inter·noise 96
25th Anniversary Congress – Liverpool

INCE: 13.2

A NEW VEHICLE NOISE MEASURING METHOD REPLACING THE ISO 362 PRINCIPLE

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1. IDENTIFICATION OF THE PROBLEM

Since the early 70's, vehicle noise emission has been regulated on the basis of noise level limits for various vehicle categories tested at type approval. The measuring method has been the ISO 362 procedure, or variations of it such as ECE/R51 or Directive 92/97/EEC (all of them hereafter referred to just as ISO 362). The method is reviewed below:

The ISO 362 method in summary:

- The vehicle selected for type approval approaches, in unladen condition and at constant speed, a line crossing the test track 10 m ahead of the microphone location. At the microphone location there is one microphone on the left side and one on the right side, each one displaced 7.5 m sideways from the centreline of travel. Measurements are always conducted outdoors.
- When the line 10 m ahead of the microphones is reached, the vehicle is accelerated with wide-open throttle (limitations apply in certain cases) until it has passed 10 m beyond the microphone location, when the throttle is closed.
- Initial constant speed is generally 50 km/h for cars (2nd and/or 3rd gears) and in the range 5-50 km/h for heavy vehicles (using a wide gear selection).
- Max. noise level in the two microphones during the acceleration is recorded and after repetition runs and some processing constitutes the final result.

Noise sources, when using ISO 362:

- Power unit (engine, transmission, exhaust, etc.); at extreme acceleration
- Tyres (powerful unladen vehicles ⇒ extreme tyre torque ⇒ tyre slip)

History of ISO 362:

The method was principally developed in the late 50's after rather extensive and ambitious development work and was found to be very useful for the purposes of that time. The limits imposed the first time (ca. 1970-75) were quite relaxed and did not require any extensive vehicle modifications.

As soon as tightened noise limits became difficult to comply with, vehicles were optimised for this situation, so that power unit noise has since been highly affected by the requirements but tyres have been virtually unaffected.

This method is receiving increasingly serious criticism for regulating noise emission inefficiently. In an extensive evaluation of the effect of emission limits, made by a working party under I-INCE [1], it was concluded that only minor parts of the nominal tightenings of noise limits were effective as environmental improvements. Therefore, it was recommended that "*A new measuring procedure for use during type approval of vehicles shall be developed. It must result in more representative driving conditions*" and also that "*Not only vehicles in new condition, but also vehicles in service should be regulated and checked with respect to noise*".

In [2] it is shown that a limit based on ISO 362 does not reject many of the cars which are "noisy" in actual traffic, but rejects some "quiet" cars. When lowering the limit by 2 dB based on ISO 362, the accepted cars had an L_{Aeq} in "representative" driving of 66.3 dB which was only 0.4 dB lower than the value when no cars were rejected. However, when using ISO 7188 the gain would be 1.8 dB which is near the ideal 2 dB. ISO 7188 was far superior in that it rejected more of the noisy but fewer of the quiet cars.

There is no corresponding study regarding heavy vehicles. However, in Japan, the type approval procedure utilises a variant of ISO 362 which is more adapted to actual driving conditions (e.g. trucks are loaded). Since noise reductions measured in actual traffic appear to be more significant in Japan than in Europe, it may be that the use of a more realistic driving condition during type approval is one of the main reasons [1].

The problems with driving conditions are highlighted in other papers at this conference [3] and [4], in which it is shown that the driving condition of ISO 362 is totally unrepresentative for cars but not too unrepresentative for trucks. It should also be mentioned that ISO/TC 43/SC 1/WG 42 has worked out an improved version of ISO 362 [5]. A review of the major problems of ISO 362 is presented in the box below.

Review of the problems with ISO 362:

1. Driving condition very unrepresentative of actual traffic, especially for cars
2. Load condition very unrepresentative for heavy vehicles

   The two first points result in poor optimisation of reduction measures
3. The two first points cause extreme tyre torque and slip ⇒ unrepresentative and high influence of tyre/road noise ⇒ suboptimisations of tyres not very useful for the overall environment
4. Mainly one, extreme driving condition determines result ⇒ suboptimisation
5. Result determined at only two directions from vehicle ⇒ suboptimisation
6. High influence of ambient temperature (< 4 dB) and influence of air humidity
7. Even when applying ISO 10844 there is influence of test surface (< 3 dB)
8. The tests are limited in time to "good" weather conditions
9. The procedure does not at all address the problem with tyre/road noise emission in actual traffic ⇒ suboptimisation
10. Due to all amendments of driving procedures over the years, they are now terribly complicated to identify correctly in all details for all types of vehicles
11. The statistical precision is low due to averaging and rounding principles

2. ROAD TRAFFIC NOISE EMISSION REGULATION PRINCIPLES

There are four parties equally responsible for reduction of road traffic noise emission: Drivers, vehicle manufacturers, tyre manufacturers and road administrations. The ideal situation would be if tests of noise emission could include all possible or at least all significantly different combinations of these. Of course, this is totally unrealistic; even to address all significant combinations of any ***two*** of these parameters would be unrealistic. Imagine testing all significant tyre/road combinations! From the exterior noise point of view, tyres are not more closely linked to vehicles than to road surfaces. It follows that regulations and the measuring methods they are based on shall separately address each of these four parameters or responsibilities, to a large extent independently of the others:

