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Rubber, vulcanized or thermoplastic — Abrasion testing — Guidance

Caoutchouc vulcanisé ou thermoplastique — Essais d'abrasion — Lignes directrices

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 23794 was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 2, *Testing and analysis*.

This second edition cancels and replaces the first edition (ISO 23794:2003), of which it constitutes a minor revision designed to update the normative references to reflect the fact that ISO 471, ISO 4648 and ISO 4661-1 cited in Clause 10 have been replaced by ISO 23529.

Rubber, vulcanized or thermoplastic — Abrasion testing — Guidance

WARNING — Persons using this International Standard should be familiar with normal laboratory practice. This standard 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 ensure compliance with any national regulatory conditions.

CAUTION — Certain procedures specified in this International Standard may involve the use or generation of substances, or the generation of waste, that could constitute a local environmental hazard. Reference should be made to appropriate documentation on safe handling and disposal after use.

1 Scope

This International Standard provides guidance on the determination of the abrasion resistance of vulcanized and thermoplastic rubbers. It covers both solid and loose abrasives.

The guidelines given are intended to assist in the selection of an appropriate test method and appropriate test conditions for evaluating a material and assessing its suitability for a product subject to abrasion. Factors influencing the correlation between laboratory abrasion testing and product performance are considered, but this International Standard is not concerned with wear tests developed for specific finished rubber products, for example trailer tests for tyres.

2 Normative references

The following referenced documents are indispensable for the application 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 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.

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

[ISO 1382:2008[1]]

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

NOTE Abrasion resistance is expressed by the abrasion resistance index.

[ISO 1382:2008[1]]

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

[ISO 1382:2008[1]]

3.4
relative volume loss
loss in volume of a test rubber due to abrasion by a specified abradant which will cause a reference rubber to lose a defined mass under the same conditions

4 Wear mechanisms

The mechanisms by which wear of rubber occurs when it is in moving contact with another material are complex, but the principal factors involved are cutting and fatigue. It is possible to categorize wear mechanisms in various ways and commonly distinction is made between:

— abrasive wear;

— fatigue wear;

— adhesive wear.

Additionally, wear by roll formation is sometimes considered as a separate mechanism.

Abrasive wear is caused by sharp asperities cutting the rubber.

Fatigue wear is caused by particles of rubber being detached as a result of dynamic stressing on a localized scale.

Adhesive wear is the transfer of rubber to another surface as a result of adhesive forces between the two surfaces.

Wear by roll formation is where there is progressive tearing of a layer of rubber which forms a roll.

There can also be corrosive wear due to direct chemical attack on the surface.

The term erosive wear is sometimes used for the action of particles in a liquid stream.

In any particular wear situation, more than one mechanism is usually involved, but one may predominate. Abrasive wear requires hard, sharp cutting edges and high friction. Fatigue abrasion occurs with smooth or rough but blunt surfaces and does not need high friction. Adhesive wear is much less common, but can occur on smooth surfaces. Roll formation requires high friction and relatively poor tear strength. Roll formation results in a characteristic abrasion pattern of ridges and grooves at right angles to the direction of movement.

Abrasive wear or roll formation results in much more rapid wear than fatigue processes. The mechanism and hence the rate of wear can change, perhaps quite suddenly, with the conditions, such as contact pressure, speed and temperature. In any practical circumstances, the mechanisms may be complex and critically dependent on the conditions. Consequently, the critical factor as regards testing is that the test conditions must essentially reproduce the service conditions if a good correlation is to be obtained. Even a comparison between two rubbers may be invalid if the dominant mechanism is different in testing and in service. The range of conditions encountered in such applications as tyres is so complex that they cannot be matched by a single test.

It follows that there cannot be a universal standard abrasion test method for rubber, and the test method and test conditions have to be chosen to suit the end application. Also, great care has to be taken if the test is intended to provide a significant degree of acceleration.

5 Types of abrasion test

A great many abrasion testing machines have been devised and several standardized at national level for use with rubber. The majority of rubber tests involve a relatively sharp abradant and were devised for use with tyre tread materials.

Abrasion tests can be divided into two main types: those using a loose abradant and those using a solid abradant.

A loose abrasive powder can be used rather in the manner of a shot-blasting machine as a logical way of simulating the action of sand or similar abradants impinging on the rubber in service. A loose abradant can also be used between two sliding surfaces. Conveyor belts or tank linings are examples of products subject to abrasion by loose materials. A car tyre is an example of the situation where there is a combination of abrasion against a solid rough abradant, the road, and abrasion against a free-flowing abradant in the form of grit particles. This situation can also occur in testing as a result of the generation of wear debris from a solid abradant.

