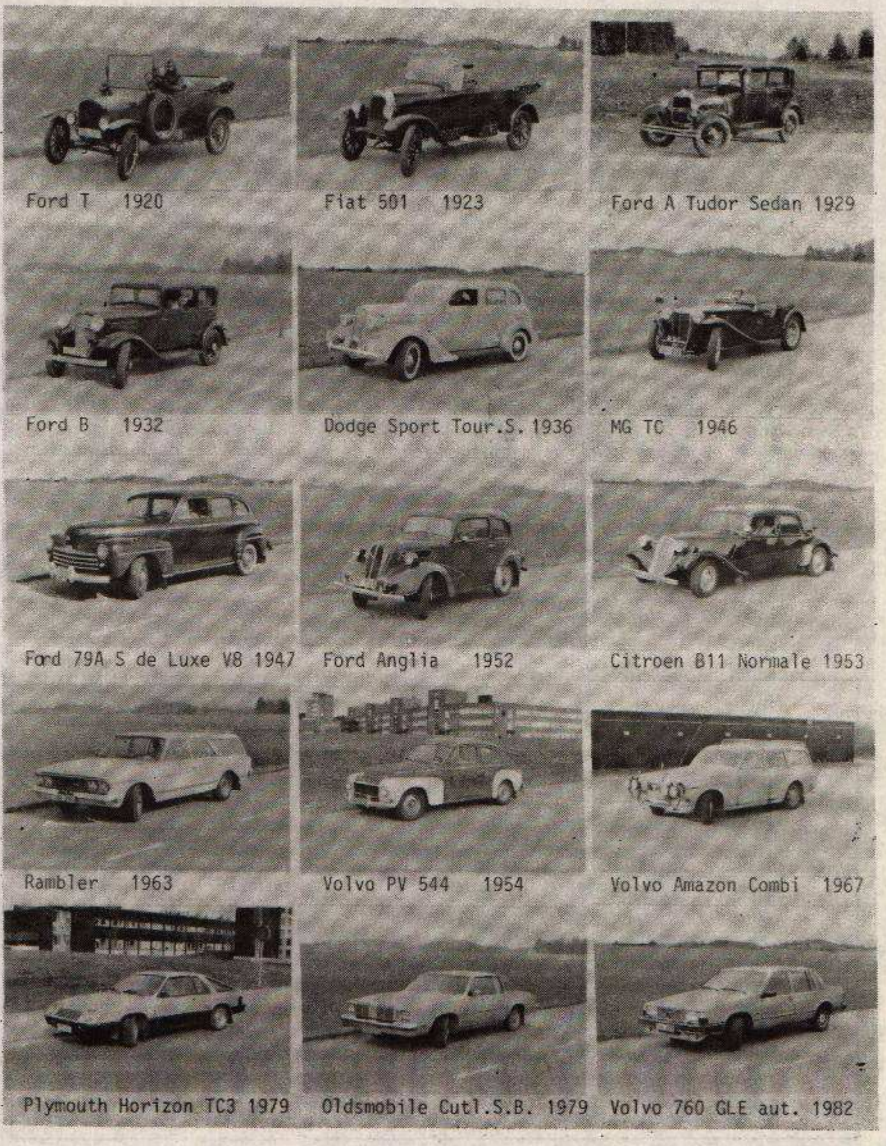

Fig. 1 The tested cars (7 cars of 1977-78 model are missing)

SIX DECADES OF VEHICLE NOISE ABATEMENT

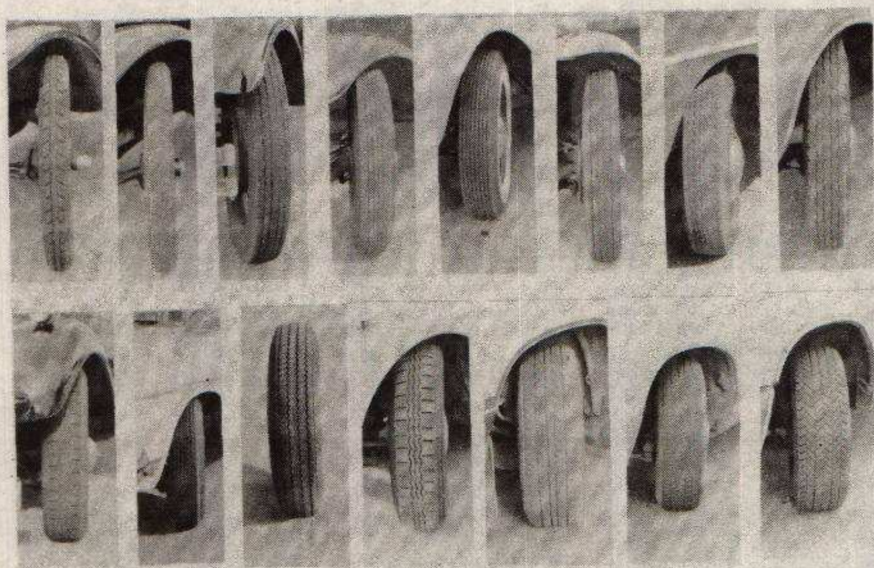

Fig. 2 The tested tires. See table 1 for identification (the tires on car models 1977-78 are missing)

