

Procedure for Rotating Wheel Abrasion Testing

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SUMMARY

This procedure is for rotating wheel abrasion testing to determine the resistance of materials to abrasion. A rotating wheel is pressed against a sample in the presence of abrasive, and the wear that is produced is measured by weight loss. The test is very versatile, and can be used in a variety of test conditions such as wet or dry, and steel wheel or rubber rimmed wheel testing.

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1 SCOPE

This procedure is concerned with ambient temperature rotating wheel abrasion testing. The test uses a rotating wheel against which test-pieces are pressed. Abrasive is introduced between the wheel and the test-piece to cause abrasion to the test piece. The procedure complements the ASTM Standard G65 [1] on Dry Rubber Wheel Abrasion, ASTM B611 Test Method for Abrasive Wear Resistance of Cemented Carbides [2], and G105 Standard Test Method for Conducting Wet Sand/rubber Wheel Abrasion Tests [3].

The test is appropriate for use in situations where test laboratories have a need to simulate abrasive damage. The procedure includes information which enables the test to be used in a variety of different conditions:

- with counterface wheels of different stiffness (for example, steel and rubber)
- wet and dry
- different abrasive sizes
- different chemical environments

2 MATERIALS

2.1 TESTPIECES

Overall size

Test-pieces are typically larger than the contact area with the rotating wheel and are typically 40-50 mm x 20-25 mm in size. These test-pieces are designed to allow for the wear scar to be contained wholly within the area of the contact face. However, some variants of the test [4] use a test-piece with a clearly defined contact shape and size where the wear takes place across the entire contact face of the sample. The thickness of the test-piece is not important as long as it is sufficiently robust and the wear takes place entirely within the test sample.

When coated samples are tested the test duration is normally adjusted to ensure that the wear occurs exclusively within the coating. This can be determined by post test examination.

Surface finish

The surface finish of the test-piece may affect the results of the test. Thus the presence of a surface that is weakened by the preparation process may lead to increased initial wear. Conversely, the presence of a residual compressive stress in the surface layer may possibly reduce initial wear. In both cases when these surface layers are worn away, the wear rate will approach the normal value for the material.

2.2 ABRASIVE

2.2.1 The test abrasive should be obtained from a consistent source with good QC procedures to ensure that variability in its properties are minimised.

2.2.2 It is well known that the results of abrasion testing depend critically on the shape, size and size distribution of the abrasive. For this reason, if it is important to compare the results of one test with another, the same abrasive should be used in the tests concerned.

2.2.3 It is important that the abrasive is dry and free flowing to avoid blockage of the test system. If necessary it should be dried in an oven before use.

2.3 REFERENCE MATERIALS

It is also effective in other circumstances to use a reference material in a sequence of tests to normalise test results to take account of minor uncontrolled variations in test conditions or changes in the make-up of the abrasive. This procedure is described later, see section 5.3.

In any case, a test should be carried out periodically on a reference material to ensure that the test system is operating correctly and gives repeatable results.

WHEEL

Material

The wheel is either made from a solid piece of the requisite material such as steel, or for elastomeric materials a rim of the elastomer is normally moulded onto the rim of a steel wheel. Suitable steel wheels are described in ASTM B611 (AISI 1020), and chlorobutyl rubber rimmed wheels with a Shore A Durometer hardness of A 58-62 are specified in ASTM G65.

Moulded polyurethane rims can also be used, but it should be noted that even if the same ambient temperature hardness is achieved for the polyurethane as for the above specified rubber, significant differences in results can occur in dry tests, possibly due to alteration of mechanical properties relative to those of the rubber due to heating by the abrasion process.

Wheel size

The wheel specified in the ASTM G65 standard has a diameter of 228.6 mm and a face width of 12.7 mm. There are other test systems of a similar type which have wheels of different size but unless there are special reasons to choose otherwise, the ASTM G65 conditions should be used. For tests which use rubber elastomer rims such as ASTM G65, the thickness of the rim should be 12.7 mm. Again, if there are no special reasons to choose otherwise, the ASTM G65 conditions should be used.