Solid abradants can consist of almost anything, but the most common are: abrasive wheels (vitreous or resilient), abrasive papers or cloths, and metal “knives”. The majority of wear situations involve the rubber moving in contact with another solid material.

Distinctions can be made on the basis of the geometry by which the test piece and abradant are rubbed together. Many geometries are possible, and some common configurations are shown in Figures 1 to 8:

Figure 1: The test piece reciprocates linearly against a sheet of abradant (or alternatively a strip of abradant can be moved past a stationary test piece).

Figure 2: The abradant is a rotating disc with the test piece held against it (or *vice versa*).

Figure 3: Both abradant and test piece are in the form of a wheel, either of which can be the driven member.

Figure 4: The abradant wheel is driven by a flat rotating test piece.

Figure 5: Both the test piece and the abradant are rotating.

Figure 6: The test piece is held against a rotating drum.

Figure 7: The test piece revolves in contact with metal knives.

Figure 8: Test pieces are tumbled together with abrasive particles inside a hollow rotating cylinder.

If the abrasion is unidirectional, abrasion patterns will develop which can markedly affect abrasion loss.

6 Abradants

Abradants can be classified into the following types:

— abrasive wheels;

— papers and cloths;

— metal knives;

— smooth surfaces;

— loose abradants.

The abrasive wheel is probably the most convenient abradant because of its low cost and mechanical stability and also because, by simple refacing, a consistent surface can be maintained. Wheels are characterized by the nature of the abrading particles, their size and sharpness, the structure of the wheel and the manner in which the abrasive is bonded (either resilient or vitreous). It follows that a very wide range of abrasive properties is possible.

Abrasive papers and cloths are inexpensive and easy to use but deteriorate in cutting power rather quickly. They are characterized by the nature of the abrading particles and their size and sharpness.

Metal “knives” can have various geometries, including the form of a mesh and a raised pattern on a wheel. The main characteristic is the sharpness of the edges in contact with the rubber, and there can be some difficulty maintaining a reproducible sharpness.

Smooth surfaces are characterized by their degree of smoothness and the material, which defines the level of friction.

Loose abradants are commonly particles of the same material as is used to form abrasive wheels or papers, and are characterized by their size and sharpness.

The choice of abradant should be made primarily to give the best correlation with service conditions, but it is also necessary for the abradant to be available in a convenient form and for its production to be reproducible.

As a consequence of these considerations, abrasive wheels and papers or cloths predominate where cutting by sharp asperities is to be simulated. It is still necessary to select an appropriate asperity size and sharpness. Materials such as textiles and metal plates are more appropriate for other applications. Smoother materials generally abrade relatively slowly and, if conditions are accelerated, give rise to an excessive temperature rise at the sliding surfaces. Because of these difficulties, abrasive wheels and papers are frequently used for convenience in situations where they are inappropriate for assessment of in-service performance.

7 Test conditions

7.1 Temperature

Although temperature has a large effect on wear rate and is one of the important factors in obtaining correlation between laboratory and service conditions, it is extremely difficult to control the temperature during testing. Abrasion tests are normally carried out at standard laboratory temperature. However, it is the temperature of the contact surfaces which is of importance rather than the ambient temperature, and the surface temperature reached is dependent on several experimental factors as outlined in 7.2 to 7.5.

7.2 Degree and rate of slip

With any geometry involving a fixed abradant, there is relative movement or slip between the abradant and the test piece, and the degree of slip is a critical factor in determining the wear rate. In Figure 1 and Figure 6, there is 100 % slip, and the rate of slip is the same as the rate of movement between abradant and test piece, whereas in Figure 3 the degree of slip can be varied by changing the angle between the wheels. In Figures 2, 4 and 5, the rate of slip will depend on the distance of the test piece from the centreline. In all cases, the rate will depend on the speed of the driven member. An increase in the rate of slip will also increase the amount of heat generated and hence the temperature.

7.3 Contact pressure

The contact pressure between the test piece and abradant is another critical factor in determining the wear rate. Under some conditions, the wear rate may be approximately proportional to the pressure, but abrupt changes will occur if, with changing pressure, the abrasion mechanism changes. Such a change can be because of a large rise in temperature.

