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Tyre sound emission test — Methods of drum

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Foreword

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This document was prepared by Technical Committee ISO/TC 31, *Tyres, rims and valves*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The external sound emission of a tyre is one out of a multitude of requirements that need to be considered by manufacturers during design and development of tyres. For health and environmental protection reasons, the sound emission should be reduced under all relevant driving conditions. To meet all these demands, an efficient test site is needed that can be operated the whole year round independent of weather conditions or other outside factors. In many countries, the meteorological conditions are so adverse that outdoor testing on a classical proving ground is only possible in a very limited timeframe. Furthermore, performing sound emission tests on various test tracks highly increases the uncertainty and multiplies the workload for a manufacturer.

This ISO standard gives specifications for an indoor noise test bench and a test procedure that delivers precise results for indoor testing, comparable to a certified type approval test track. The results are intended to be within the run-to-run variation of the actual valid exterior noise test described in ISO 13325:2019, which is the test standard used for type approval of tyres. An indoor test bench requires tight specifications for the equipment and set up, such as the acoustical treatment of the walls and the ceiling, the microphone array, the roller bench, the adjustment of the tire load on the roller bench. Special treatment needs to ensure that all rolling sound components of the tire are comparable to the rolling sound on a road surface as specified in ISO 10844 and as applied in type approvals. This ISO 20908 standard provides all necessary specifications and procedures to ensure comparability between todays common and well accepted testing on outdoor test tracks with future indoor facilities. It incorporates all relevant International Standards for equipment, measurement uncertainty, and test procedures.

The current outdoor method (described in ISO 13325:2019) requests the vehicle to move at various speeds in between 2 microphones. This imposes to the tyre a high rotation speed which is at the source of sound emission, by creating tyre parts movements, slip and shocks against the track surface. As a vehicle movement is not possible in a semi-anechoic room, the rotation of a drum is used to create tyre rotation similar to the one observed on track. In order to create excitation similar to the one created on the track, the drum is coated with a surface similar to the one of the tracks. Finally, the vehicle trajectory between the microphones is simulated by a line of microphones, signals of each microphone being used to estimate the noise level of the car moving between microphones

The results are intended to be within the run-to-run variation of the actual valid exterior noise test described in ISO 13325:2019.

Tyre sound emission test — Methods of drum

1 Scope

This document specifies methods for measuring tyre-to-road sound emissions from tyres fitted on rig applying the tyre on a rotating drum under coast-by conditions — i.e. when the tyre is in free-rolling, non-powered operation.

The specifications are intended to achieve a correlation between results of testing the exterior noise of tyres in a semi anechoic chamber and outdoor testing as described in ISO 13325.

This document is applicable to passenger cars and light commercial vehicles tyres of class C1 and C2, as defined in ISO 3833. It is not intended to be used to determine the sound contribution of tyres applying a torque, nor for the determination of traffic sound nuisance at a given location.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4223-1, *Definitions of some terms used in the tyre industry—Part1: Pneumatic tyres*

ISO 3745, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for anechoic rooms and hemi-anechoic rooms*

ISO 10844, *Acoustics — Specification of test tracks for measuring noise emitted by road vehicles and their tyres*

ISO 13325:2019, *Tyres — Coast-by methods for measurement of tyre-to-road sound emission*

ISO 26101, *Acoustics — Test methods for the qualification of free-field environments*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61672-3, *Electroacoustics — Sound level meters — Part 3: Periodic tests*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement*

ISO 4223-1, *Definitions of some terms used in the tyre industry — Part 1: Pneumatic tyres*

IEC 60651:2001, *Sound level meters*

ISO 362-3:2016, *Measurement of noise emitted by accelerating road vehicles — Engineering method — Part 3: Indoor testing M and N categories*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 4223-1 and the following symbols and abbreviated terms apply.

3.1
classes of tyre
C1 Passenger car tyres

C2 Commercial vehicle tyres with LI in single formation lower or equal to 121 and speed category symbol higher or equal to “N”

3.2
category of tyres
normal tyre, as defined by ISO 4223-1 3.1.1

snow tyre, as defined by ISO 4223-1 3.1.3

severe snow use tyre, as defined by ISO 4223-1traction tyre, as defined by ISO 4223-1 3.1.5

Special use, as defined by ISO 4223-1 3.1.2

traction tyre, as defined by ISO 4223-1 3.1.8

3.3
LI (load index)
numerical code associated with the maximum load a tyre can carry at the speed indicated by its speed symbol under the service conditions specified by the tyre manufacturer

Note 1 to entry: In cases where the LI consists of two numbers, reference shall be made to the first number. For tyres where the load index is not available, reference shall be made to the maximum load marked on the tyre sidewall.

