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Rubber, vulcanized or thermoplastic — Determination of abrasion resistance using the Improved Lambourn test machine

Caoutchouc vulcanisé ou thermoplastique — Détermination de la résistance à l'abrasion à l'aide d'une machine de Lambourn perfectionnée

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Testing and analysis.*

This third edition cancels and replaces the second edition (ISO 23337:2016), which has been technically revised.

The main changes are as follows:

— an optional test piece thickness has been added.

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

Various types of laboratory test equipment for determining the wear resistance of rubber compounds have been developed, depending on the products to which rubber compounds have been applied in the past. One such piece of equipment, called the “Improved Lambourn” abrasion test machine, is briefly introduced with other types in ISO 23794[3] and the test method for using it is described in detail in this document.

The main features of the Improved Lambourn machine are as follows.

a) The slip rate is adjustable by virtue of the fact that the abrasive wheel and test piece are driven separately. A servo-mechanism is used for driving both the abrasive wheel and the test piece to ensure accurate speed control. In older types of equipment, both the abrasive wheel and the test piece were driven by the same drive system, with the speeds of rotation controlled by braking systems, which could result in an inaccurately controlled slip rate.

b) A controlled feed of carborundum grit to the nip between the rubber test piece and the abrasive wheel ensures that abraded particles are prevented from adhering to the surface of the test piece or abrasive wheel, which is important for obtaining reproducible test results.

A previous wear study for rubber compounds using the Improved Lambourn machine showed that, at higher slip rates, wear resistance decreased in the order: butadiene rubber (BR) base compound, natural rubber (NR) base, styrene-butadiene rubber (SBR) base. However, at low slip rates, the order was reversed. This is interesting since the tread compound in truck and bus tyres generally uses NR or a blend of NR and BR base compound, while SBR base compound is used in car tyres. More details can be found in Reference [4].

Rubber, vulcanized or thermoplastic — Determination of abrasion resistance using the Improved Lambourn test machine

WARNING 1 — Persons using this document should be familiar with normal laboratory practice. This document does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to determine the applicability of any other restrictions.

WARNING 2 — Certain procedures specified in this document might involve the use or generation of substances, or the generation of waste, that can constitute a local environmental hazard. Reference should be made to appropriate documentation on safe handling and disposal after use.

1 Scope

This document specifies a method for the determination of the resistance of rubber to abrasion using the Improved Lambourn test machine.

The abrasion loss resulting from the slip caused by the difference in circumferential speed between a disc-shaped rubber test piece and an abrasive wheel, which are driven to rotate independently with their circumferences pressed against each other by a specified load, is determined. The test result can be reported as a volume loss per abrasion test time or running distance, and/or as an abrasion resistance index compared with a reference compound.

As the Improved Lambourn test machine is capable of setting various abrasive conditions, such as slip rate, sliding speed and load, independently, this method is suitable for the evaluation of compounds for a range of rubber products, especially tyres, under a wide range of severity conditions. An example of the testing of tyre tread rubber is given in Annex A.

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 525, *Bonded abrasive products — Shape types, designation and marking*

ISO 2781, *Rubber, vulcanized or thermoplastic — Determination of density*

ISO 8486-1, *Bonded abrasives — Determination and designation of grain size distribution — Part 1: Macrogrits F4 to F220*

ISO 18899:2013, *Rubber — Guide to the calibration of test equipment*

ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
abrasion
loss of material from a surface due to frictional forces

[SOURCE: ISO 23794:2023, 3.1]

3.2
abrasion resistance
resistance to wear resulting from mechanical action on a surface

Note 1 to entry: Abrasion resistance is expressed by the abrasion resistance index.

[SOURCE: ISO 23794:2023, 3.2]

3.3
abrasion resistance index
ratio of the loss in volume of a reference compound to the loss in volume of a test rubber, measured under the same specified conditions and expressed as a percentage

[SOURCE: ISO 23794:2023, 3.3, modified — Note to entry has been omitted; "standard rubber" has been replaced by reference compound.]