The wheel is subjected to damage during the testing, and should be checked periodically for damage. If significant damage has occurred the wheel should be replaced. The overall diameter of the wheel should also be checked and when it is reduced in size by the recommended amount (12.7 mm for ASTM G65 and 4 mm for ASTM B611), the wheel should also be replaced.

The flatness and squareness of the contact area on the wheel is most easily checked by examining a wear scar (Figure 2). If this is even and regular, then the contact is flat and square.

3 TEST

3.1 SUMMARY OF TEST SYSTEM

Schematics of typical test systems are shown in Figure 1. Two variants are shown, the first [5,6] where the test-piece is horizontal and pressed into the top of the wheel; in the second [1,7] the test-piece is held vertically and pressed into the side of the wheel.

The abrasive is fed from a hopper into the abrasive feed system and thence into the contact between the test-piece and rotating wheel.

The test conditions can also be varied by adding a supply of fluid just in front of the abrasive feed, or by immersing the wheel in a bath of fluid that wets the wheel.

ABRASIVE FEED MECHANISM

The abrasive can be fed to the test-piece / wheel interface by a number of different methods. These include

- a vibrating feed
- a screw auger
- a slotted rotating disc to control flow coupled with a chute

The essential feature of all these methods is that the abrasive is fed steadily and in a well controlled way to the test-piece / wheel interface. All of these methods have been shown to be effective in giving good control of feed rates.

VACUUM EXTRACTION

It is important that for dry tests a vacuum extraction system is fitted to ensure that any used fine debris from the abrasive test-piece that might be a health risk is collected and can subsequently be disposed of safely.