3.4
rig
device applying a load to tyre and measuring it during the test.

4 Symbols and abbreviated terms

Table 1 — Symbols used and corresponding clauses

Symbol	Unit	Clause	Designation
x, y, z	m	6.2.1	Axis of Cartesian coordinate system
m	m	6.2.1	Number of a microphone
x_m, y_m, z_m	m	6.2.1	Coordinates of the microphone number *m*
M_+, M_-		6.2.1	Number of array microphones in positive and negative *x*-directions, respectively
M		6.2.1	Total number of the microphones in the array
y_{array}	m	6.2.2	Distance from linear microphone array to the vertical tire mid-plane
z_{array}	m	6.2.2	Height of linear microphone array above the tire contact patch center (drum top)
Y_{CBY}	m	6.2.2	Distance from microphone to track center as defined in ISO 13325; Reference distance for SPL correction in ISO 20908
Z_{CBY}	m	6.2.2	Height of microphones above the ground as defined in ISO 13325; Reference height for definition of array microphones height in ISO 20908
Δx	m	6.2.2	Spacing of linear array microphones in *x*-direction; Reference distance for definition of coordinates of circular array microphones
Δx_{max}	m	6.2.2	Maximum allowed value of Δx
$l^{+}_{array}, l^{-}_{array}$	m	6.2.2	Lengths of linear microphone array in positive and negative *x*-directions, respectively

Table 1 *(continued)*

Symbol	Unit	Clause	Designation
$l_{array\,min}$	m	6.2.2	Minimal acceptable value of l^{+}_{array} and l^{-}_{array}
L_{CBY}	m	6.2.2	Reference distance for definition of $l_{array\,min}$ and $\alpha_{array\,min}$
r_{array}	m	6.2.3	Radius of the base circle of the circular microphone array
α_m		6.2.3	Signed angle between projection of the microphone number *m* of the circular array onto the *xy*-plane and the *y*-axis
$\alpha^{+}_{array}, \alpha^{-}_{array}$		6.2.3	Angles spanned by the circular array in the *xy*-plane in positive and negative *x*-directions, respectively
$\alpha_{array\,min}$		6.2.3	Minimal acceptable value of α^{+}_{array} and α^{-}_{array}
D	m	6.3	The largest expected size of acoustic source on the tire
λ_{min}	m	6.3	The wavelength of sound wave in the air at the highest frequency of concern
SPL		6.5	Sound Pressure Level
r_m		6.5	Distance from the acoustic source to the *m*-th microphone of the array
r_0		6.5	Distance from the acoustic source to the central microphone of the array
$\Delta L(x_m)$		6.5	Relative Sound Pressure Level decay at microphone number *m* with respect to the central microphone
Q_t	N	9.1.1	Test load for the tyre
Q_r	N	9.1.1	Reference load, corresponding to max load associated with tyre load index
P_t	kPa	9.1.2	Test inflation pressure
P_r	kPa	9.1.2	Reference pressure
n		9.1.4	Number of test speeds
v_i	km/h	9.1.4	Value of the *i*-th test speed
$p_m(t)$	Pa	9.2.1	Time-signal of the *m*-t microphone
$p_{mA}(t)$	Pa	9.2.1	A-filtered time signal of the *m*-th microphone
$P_A(x_m)$	Pa^2	9.2.1	Mean square value of $p_{mA}(t)$
T	s	9.2.1	Averaging time for mean square calculation
X_m	m	9.2.2	Distance-corrected *x*-coordinate of the microphone □
$P^{corr}_{A}(X_m)$	Pa^2	9.2.2	Distance corrected mean-square pressure of the microphone *m*
$P^{corr}_{FA}(X_m)$	Pa^2	9.2.3	Distance-corrected mean-square pressure of the microphone *m* with emulation of Fast time weighting through exponential weighting in *X*
C_t		9.2.4	Coefficient for tyre impact on sound propagation
C_v		9.2.4	Coefficient for vehicle impact on sound propagation
L_i	dB(A)	9.2.4	Representative SPL (test result) at speed v_i
p_0	Pa	9.2.4	Reference acoustic pressure for dB scale
v_{ref}	km/h	9.2.6	Reference speed for test results interpolation
L_R	dB(A)	9.2.5	Interpolated value of SPL at the speed v_{ref}
$\bar{L}$	dB(A)	9.2.5	Mean value of representative SPLs
v_{*i}		9.2.5	Decimal logarithm of the test speed v_i
$\bar{v}_{*}$		9.2.5	Mean value of v_{*i}