3.4
slip rate
ratio of the difference between the circumferential speed of the test piece and that of the abrasion wheel to the circumferential speed of the test piece, expressed as a percentage

3.5
running distance
total distance travelled by a point on the circumference of the test piece, determined from the initial outer diameter of the test piece, its speed of rotation and the abrasion time

3.6
reference compound
compound whose abrasion resistance is to be compared with that of the test rubber

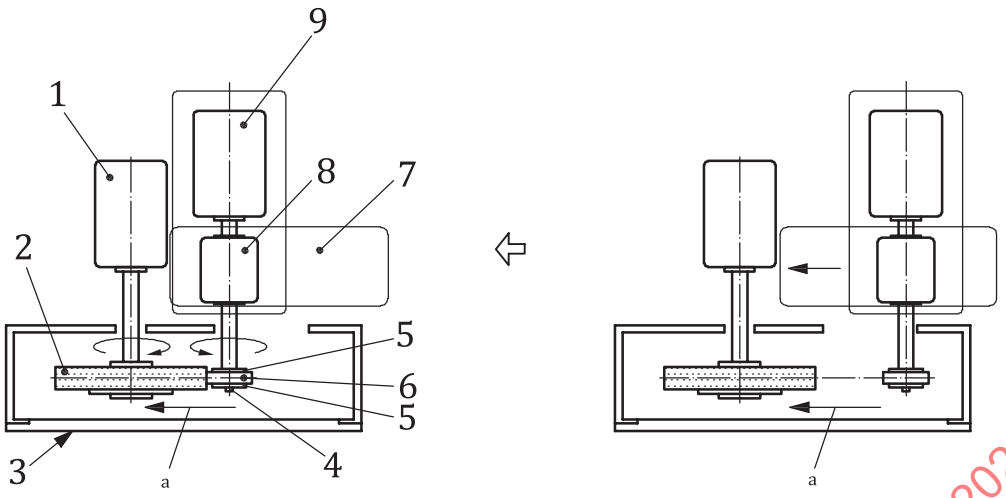
4 Principle

Wear occurs due to the slip caused by the difference in circumferential speed between a disc-shaped rubber test piece and an abrasive wheel rotating against each other for a specified length of time.

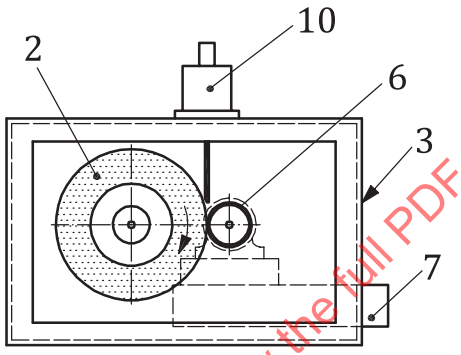
The test piece and the abrasive wheel, aligned with their circumferences pressed against each other by a specified load and with their axes of rotation parallel, are driven independently (see Figure 1).

Grit is fed into the nip between the test piece and the abrasive wheel to prevent smearing of the test piece and the abrasive wheel surface.

The loss in mass of the test piece is determined and the loss in volume per unit abrasion time or running distance is calculated from the density of the test material. The abrasion resistance index, if required, is determined by comparing this loss in volume with the loss in volume of a reference compound tested under the same conditions.



a) Top view



b) Front view

Key

1	drive motor for abrasive wheel	6	test piece
2	abrasive wheel	7	mechanism for exerting load on test piece
3	test chamber	8	torque meter
4	test piece mounting	9	drive motor for test piece
5	test piece guide	10	grit-dropping mechanism
a	Test piece pressed against abrasive wheel.		

The torque meter fitted to the test piece drive shaft detects any abnormal conditions from torque changes during the test. It shall be capable of measuring torques ranging from 0 N·m to 5 N·m to the nearest 0,01 N·m.

Figure 1 — Schematic illustration of apparatus

5 Apparatus

5.1 Abrasion test machine

The test machine (see Figure 1) shall consist of a test piece mounting, an abrasive wheel, a drive mechanism to rotate the test piece and the abrasive wheel at different speeds, a loading mechanism to press the test piece against the abrasive wheel at the specified load, a grit-dropping mechanism to prevent smearing of the test piece and the abrasive wheel surface, and a test chamber to prevent grit from spreading and to ensure safety during the test.