Basic four-point programme to reduce road traffic noise emission:

- Drivers must accept restrictions as to driving behaviour. This is already effective in most situations and places (speed limits). Future potential also for local acceleration limits. "Testing" of drivers takes the form of police actions.
- Vehicles (tyre noise negligible) must be tested and comply with emission limits. This requires a test of power unit noise. ISO 362 was at least originally a potential method for this, although poor.
- Tyres must be tested and comply with emission limits. This requires a test of tyre noise emission. The European Union (EU) has agreed in principle to introduce a directive for tyre noise emission [6].
- Road surfacings must be tested and comply with some traffic noise emission criteria. The recently approved ISO 11819-1 [7] supplies a tool for this to Road Administrations; administrative procedures still to be elaborated but on-going.

Will also this principle result in poor suboptimisations? There will indeed be suboptimisations, since there is only one driver/vehicle/tyre/road combination which is ***the*** best one! The problems are (1) the society will not accept such monopoly situations, (2) one must allow for combinations which are not the ideal for noise but which meet other criteria such as economy and safety, and (3) experience has shown that even controlling one parameter is very complicated [m]; controlling combinations of them would be impossible. We must thus accept that the ideal noise goal will never be achieved, and instead try to reduce the drawbacks of the suboptimisations.

With the present knowledge, we know that there are interactions between all four of the variables in all combinations except (?) driver/road. There are no indications that noise reduction due to each one of them separately would generally and significantly be much less than from the additive effects of each one. At least such interaction effects are much less than the effects due to problems with the present ISO 362. Besides, there is no choice, since taking full care of the interaction effects would result in either unacceptable market restrictions (only few vehicles, tyres and/or roads allowed) or totally impractical and uneconomical test requirements.

In conclusion: it is now necessary to address missing links in the four-point program above. Relying on continuation of work already initiated with tyres and roads, the missing link is an appropriate power unit noise test!

3. ALREADY INITIATED STUDIES

The European vehicle manufacturers (ACEA - Association des Constructeurs Européens d'Automobiles) have started a project with the main objective to develop a new measuring method. The total project has been divided into these four blocks:

- Block A: Noise source analysis in real-world traffic
- Block B: Analysis of representative driving cycles
- Block C: Evaluation of noise emission characteristics of vehicles driven according to Block B
- Block D: Evaluation of a new test method(s)

The first block has essentially been conducted already, utilising three European contractors (a report may have been released when this is printed). The second block will find useful data in the two other already mentioned papers at this conference [3][4].

The task of outlining a new method replacing ISO 362 has been assigned by ISO to the working group ISO/TC 43/SC 1/WG 42. This group has initiated discussions on this, but there is not yet any decision or document available. The problem has been recognised also within the EU, where the ERGA Noise group under DG-III has decided to initiate such discussions, beginning in an ad hoc group, but so far this subject has been delayed and the ad hoc group has not yet been appointed.

4. REQUIREMENTS THAT THE NEW METHOD SHALL SATISFY

A new method should satisfy as far as possible the following requirements:

- It should be simple and economical to perform
- It will be an advantage if the method is basically the same for all types of road vehicles (harmonised)
- It should give values representative of real traffic and of noise nuisance
- It should result in "stable" measuring results, i.e. repeatability and reproducibility should be high
- It should be insensitive to ambient conditions
- Measurements should be possible at any time and in any place

Of course, it is not possible to satisfy all requirements with the same method. ISO 362 meets roughly half of the requirements above, so the new method should be significantly better.

5. WHY NOT USE ISO 7188?

As mentioned earlier, ISO 7188 has a more representative driving condition than ISO 362 and is more effective to reject really noisy vehicles. Why not simply switch to ISO 7188? The reasons against this are:

- It is more sensitive to tyre/road noise than ISO 362. It will be extremely difficult to separate out tyre noise. More sensitive to test surface.
- There is no heavy vehicle version of it, it is just for cars.
- It is better than ISO 362 only with regard to representativity (for cars).

6. POSSIBILITIES TO ELIMINATE THE EFFECT OF TYRE/ROAD NOISE

A key feature of a new method must be its ability to reduce tyre/road noise during the test to negligible levels or negligible influence, while still allowing rather high power to be created by the vehicle. The following methods to achieve this might be considered, for example:

- Choose driving condition when tyre/road noise is negligible, such as low speed, high axle loads and only moderate acceleration. This is generally not easy and such a driving condition might not be representative.
- Use extremely quiet tyres and extremely quiet test track. Perhaps the composite wheel concept may be developed for this. It will not be easy to find a sufficiently quiet surface, since there must be no absorption in it. Not even slick tyres on a totally flat surface will be enough.
- Use screening devices to reduce tyre noise propagation. This would be possible in a laboratory, with rollers, but not outdoors.
- Use another type of loading of the drive axle momentum than via tyres, e.g. a hydraulic dynamometer connected directly to the axle, maybe with long extension axle. There are such systems today, e.g. "Rototest APG".
- Use directive microphone arrays to measure the tyre/road noise contribution and subtract this from the overall noise. This would be impractical (but not impossible) outdoors, but feasible indoors.