Table 1 *(continued)*

Symbol	Unit	Clause	Designation
a		9.2.5	Slope of the regression line L_i vs. v_{*i}
L_v		9.2.5	Interpolated value of SPL at a speed v
M		11.3	Slope of the regression line $L_{R\,track\,i}$ vs. $L_{R\,drumi}$
Q		11.3	Shift at origin of the regression line $L_{R\,track\,i}$ vs. $L_{R\,drum\,i}$
R^2		11.3	Correlation coefficient of the regression line $L_{R\,track\,i}$ vs. $L_{R\,drum\,i}$
$L_{raligned}$	dB(A)	9.2.6	Interpolated value corrected for lab alignment with outdoor
L_f	dB(A)	9.2.5	Final test result

5 Instrumentation

5.1 Instruments for acoustical measurement

The sound pressure level meter or equivalent measuring system (including microphone and acquisition system), shall meet the minimum requirements of a Class 1 instrument in accordance with IEC 61672-1. Alternatively, IEC 60651 may be used.

The measurements shall be made using the "A" frequency weighting.

The calibration of the sound pressure level meter shall be checked and adjusted in accordance with the manufacturer's instructions or with a standard sound source (e.g. pistonphone) at the beginning of the measurements and rechecked and recorded at the end of them. The calibration device shall meet the requirements of Class 1 in accordance with IEC 60942.

If the sound pressure level meter indications obtained from these calibrations differ by more than 0.5 dB during a series of measurements, the test shall be considered invalid. Any deviation shall be recorded in the test report.

NOTE The tests of IEC 61672-3 cover only a limited subset of the specifications in IEC 61672-1 for which the scope is large (temperature range, frequency requirements up to 20 kHz, etc.). It is economically not feasible to verify the whole IEC 61672-1 requirements on each item of a computerized data acquisition systems model.

5.2 Microphones

The microphones setup will be described in the §6.2 "Microphone array setup". In the vicinity of the microphones, there shall be no obstacle that could influence the acoustical field.

5.3 Temperature measurement

5.3.1 General

For air temperature measurement, the measuring instrument shall have an overall accuracy of at least ± 1 °C. Meters utilizing the infrared technique shall not be used for air temperature measurements.

Continuous registration through an analog output may be employed. If such an option is not available, single values are to be measured.

Measurements of air temperature are mandatory and shall be made in accordance with the instrument manufacturer's instructions.

Temperature measurements shall correspond reasonably over time with sound measurements. Alternatively, the average of the temperature at the beginning and the end of the set of tests may be used.

5.3.2 Room temperature

One should position the temperature sensor in an unobstructed location close to the microphone array. The sensor should not be positioned higher than the height of the microphone array (see 6.2).

5.3.3 Calibration

At the beginning and at the end of every measurement session (typically one day of measurement), the entire sound measurement system shall be checked by means of a sound calibrator as described in 5.1. Without any further adjustment, the difference between the readings shall not exceed 0,5 dB. If this value is exceeded, the results of the measurements obtained after the previous satisfactory check shall be discarded.

5.4 Conformity with requirements

At intervals of not more than two years, the sound pressure level meter shall be verified with the requirements of IEC 61672. Alternatively, IEC 60651 may be used. At intervals of not more than one year, the calibration device shall be verified with the requirements of IEC 60942.

When no general statement or conclusion can be made about conformance of the sound level meter model to the full specifications of IEC 61672-1, the apparatus used for measuring the sound pressure level shall be a sound level meter or equivalent measurement system meeting the compliance requirements of Class 1 instruments as described in IEC 61672-3.

All conformity testing shall be conducted by a laboratory which meets the requirements of ISO/IEC 17025.

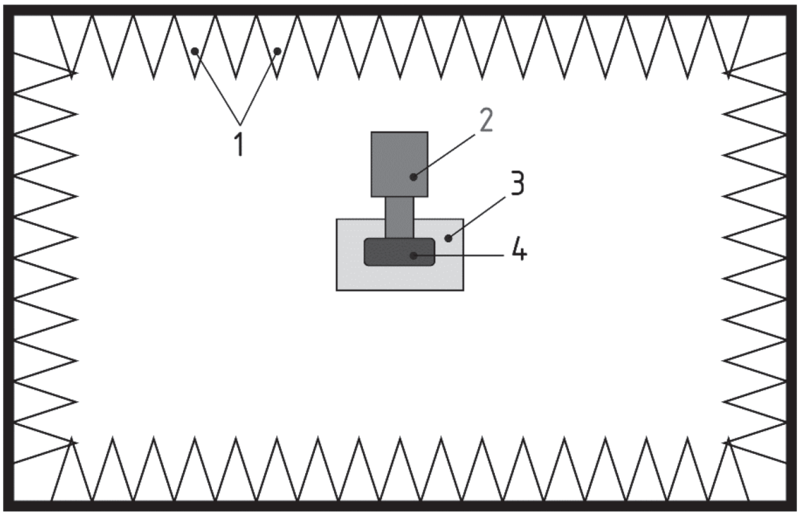
6 Test room requirements

6.1 General

One of the principal criteria of ISO 13325:2019 for tyre sound emission measurement is testing in an acoustic free field.