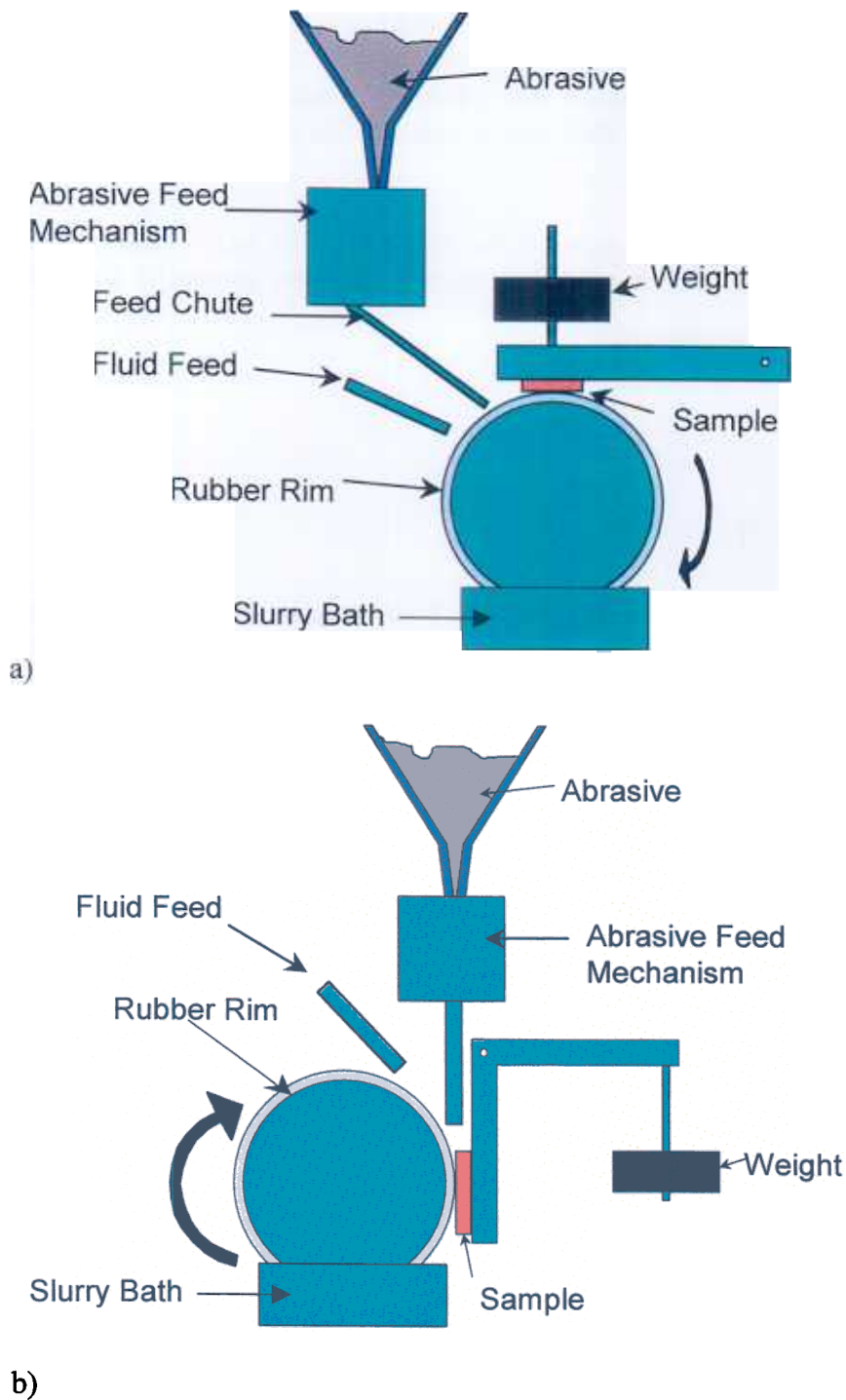


Figure 1 Schematic diagram of rotating wheel abrasion test system a) with horizontal test-piece, b) with vertical test-piece. Note that abrasive is either fed by means of a slurry bath, or by means of an abrasive feed from a hopper. Both types of supply are not required. In addition, the fluid feed is not required for dry tests.

3.4 CONTROL OF WHEEL SPEED

The wheel speed needs to be well controlled with a motor of adequate power such that a stable constant speed is achieved independent of load applied. The rotational speed should be calibrated periodically to ensure stable operation.

3.5 CALIBRATION OF ABRASIVE FLOW

The abrasive flow is clearly a critical parameter in the testing. This needs to be carefully measured. It is important to ensure that only the abrasive that actually passes through the wearing contact is measured. This is normally achieved by arranging a series of baffles to divert away any abrasive that does not pass through the contact so that only the abrasive that does pass through is measured by collecting and weighing for a pre-determined period and calculating a rate of abrasive flow-rate.

Some test systems [4,8] are specifically designed to ensure that all the abrasive passes through the test contact. In these systems the abrasive flow can be calculated by a simple measurement of all the abrasive passing through the contact.

To enable a comparison of abrasion loading to be carried out from one rig to another, the abrasive flow rate can be converted to an abrasive coverage (AC) figure where

$$AC = \frac{FR}{CA}$$

where FR is the mass flow rate of abrasive through the contact and CA is the contact area.

This procedure only makes sense where the counterface is compliant so that the contact area does not increase markedly as wear takes place during the test.

3.6 TEST LOAD

Normally the dead-weight loading is applied through a lever arm system. However, other types of loading system can be used effectively. The actual load applied should be calibrated before use of the test system and should be checked periodically.

3.7 FLUID FLOW

In systems fitted with a fluid feed, the flow rate should be calibrated before use. This is normally done by simple gravimetric procedures.

4 PERFORMING TEST

Tests can either be carried out with a single step of a relatively long duration, or an interrupted test can be carried out with a number of abrasion steps of shorter duration with the test-piece reweighed between each step.

The interrupted test can be useful to determine if transitions in wear are encountered, for instance due to the effect of surface damage to the test-piece. However, it should be noted that there is a possibility that interrupted tests will give different results to a non-interrupted test of the same duration. This possibility is due to the disturbance of the surface during the cleaning and reweighing process at the end of each step, and the possible effect of not being able to replace the test-piece exactly from one step to the next.

4.1 TEST-PIECE CLEANING

The test-piece should be cleaned before placing in the test system by the normal cleaning procedure for the test material. For many materials this can be carried out by cleaning ultrasonically in acetone for 10 minutes.