Rather than consider contact pressure and degree of slip separately, it has been proposed that the power consumed in moving the rubber over the abradant should be used as a measure of the severity of an abrasion test. The power used will depend on the friction between the surfaces and will determine the rate of temperature rise.

7.4 Continuous/intermittent contact

An important difference between the types of apparatus shown in, for example, Figure 1 and Figure 4 is that, in the first case, the test piece is continuously and totally in contact with the abradant and there is no chance of the heat generated at the contact surfaces being dissipated.

7.5 Lubricants and contamination

Any change in the nature of the contact surfaces will affect the rate of wear, and this includes changes in the abradant and the test piece as the wear process proceeds. Additionally, there can be deliberate addition of another material between the contact surfaces, accidental contamination, debris from the abradant and debris from the test piece.

Introduction of a particulate material between the contact surfaces can be made to simulate service conditions, such as a car tyre running on a dusty road. Similarly, a lubricant such as water can be introduced. Relatively few types of apparatus are capable of operating under these conditions.

It is common practice to remove wear debris by continuously brushing the test piece or by the use of air jets. In the latter case, care has to be taken to ensure that the air supply is not contaminated with oil or water from the compressor. Clogging or smearing of the abradant is a common problem with abrasive wheels and papers, and its occurrence will invalidate the test. It is normally caused by a high temperature at the contact surfaces and, although the problem can sometimes be reduced by introducing a powder between the surfaces, it should be treated as an indication that the test conditions are not suitable. If high temperatures are experienced in service, a test method in which new abradant is continually used should be chosen.

If correlation between laboratory tests and service conditions is required, the test conditions will have to be chosen extremely carefully to match those found in the application concerned.

8 Abrasion test apparatus

A large number of abrasion testers have been developed, and the following list is not exhaustive but covers those of greatest significance in the rubber and plastics industries (the main features of each are presented in Table 1):

— **Akron:** Wheel-on-wheel geometry, notable for the ability to vary the degree of slip by changing the relative angle of the wheels.

NOTE 1 An example of the use of this method can be found in BS 903 Part A9 [2].

— **DuPont (Grasselli):** Pair of small, flat-faced moulded test pieces on a rotating abrasive paper disc.

NOTE 2 An example of the use of this method can be found in BS 903 Part A9 [2].

— **Frick Taber:** Abrasive wheels on disc test piece with additional flow of abrasive powder. Noted for simulating wear of flooring.

NOTE 3 An example of the use of this method can be found in EN 660-2 [3].

— **Laboratory Abrasion Tester 100 (System Dr Grosch):** Sophisticated computer-controlled apparatus allowing variation of several parameters. Wheel-on-disc geometry.

— **Lambourn (Dunlop):** Both test piece and abrasive wheel are driven, slip being produced by eddy current braking.

— **Improved Lambourn:** Significantly improved design. Test piece and abrasive wheel driven independently.

— **Martindale:** Disc test piece on cloth abrasive disc. The pattern of relative movement forms a Lissajous figure giving multidirectional wear. A standard method for coated fabrics.

NOTE 4 An example of the use of this method for coated fabrics can be found in ISO 5470-2 [4].

— **NBS (Footwear Abrader):** Small square test piece in contact with a revolving drum covered with abrasive paper. Used particularly for footwear compounds.

NOTE 5 An example of the use of this method, primarily for shoe soles and heels, can be found in ASTM D1630 [5].

— **Pico:** Disc test piece rotated in contact with a pair of tungsten knives supplied with a uniform flow of dusting powder.

NOTE 6 An example of the use of this method can be found in ASTM D2228 [6].

— **Rotating cylindrical drum (DIN, Conti):** Small disc test piece traverses rotating cylinder covered with abrasive paper which gives large abradant/test piece area.

NOTE 7 An example of the use of this method can be found in ISO 4649 [7].

— **Rotating cylindrical mill:** A number of designs involving test pieces (usually discs) and particulate abrasive being tumbled together inside a rotating hollow drum. The motion simulates the action of free-flowing abrasive materials.

— **Schiefer (WIRA):** The test piece and abradant are two discs arranged as shown in Figure 5. The movement produces multidirectional abrasion. Various abradants may be used, including serrated metal surfaces.

— **Taber:** A pair of abrasive wheels are in contact with a driven flat-disc test piece. The force on the wheels and the nature of the abradant can easily be varied and the test can be carried out in the presence of liquids.

NOTE 8 An example of the use of this method for coated fabrics can be found in ISO 5470-1 [8].