In order that the rotational speed of the shaft is accurately transmitted to the test piece, the mounting of the test piece shall be designed so that the test piece does not slip on the rotating shaft when torque is applied. A

pair of disc-shaped test piece guides 4 mm thick and 43 mm or 58,5 mm in diameter shall be fitted each side of the test piece to hold it in place.

In order that the rotational speed of the shaft is accurately transmitted to the abrasive wheel, the mounting of the abrasive wheel shall be designed so that the abrasive wheel does not slip on the rotating shaft when torque is applied. The specifications of the abrasive wheel shall be in accordance with ISO 525: abrasive C (silicon carbide), grit size 80 (equivalent to the designation F80 specified in ISO 8486-1), hardness grade K, nature of bond V (vitrified bond) and maximum operating speed <16 m/s (less than 16 m/s). The diameter of the abrasive wheel shall be 175 mm, 205 mm or 305 mm, with a thickness of 20 mm to 50 mm.

Permissible combinations of the dimensions of the test piece, the test piece guide and the abrasive wheel are given in Table 1.

Table 1 — Permissible combinations of dimensions of the test piece, the test piece guide and the abrasive wheel

Dimensions in millimetres

Combination	Test piece		Test piece guide		Abrasive wheel	
	Diameter	Thickness	Diameter	Thickness	Diameter	Thickness
A	49,0	5,0 or 10,0	43,0	4,0	175,0	20 to 50
B	63,5	5,0 or 10,0	58,5	4,0	205,0	20 to 50
C	49,0	5,0 or 10,0	43,0	4,0	305,0	20 to 50

To independently control their circumferential speeds, which shall be between 10 m/min and 200 m/min, the drive mechanism shall have two motors, one for the test piece and one for the abrasive wheel.

A loading mechanism shall be fitted to press the test piece against the abrasive wheel at the specified load in the range 5 N to 80 N during the test, regardless of the combination of dimensions used.

A mechanism shall be fitted to drop grit at the specified rate into the gap between the test piece and the abrasive wheel. The drop rate shall be adjusted to be in the range 10 g/min to 30 g/min. The type of grit used shall be silicon carbide corresponding to a designation between F80 and F100 as specified in ISO 8486-1.

The cleaning mechanism, such as brushing or air jets, may be applied to prevent clogging or smearing the abrasive wheels.

5.2 Balance

The balance shall be of sufficient accuracy to enable the loss in mass of the test piece to be determined to ±1 mg.

6 Calibration

The test apparatus shall be calibrated in accordance with the schedule given in Annex B.

7 Test pieces

7.1 Type and preparation

The test pieces shall be disc-shaped, of diameter 49 mm or 63,5 mm and of thickness 5 mm or 10 mm. The test pieces shall be prepared by moulding or by cutting from test sheets or products using a rotary cutter. The surface of the test pieces which is to be abraded shall be smooth.

NOTE For samples with low hardness, 10 mm thickness is more appropriate.

7.2 Number

A minimum of two test pieces shall be tested.

7.3 Time interval between vulcanization and testing

Unless otherwise specified for technical reasons, the following requirements shall be observed in accordance with ISO 23529.

— For all normal test purposes, the minimum time between vulcanization and testing shall be 16 h. In cases of arbitration, the minimum time shall be 72 h.

— For non-product tests, the maximum time between vulcanization and testing shall be four weeks and, for evaluations intended to be comparable, the tests, as far as possible, shall be carried out after the same time interval.

— For product tests, whenever possible, the time between vulcanization and testing shall not exceed three months. In other cases, tests shall be made within two months from the date of receipt by the purchaser of the product.

8 Test conditions

The test conditions specified in Table 2 shall be employed.