To reproduce this acoustic criterion in a laboratory, the room design shall be able to provide the same effective propagation characteristics as an open space over a reflecting surface (see specifications in 6.5 Acoustical qualification of the room).

One solution is a semi-anechoic chamber with absorptive materials. Several different techniques are



Key

1 absorbing elements
2 rig
3 drum
4 tire

Figure 1 — Room Example

6.2 Microphone array setup

6.2.1 General

There are 2 possible microphone array setups described in 6.2.2 and 6.2.3.

In both setups:

— Position of each microphone is proportionally simulating a relative position of the tyre contact patch and the microphone position used in ISO 13325:2019 standard.

— All microphones of the array shall be located in the far field zone of the tire noise acoustic field (see 0).

— Microphones of the array shall be placed at a distance from the walls of the room at least equal to quarter-wavelength of the sound wave in the air at the lowest frequency of concern.

Origin of the coordinate system used to define microphone coordinates in both setups is the projection of tyre center onto the drum. Axes of the coordinate system are directed as follows:

— *x*-axis is directed opposite to the tire rotation direction;

— *y*-axis is directed along the tire rotation axis towards the microphone array;

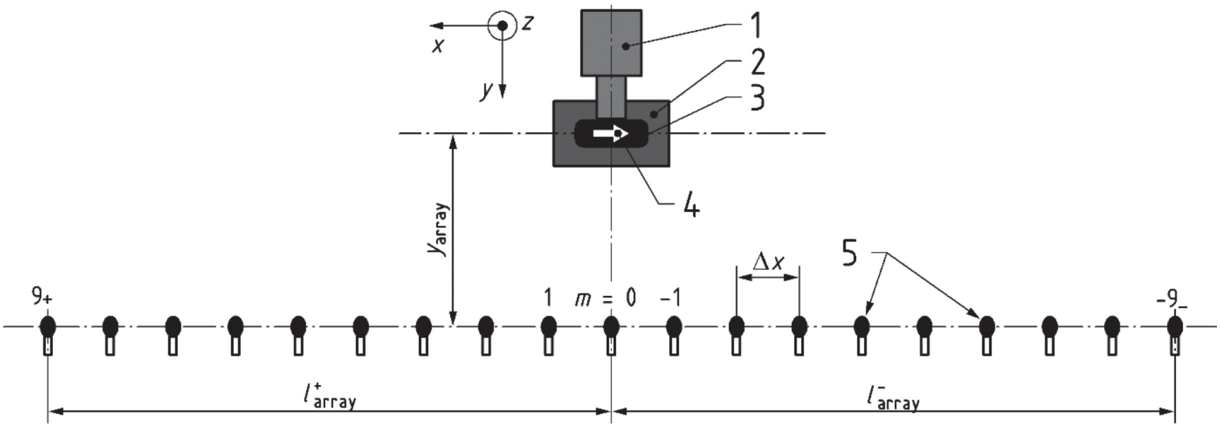
— *z*-axis is directed vertically upwards;

The microphones of the array are numbered as follows. The microphone with $x = 0$ has number $m = 0$. The microphones in the positive *x*-direction have numbers $m = 1, 2 \ldots 9_+$ and the microphones in the negative *x*-direction have numbers $m = -1, -2, \ldots, -9_-$.vThe total number of microphones is 19 and M is equal to 0 in all clauses.

Microphone coordinates shall be accurate to ± 1 cm.

6.2.2 Linear array

A linear array of microphones will be set on a straight line perpendicular to the tyre rotation axle at a distance y_{array} (Figure 2). The distance y_{array} should be chosen so that all microphones are in the far field zone of the tire noise acoustic field (see 6.3). Microphone array facing the tyre as shown in the Figure 2 shall then respect the following constraints:



Key

1 rig

2 drum

3 tire

4 rotation direction

5 microphones

Figure 2 — Linear microphone array setup

All microphones of the array shall have the same *y*-coordinate:

$$y_m = y_{array}, \quad m = -M_- ... M_+ \tag{1}$$

All microphones of the array shall have the same height with respect to the tyre center (drum top) which is scaled by the distance as

$$z_m = z_{array} = Z_{CBY} \times \frac{y_{array}}{Y_{CBY}}, \quad m = -M_- ... M_+ \tag{2}$$

with $Z_{CBY} = 1.2\,\text{m}$, as in ISO 13325:2019 and $Y_{CBY} = 7.5\,\text{m}$ is the reference distance defined in 9.2.2.