Table 1 — Summary of types of abrasion apparatus

	Test piece	Abradant	Motion	Slip	Speed	Contact	See Figure
Akron	Wheel	Abrasive wheel	Test piece driven	Variable	0,2 m/s to 0,35 m/s	Intermittent	3
DuPont	Moulded or cut from sheet	Abrasive paper	Abrasive paper rotates	100 %	0,19 m/s to 0,3 m/s	Continuous	2
Frick Taber	Flat disc	Wheel + powder	Test piece rotates	100 %	0,25 m/s	Intermittent	4
LAT 100	Wheel	Abrasive disc	Disc rotates	Variable	Variable	Intermittent	4
Lambourne	Wheel	Abrasive wheel	Test piece/ abradant driven	Variable	0,21 m/s	Intermittent	3
Improved Lambourne	Wheel	Abrasive wheel	Test piece/ abradant driven	Variable	0,15 m/s to 3,6 m/s	Intermittent	3
Martindale	Disc	Various	Test piece driven in pattern	100 %	Varies	Continuous	Modification of 1
NBS	Square cut from sheet	Abrasive paper	Rotating drum	100 %	0,3 m/s to 0,4 m/s	Continuous	6
Pico	Disc	Tungsten knives	Test piece rotates	100 %	1,7 m/s to 5,3 m/s	Continuous	7
DIN	Disc	Abrasive paper	Rotating drum	100 %	0,31 m/s	Continuous	6
Mill	Disc	Abrasive particles	Tumbled in drum	NA	NA	Continuous	8
Schiefer	Disc	Various	Test piece/ abradant driven	100 %	Varies	Continuous	5
Taber	Flat disc	Various wheels	Disc rotates	100 %	0,045 m/s	Intermittent	4

9 Reference materials

Because of the difficulty in ensuring reproducibility of the abradant and/or test conditions, it is common practice to use a reference material against which results on the test material can be normalized.

Some workers prefer to use a standard rubber to normalize or certify the abradant. This is most useful when the abradant is certified by one source only, but does not enable corrections to be made for machine variations and ageing of the abradant.

The alternative, or additional, approach is to refer results on the test material to results obtained at the same time on a reference rubber, with the objective of eliminating variability due to differences between nominally identical machines and abradants.

The drawback to either approach is the difficulty in producing an accurately reproducible reference rubber. It may be difficult to decide whether it is the abradant or the reference rubber that is the most stable and reproducible.

A reference rubber can be produced and certified by one source, be produced locally to a given formulation or specification or be an in-house or user-defined standard representative of the type of compound being evaluated.

The most common type of reference rubber is based on a tyre tread compound, but shoe-sole type material is also widely used. Reference rubbers are specified in some specific abrasion test method standards, but no generally applicable reference materials have been established.

A material other than rubber could be used as a reference material, and could be more suitable in terms of reproducibility. A very soft metal and a plastic have been suggested, but no such material is in common use.

10 Test procedure

The main objective in selecting the test method and test conditions for a particular application is to achieve correlation with service conditions. Good correlation is only possible if the abradant and test conditions reproduce the essential conditions and, particularly, the abrasion mechanisms of service. Where service conditions are not well defined, it will be advisable to carry out tests with a range of abradants and test conditions.

In practice, good correlation is often extremely difficult or impossible to achieve because of the complexity of the wear mechanisms and the multiple climatic conditions in service.

Even for purely quality control purposes, it is necessary for the abradant and conditions to be chosen so as to be similar to those in service, although it will generally be sufficient to test with one abradant and one set of defined test conditions.

The abrasion pattern is a good, although not foolproof, indication of the wear mechanism, and examination of the worn surfaces of both the product and test pieces can show how well the service conditions have been matched in the laboratory.

Even if there is no quantitative correlation, valuable results can be obtained if the test produces the same ranking of materials as in service. For example, if the wear resistance depends on the hardness, resilience or coefficient of friction, the test should show a similar dependence. Fatigue wear can sometimes be changed by the type of antidegradant present in the rubber under both test and service conditions.

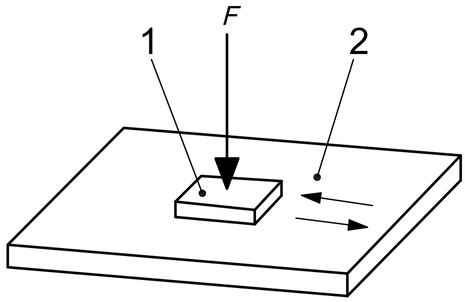
In seeking correlation, consideration should be given to factors other than the test conditions and wear mechanism. These include the effect of product bulk, the role of inflation where applicable, differences in the state of cure between the product and test pieces, and the effect of ageing of the product. Thus, it may sometimes be appropriate to examine the effect of cure or ageing on test performance for closer correlations.