Table 2 — Standard test conditions

Parameter	Standard value	Range
Temperature	Standard laboratory temperature (refer to ISO 23529)	—
Circumferential speed of test piece	50 m/min	10 m/min to 200 m/min
Slip rate	30 %	5 % to 80 %
Load	40 N	5 N to 80 N
Grit-dropping rate	20 g/min	10 g/min to 30 g/min

NOTE 1 During a test run, there can be a considerable increase in temperature at the abrading interface, which can lead to a temperature rise within the test piece. For the purposes of this document, such a temperature rise can be disregarded.

NOTE 2 The slip rate S, in percent, is defined as follows:

$$S = \frac{d - D}{d} \times 100$$

where

D is the circumferential speed of the abrasion wheel, in m/min;

d is the circumferential speed of the test piece, in m/min.

To determine the abrasion resistance index, the same conditions shall be used with the test pieces of the reference compound.

The abrasion test time shall be such that the abraded volume is 0,1 cm^3 to 0,2 cm^3, this time being determined as follows.

a) Using one of the test pieces, conduct an abrasion test (see 9.2) beforehand for several ten-second intervals under the standard test conditions (see Table 2).

b) From the time and the loss in volume of the test piece, calculate the abrasion test time which will give an abrasion volume of 0,1 cm^3 to 0,2 cm^3.

9 Procedure

9.1 Preliminary wear

Carry out preliminary abrasion of the test piece for 10 s to 20 s under the standard test conditions (see Table 2).

9.2 Abrasion test

Carry out the abrasion test as follows.

a) Weigh the test piece to the nearest 1 mg after the preliminary-wear run.

b) After weighing, mount the test piece on its rotating shaft in the abrasion test machine.

c) Conduct the abrasion test under the specified test conditions (see Clause 8) for the abrasion test time calculated at the end of Clause 8.

d) On completion of the test, weigh the test piece again to the nearest 1 mg.

Before reweighing the test piece, remove any abrasion dust and grit smeared over the surface of the test piece. Sometimes, it is also necessary to pull off a small edge hanging from the test piece before weighing.

9.3 Density

Determine the density of the test material in accordance with ISO 2781.

10 Expression of results

The results are expressed either as a loss in volume or as the abrasion resistance index.

From the loss in mass and the density of the test material, calculate the loss in volume per unit abrasion time V (expressed in mm^3/min) and the loss in volume per unit running distance V' (expressed in mm^3/km) from the average of the results obtained from the individual test pieces, using Formulae (1) and (2):

$$V = \frac{m}{\rho \times t} \tag{1}$$

$$V' = \frac{m}{\rho \times l} \tag{2}$$

where

V is the loss in volume per unit abrasion time, in mm^3/min;

V' is the loss in volume per unit running distance, in mm^3/km;

m is the average loss in mass of the two test pieces, in mg;

ρ is the density of the test material, in g/cm^3;

t is the abrasion test time, in min;

l is the running distance, in km.

Calculate the abrasion resistance index using Formula (3):

$$I = \frac{V}{T} \times 100 = \frac{V'}{T'} \times 100 \quad (3)$$

where

I is the abrasion resistance index, in percent;

V is the loss in volume per unit abrasion time for the reference compound, in mm^3/min;

T is the loss in volume per unit abrasion time for the test piece, in mm^3/min;

V' is the loss in volume per unit running distance for the reference compound, in mm^3/km;

T' is the loss in volume per unit running distance for the test piece, in mm^3/km.

11 Precision

See Annex A.

12 Test report

The test report shall include the following information:

a) sample details:
   1) a full description of the sample and its origin,
   2) details of the compound and its condition of cure, if known,
   3) the time interval between vulcanization and testing,
   4) the method used to prepare the test pieces (e.g. whether cut or moulded);

b) test method used, with a reference to this document, i.e. ISO 23337;

c) test details:
   1) the test temperature used,
   2) the circumferential speed of the test piece, the slip rate, the load applied, the grit-dropping rate used and the abrasion time,
   3) details of any procedures not specified in this document;

d) test results:
   1) the number of test pieces tested,
   2) the abrasion rate per unit time, the abrasion rate per unit running distance and the average abrasion resistance index,
   3) the density of the test compound and that of the reference compound (if used);

e) date of test.