Vehicle type	Year model	Car weight in kg	Tyre type	Tyre size	Tyre/road noise 30 km/h	Tyre/road noise 50 km/h	Tyre/road noise 70 km/h	Vehicle noise 40 km/h cruise	Vehicle noise 50 km/h acceler.
Ford T	1920	850	Dunlop Cord (block/rib)	30-3.5	(65.1)	(72.2)	-	73.0	77.1
Fiat 501	1923	1050	Dunlop Cord (block/rib)	760-90	59.7	68.4	74.2	68.7	72.6
Ford A Tudor Sedan	1929	1130	Dunlop (5 ribs)	4.50-21	63.4	69.3	75.0	76.9	76.2
Ford B	1932	1230	Dunlop Gold Seal (5 ribs)	5.25-18	63.6	72.5	77.8	72.1	84.7
Dodge Sport Tour. Sedan	1936	1520	Firestone de Luxe Champion	6.00-16	62.4	70.6	74.6	73.4	81.7
MG TC	1946	880	Dunlop G (5 ribs)	4.50-19	61.8	71.1	76.1	73.4	89.1
Ford 79A S de Luxe V8	1947	1610	Fore: Goodyear All W. Ride Aft: Firestone de Luxe Ch.	6.00-16	64.0	72.2	78.4	71.2	79.0
Ford Anglia	1952	850	Trelleborg T71, Atlas 4S	5.00-16	58.6	68.1	73.0	77.3	83.0
Citroen B11 Normale	1953	1260	Michelin X (radial)	165-400	62.2	70.1	75.3	74.7	79.6
Rambler Ambassador 6388	1963	1980	Goodyear All Weather Rib	6.70-15	63.9	72.1	78.2	68.8	78.1
Volvo PV 544	1964	1080	Goodyear G8 (bias ply)	165 S15	62.5	70.2	75.2	67.9	78.6
Volvo Amazon Combi	1967	1260	Michelin X	185SR15	61.6	68.7	74.1	68.1	80.8
Saab 99GL Combi	1977	1220	Conti TS771	165SR15	61.4	68.9	74.1	66.5	76.9
VW Golf GLS	1977	805	Gislaved Speed 116	155SR13	62.4	69.8	75.5	66.7	79.4
Renault 14TL	1978	865	Michelin ZX	145SR13	58.1	66.7	72.1	65.0	80.1
Ford Taunus 2.0L Combi	1978	1145	Michelin ZX (reinf.)	175SR13	59.4	67.3	72.5	66.6	78.3
Ford Granada 2.0	1978	1315	Uniroyal Rallye 180	175SR14	62.5	70.9	75.8	66.2	78.6
Volvo 244L Automatic	1978	1250	Gislaved Speed 116	175SR14	61.3	70.1	74.8	66.1	74.4
Volvo 245L Combi	1978	1325	Firestone Cavallino S1	185SR14	62.2	70.5	75.8	67.4	80.5
Plymouth Horizon TC3 C.	1979	1100	Goodyear GT Radial	P185/70R13	62.7	70.7	76.0	67.9	77.5
Oldsmobile Cutl.Supr.B.	1979	1660	Uniroyal Steel Belted R.	P195/75R14	64.1	71.7	76.9	66.3	77.0
Volvo 760 GLE (autom.)	1982	1390	Pirelli P6	195/60R15	62.5	71.0	76.1	67.9	76.9

Table 1 Vehicle/tyre data and A-weighted sound levels. See text for comments

RESULTS

Overall A-weighted sound levels

Table 1 shows the A-weighted sound levels obtained for the five driving conditions listed above. The following should be observed: A few of the oldest vehicles emitted noise from the transmission which was not completely negligible during the coast-by measurements. However, a special transmission noise test was made and the resulting sound was subtracted from the coast-by results. Therefore the coast-by values given in the table are valid for tyre/road noise. The only exception is for Ford T which was not tested for transmission noise, but where this noise was clearly audible. The coast-by values for this car concern tyre/road noise AND transmission noise. A few of the oldest vehicles had difficulty in reaching 70 km/h. In those cases the values for 70 have been extrapolated from the max speed reached.