The general test procedure should follow a particular test method standard or the apparatus manufacturer's instructions. Attention is drawn to ISO 23529 for conditioning of test pieces, determination of dimensions and preparation of test pieces, which should be followed as appropriate.

For some methods, it is advisable to make trial runs to establish suitable test conditions.

It is necessary to resurface or renew the abradant and to plan the order in which materials are tested to minimize the effects of changes in the abradant with time. Ideally, a new abradant would be used for each test, but the frequency at which resurfacing or renewal is necessary will depend on the particular abradant and the nature of the materials tested. A common practice is to test a reference material at intervals between the testing of the materials under study and to run repeat test pieces of a series of materials in reverse order.

Most methods are based on determining the difference in mass of the test piece before and after abrasion. Care will have to be taken that erroneous results are not obtained where microscopic examination shows that material has been scraped from the surface but remains attached to the test piece.

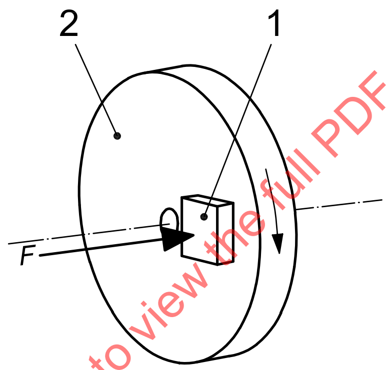


Key

1 test piece

2 abradant

Figure 1 — Test piece reciprocating linearly against a sheet of abradant

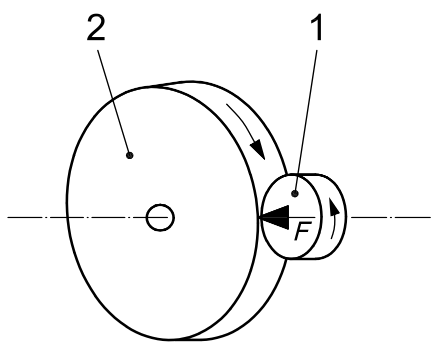


Key

1 test piece

2 abradant

Figure 2 — Test piece held against a rotating disc of abradant

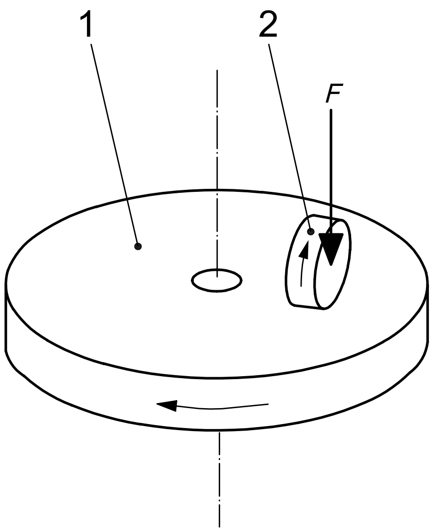


Key

1 test piece

2 abradant

Figure 3 — Test piece and abradant in the form of wheels either of which could be driven