Annex A
(informative)

Precision

A.1 General

Precision calculations to express the repeatability and reproducibility were performed in accordance with ISO/TR 9272[1], which has now been withdrawn and replaced with ISO 19983[2]. Outliers in the original data were dealt with at the 5 % and 2 % significance levels in accordance with the procedures described in ISO/TR 9272.

A.2 Precision details

A.2.1 An interlaboratory test programme (ITP) was organized by Japan in 2004. Two compounds, designated E1 (SBR) and A (NR), were used for the abrasion tests.

A total of six laboratories participated in the ITP. Fully prepared rubber test pieces were sent to each laboratory for the testing in the ITP, thus giving a type 1 precision.

A.2.2 The two sets of test conditions given in Table A.1 were used. Set of conditions 1 corresponds to high severity and set 2 to low severity.

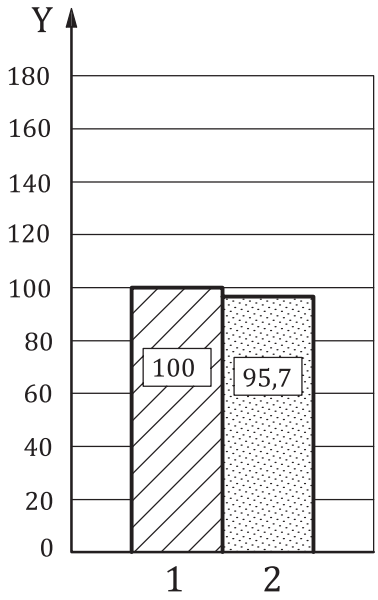
Table A.1 — Test conditions

	Set of conditions 1	Set of conditions 2
Circumferential speed of test piece	50 m/min	50 m/min
Slip rate	30 %	15 %
Load	40 N	40 N
Grit-dropping rate	20 g/min	20 g/min
Abrasion test time	3 min	13 min

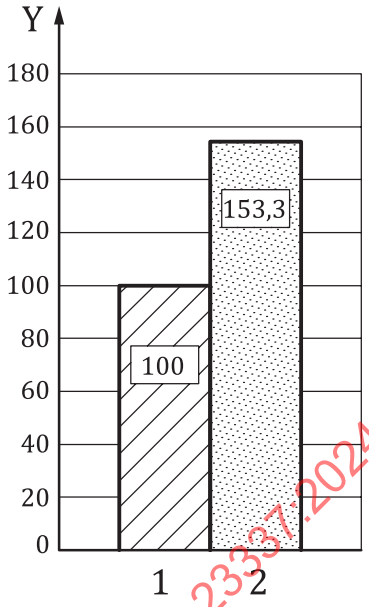
A.3 Test results

The test results, calculated as the abrasion resistance index with compound A as the reference compound, are shown in Figure A.1. Under high-severity conditions (slip rate 30 %), these two compounds have equivalent abrasion resistance. Under low-severity conditions (slip rate 15 %), compound E1 (SBR) shows better abrasion resistance than compound A (NR).

The rankings are similar to those found in road trials.



a) Slip rate 30 %



b) Slip rate 15 %

Key

Y abrasion resistance index (%)
1 A (NR compound)
2 E1 (SBR compound)

Figure A.1 — Test results

A.4 Precision results

The results calculated for the precision are given in Table A.2.

The symbols used in the table are defined as follows:

r = repeatability, in measurement units;

(r) = repeatability, in percent (relative);

R = reproducibility, in measurement units;

(R) = reproducibility, in percent (relative).

Table A.2 — Precision data

Abrasion resistance index %	Mean value ($N = 6 \times 2 = 12$)	Within-laboratory repeatability		Interlaboratory reproducibility	
		r	(r)	R	(R)
Set of conditions 1	95,7	9,9	10,4	20,6	21,6
Set of conditions 2	153,3	17,1	11,2	40,8	26,6

NOTE The Improved Lambourn abrasion tester gives almost the same precision as the rotating cylindrical drum (DIN) tester.