The following would be a concept worth testing: In a lab, load the drive tyres with a drum dynamometer. As tyres, use either a developed version of the composite wheel or slick tyres preferably filled with polyurethane. As drum surface, use "Safety Walk" or other steel drum treatment giving extremely high microtexture (to minimise tyre slip). The surface could be "refined" with drilling ventilation holes through it or even equipping it with "Euphonic Road" absorptive resonators [8]. Furthermore, each tyre should be screened with enclosures as tight as possible so as not to screen power unit noise and without causing too low tyre cooling. Finally, a screen should take care of noise very close to the drum surface.

7. OVERALL ASSESSMENT - INDOOR OR OUTDOOR TESTING?

An overall assessment of the test options is presented in the table on next page (+ means good merits, - means poor merits). Options considered are:

- Completely new method, indoors, in semianechoic room, using either drums or hydraulic dynamometers for loading, tyre noise suppressed, noise averaged (also max. levels recorded) over typical drive cycle
- Completely new method, outdoors, ISO10844 surface, using 3-6 driving conditions (representative in total), some tyre/road noise suppression
- ISO 7188 method performed outdoors on an ISO 10844 surface, supplemented with a similar procedure for trucks, some tyre noise suppression
- Basically ISO 362 method, outdoors, ISO 10844 surface, improved in most technical details and with a more representative driving condition

The table shows that indoor testing with a representative drive cycle is favoured, with exception of investment costs and simplicity. On the other

hand, such a method will give entirely new and better possibilities to get rid of the shortcomings of the present method. In total, it should give superior accuracy, representativity and precision. The big investment may perhaps be outweighed in a longer perspective by lower measurement costs (e.g. no restrictions due to climate or weather). Measuring rooms useful for this purpose are already available at most manufacturers. An indoor method like this would be somewhat similar to the method used for testing exhaust emissions (drive cycles harmonised?), a case where it is rarely questioned.

Characteristics assessed	Indoors New method Represent. drive cycle	Outdoors New method 3-6 driving conditions	Outdoors ISO 7188 2 driving condition	Outdoor ISO 362 modified
Investment costs	- - -	++	++	++
Measuring costs	+	- -	-	+
Simplicity and harmonization	-	+	+	+
Representative driving condition	+++	++	+	- -
Sensitivity to tyre/road noise	+	- -	- - -	- -
Test surface influence	+++	-	- - -	- -
Sensitivity to ambient conditions	+++	- -	- -	- -
Repeatability & reproducibility	++	-	- -	-
Time when possible to measure	+++	- -	- -	- -

8. CONCLUSIONS AND RECOMMENDATIONS

A new measuring procedure that will eliminate the shortcomings of ISO 362 is proposed. With a separate regulation addressing tyre/road noise, it is now logical to separate out power unit noise with the new method. Recognising a considerable investment cost, an indoor method using a representative drive cycle seems to have the best overall merits.

9. REFERENCES

[1] **SANDBERG, U. (1995):** "Report by the International Institute of Noise Control Engineering Working Party on The Effect of Regulations on Road Vehicle Noise". Noise News International, June 1995, pp. 82-113.

[2] **BIEGSTRAATEN, F.J.W.; TUKKER, J.C. (1982):** "Noise Emission by Passenger Cars in Urban Traffic." Rpt 107.833A, TPD Tech. Phys. Dienst, TNO-TH, Delft, Netherlands.

[3] **Steven, H. (1996):** "Typical Driving Patterns of Cars and Trucks and How They Coincide with Driving According to Noise Measuring Standards". Proc. of Inter-Noise 96, Liverpool, United Kingdom.

[4] **Abe, T.; Oshino, Y.; Noba, M. (1996):** "Driving Patterns in Japan and Their Relation to Vehicle Noise Testing Methods". Proc. of Inter-Noise 96, Liverpool, United Kingdom.

[5] **ISO/DIS 362 (1996):** "Acoustics - Measurement of Noise Emitted by accelerating Road Vehicles - Engineering Method (Revision of ISO 362:1994)". ISO, Geneva, Switzerland

[6] As far as this author is aware there is a proposed measuring method for tyre noise (DG-III, ERGA-Noise document III/4204/93-R.1) as well as a proposal from ETRTO (letter 0053/95) and from the Nordic countries (30 March 1995) re. noise level limits.

[7] **SANDBERG, U. (1995):** "Development of an International Standard for Measurement of the Influence of Road Surfaces on Traffic Noise". Paper for ICA '95, Trondheim, Norway. Reprint No. 246, Swedish Natl. Road and Transport Research Inst., Linköping.

[8] **OECD (1995):** "Roadside Noise Abatement". OECD, Paris, pp. 83-84.