A few features may be commented. If one interpolates the tyre/road noise to speeds comparable with those in the vehicle noise test it appears that tyre/road noise dominates over power-train noise for all the tested cars of model 1977-82 at 40 km/h and for one car (Volvo 244L Autom.) at 50 km/h full throttle acceleration. The maximum noise difference between all the tyres is only 6 dB(A) while the corresponding difference between the cars when accelerating or cruising is 11-15 dB(A). If the tyre/road noise values are plotted against vehicle weight one finds that the noise increases about 0.4 dB(A) per 100 kg.

Spectral characteristics

The spectral characteristics for a sample of the cars is shown in fig 3 (tyre/road noise at 50 km/h) and fig 4 (cruising noise at 40 km/h on second highest gear). In the latter case, for the two newest cars the noise is dominated by tyre/road noise. For cruising noise there is a considerable variation in both level and spectral shape. This has no correspondence regarding tyre/road noise. However, one feature is that the rib tyres seem to peak at 1-2 kHz which well fits the pipe resonance theory. Another feature is that the old Dunlop Cord tyre has a peak both at its tread impact frequency 375 Hz and at very high frequencies. It is the only tyre that has any air pockets in the tread, see fig 8. These are vented to the side and should thus give a Helmholtz resonance emitting sound at high frequencies.

Directional characteristics

By studying the time records of the noise at pass-by and correcting for the distance variation, the directional characteristics can be investigated. It was found here that these properties are very different between modern and old tyres. Fig 5 shows the difference in A-weighted overall levels between the tyre/road noise in the direction 30° relative to the running direction (backwards right) and the noise in the direction perpendicular (90°) to the car. This can be seen as a directional factor and is obviously correlated with the tyre dimensions.

The results indicate that for high and narrow tyres the sound is quite omnidirectional, while for wider and lower tyres the sound is more and more concentrated backwards. Unfortunately this increase backwards is not detected by the pure max sound level measurement at a coast-by. The increased directional concentration is in support of the horn effect presented in ref 3, i e the volume between the tyre tread at the trailing end and the road builds up as an acoustical horn which amplifies the generated sound. The wider the tyre, the more effective is the horn.

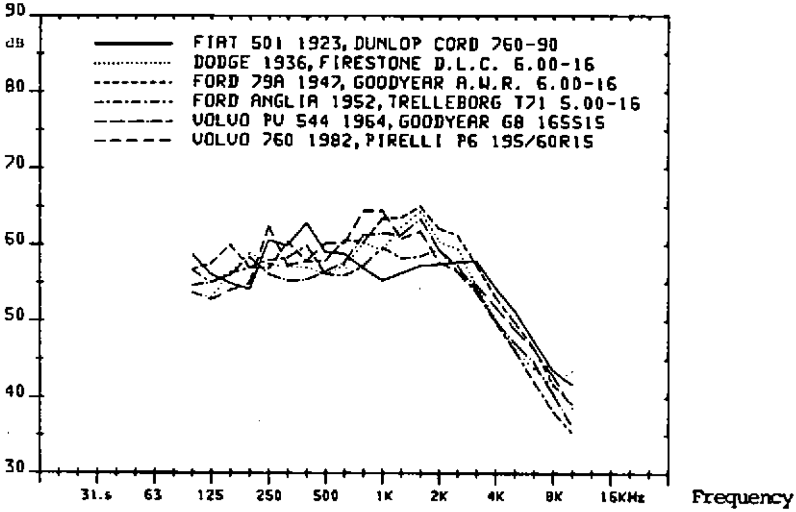

Fig. 3 Third-octave band spectra for six of the cars when coasting at 50 km/h (tyre/road noise)

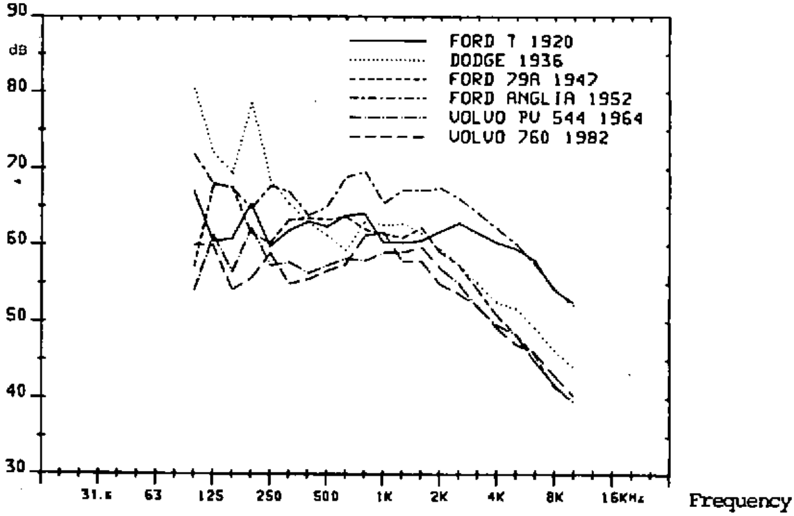

Fig. 4 Third-octave band spectra for six of the cars when cruising on the second highest gear at 40 km/h