4.2 TEST-PIECE WEIGHING

The mass of the test-piece should be measured before the test.

4.3 TEST-PIECE CLAMPING

The test-piece is clamped in position in the test system. The alignment of the test-piece should be checked and adjusted if necessary to give a flat contact across the width of the wheel.

4.4 START OF TEST

The test-piece should be lifted off the wheel. The motor should be started and the speed of the wheel allowed to stabilise. The abrasive flow should be switched on and allowed to stabilise before the test-piece is lowered gently against the wheel and the test is started.

4.5 END OF TEST OR TEST STEP

At the specified contact duration, the motor and abrasive flow should be switched off. The test-piece should be removed and cleaned as described in Section 4.1 before being reweighed.

It is worth examining the test-piece by eye to check if the wear scar is even in shape (Figure 2). If this is not the case, the alignment of the test system and the wheel shape should be checked and the test repeated.

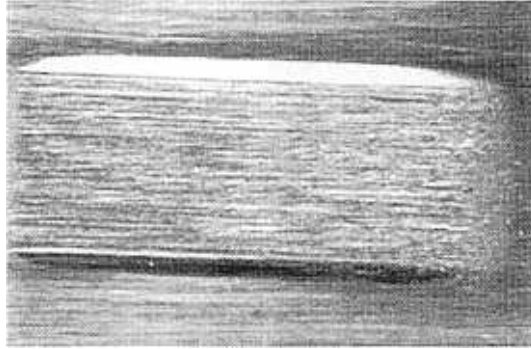


Figure 2 Even wear scar formed on steel test-piece with steel wheel and silica abrasive.

4.6 INTERRUPTED TESTS

For tests where a sequence of test steps are carried out for small test durations, with the test-piece reweighed after each step followed by replacing in the test system and another test step, Sections 4.1-4.5 should be repeated until the required total test duration has been achieved. Normally this will consist of at least 5 steps.

5 ANALYSIS OF RESULTS

5.1 SINGLE STEP TEST

The mass loss M is calculated by subtracting the value of mass measured at the end of the test from the initial mass. This is converted to a volume loss as $V = M/\rho$ by using the known test-piece density ρ .

5.2 MULTIPLE STEP TEST

5.2.1 Tabulation

The values of mass measured in 4.2 and 4.8 are tabulated, the mass losses calculated by subtracting these values from the initial mass, and a table of mass loss against mass of erodent calculated using a spreadsheet or equivalent program. The test-piece mass loss is converted to a volume loss by using the known test-piece density. The volume loss is normally presented as a graph with respect to mass of erodent.

5.2.2 Calculation of Abrasion Rate

Regression analysis should be used to obtain an abrasion rate for the material under the conditions of the test. It is important that this regression analysis only includes data points from the linear portion of the data.

5.3 USE OF A REFERENCE MATERIAL

If the results of the test are going to be compared to the results obtained with a reference material, then a test should be carried out under the same conditions. The ratio of the wear rate for the test material to the wear of the reference material is then calculated.

5.4 NUMBER OF REPEAT TESTS

At least two repeat tests should be carried out under the same conditions for each material.

6 REPORTING OF RESULTS

The results that should be reported include:

- Operator
- Date
- Material to be tested
- Surface finish of test-piece
- Abrasive material
- Abrasive size
- Mass of abrasive used
- Abrasive flow rate through contact
- Test duration
- Velocity of wheel periphery
- For a stepped test, graph of volume of wear with respect to mass of abrasive
- Abrasion rate
- Comments on any unusual behaviour (non-linear behaviour, incubation time etc).

If a reference material is used, then the following parameters should also be reported.

- Reference material
- Wear rate of the reference material
- Ratio of wear rates of test material to reference material

7 TYPICAL OPERATING CONDITIONS

The operating conditions for the test should be designed to match the conditions that occur in the application that is being simulated. In the absence of this information, the following conditions have been found to give useful results.

Load	130 N
Speed	1 ms ⁻¹
Abrasive Flow	150 g/min through contact
Test Duration	20 minutes

8 REFERENCES

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9 ACKNOWLEDGEMENTS

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