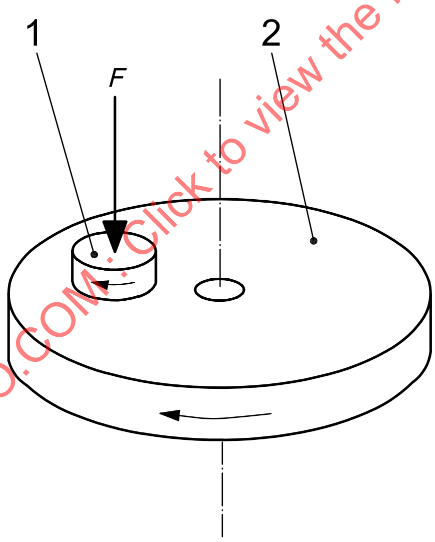


Key

1 test piece

2 abradant

Figure 4 — Rotating test piece driving the abradant wheel

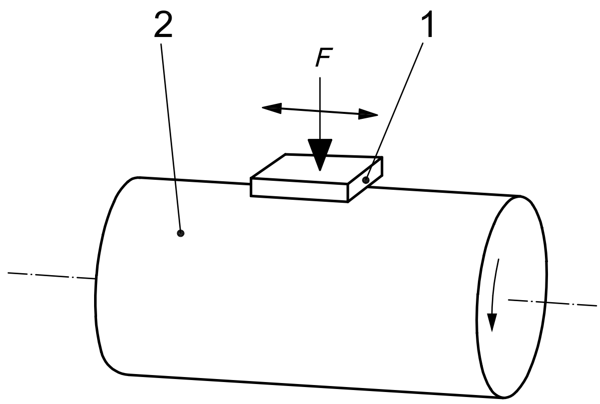


Key

1 test piece

2 abradant

Figure 5 — Rotating test piece held against a rotating abradant disc

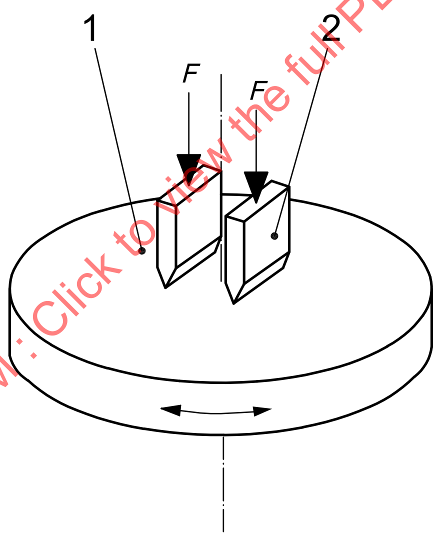


Key

1 test piece

2 abradant

Figure 6 — Test piece held against a rotating abradant drum

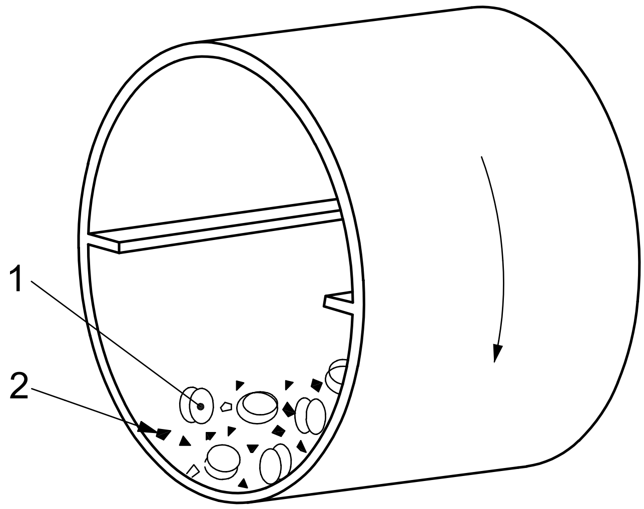


Key

1 test piece

2 abradant

Figure 7 — Abradant held against test piece in the form of a rotating disc



Key

1 test piece

2 abradant

Figure 8 — Test pieces and abradants inside a rotating drum

11 Expression of results

In standard abrasion tests, it is usually mass loss which is the parameter measured, although in certain cases the change in test piece thickness is more convenient. Because it is the amount of material lost which matters, it is usual to convert the mass loss to a volume loss by dividing by the density. The volume loss can be expressed as the loss per unit distance travelled over the abradant, loss per 1 000 revolutions of the apparatus, or loss per some other measure of length or time. A less usual practice is to express the result as the loss in volume per unit of energy consumed in causing abrasion, which is sometimes referred to as abradability and can be linked to the relative sliding speed through the Williams Landel Ferry (WLF) relationship. The loss in volume can also be calculated per unit surface area to give a specific wear rate.

Whatever measure is used to represent the loss, the rate of wear may not be constant because of inhomogeneity of the test piece, changes in the test piece surface or gradual changes in the nature of the abradant. To investigate the test piece effects, wear rate can be plotted against the number of cycles or the distance travelled. Abradant effects can be compensated for as discussed in Clause 10.

The abrasion resistance can be calculated as the reciprocal of the loss in volume.

If a reference material has been used to normalize the abradant, the relative volume loss, V_{RVL}, is calculated from:

$$V_{\text{RVL}} = \frac{V_{\text{test}} \times V_{\text{const}}}{V_{\text{ref}}}$$

where

V_{test} is the loss in volume of the test rubber;

V_{const} is the defined loss in volume of the reference rubber;

V_{ref} is the measured loss in volume of the reference rubber.