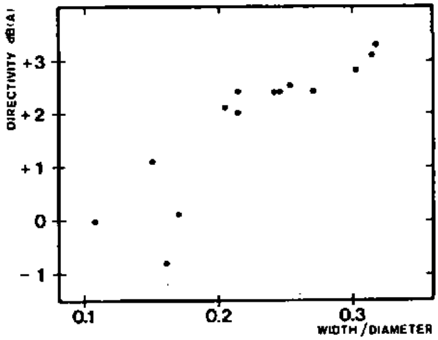

Fig 5.
Directivity of tyre/road noise, expressed as the difference between noise levels 30° backward of the cars and those in sideward direction, plotted against tyre width/diameter (outer dimensions). Speed is 50 km/h and level comparison concerns 7.5 m from the cars.

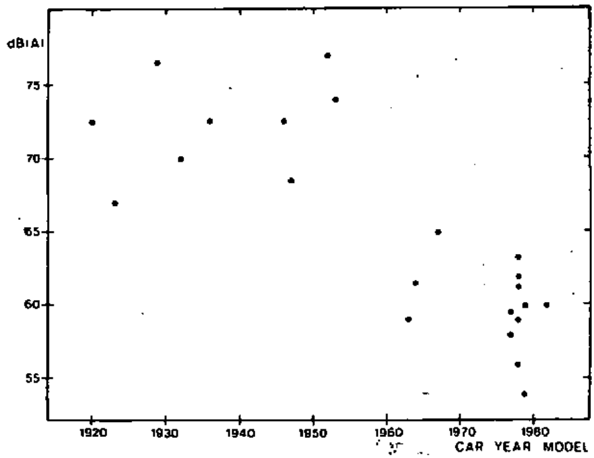

Fig. 6 Power-train noise at cruising 40 km/h as a function of car year model. Tyre/road noise has been subtracted (see text).

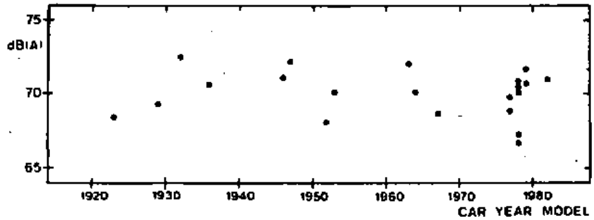

Fig. 7 Tyre/road noise at 50 km/h as a function of car year model

Noise level versus year model

Fig 6 displays the power-train noise level (tyre noise excluded) versus year model of the car. The values are based on the 40 km/h cruising noise, from which the tyre/road noise at 40 km/h has been subtracted. The latter was calculated by interpolating the measured values at 30, 50 and 70 km/h. The corresponding age influence on tyre/road noise at 50 km/h is shown in fig 7.

For the limited sample included in this investigation it is obvious that power-train noise has been greatly reduced during the last 30 years. The reduction is in the order of 10-15 dB(A), a result which is not very surprising. More surprising is, however, that tyre/road noise has not been reduced at all. Considering the change in directional characteristics it might even have increased somewhat. It must then be remembered that the tyres have been developed as much as the rest of the cars; the only visible similarity 1920-1980 being that the tyres are still round and mostly black.

CONCLUSIONS

An investigation on the vehicle and tyre/road noise emissions from a sample of cars covering the time period 1920-1982 has been performed. It is shown that while power-train noise has been reduced 10-15 dB(A) in that period, tyre/road noise has not been reduced at all, despite 60 years of intensive tyre development.

This has resulted in that far from all of the power-train noise reduction has been exploited as an environmental improvement as the tyre/road noise has put a limit to what is obtainable in total reduction.

However, the directional characteristics of the tyre/road noise have been changed as the tyres have gradually developed from high and narrow to low and wide. The latter has resulted in tyre/road noise becoming more directional, i e more noise radiates backwards. This is believed to be caused by the so-called horn effect.

The results are illustrating the difficulty of reducing tyre/road noise, yet it demonstrates that this is more necessary than ever if any total traffic noise reduction is required. No "automatic" tyre/road noise reduction can be expected if one extrapolates these trends.

Fig 8
The contact patch tread pattern of the oldest and newest tyres in the test. Note the difference in width/length ratio and the side vented air pockets of the old Dunlop tyre.

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