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Procedure for Gas Jet Erosion Testing

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SUMMARY

This procedure is for erosion testing to determine the resistance of materials to gas borne particulate erosion. Erodant particles are introduced into a gas stream which is directed at a controlled angle against a test sample. The wear that is produced is measured by weight loss.

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CONTENTS

1 SCOPE

This procedure is concerned with ambient temperature gas jet erosion testing. The test uses pressurised air that is blown through a nozzle. Erosive particles are introduced into the air stream by the venturi effect. This procedure is concerned with nozzles with an inner diameter greater than 3 mm and with a length greater than 200 mm. This procedure complements ASTM Standard G76 on Erosion Testing [1]

This test is appropriate for use in situations where test laboratories have a need to simulate damage of pipe work or other components that have been subject to erosion by particles in a high velocity gas stream.

2 MATERIALS

TESTPIECES

Overall size

Test-pieces are typically 50 mm x 50 mm, but the key point is that the size of wear scars on the test-pieces should be wholly encompassed by the test-piece. On test-pieces with a small size trial experiments can be conducted to ensure that this condition is met. The thickness of the test-piece is not critical, but it must be sufficient to completely enclose the wear that takes place.

Surface finish

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

TEST ERODENT

The test erodent should be obtained from a consistent source with good QC procedures to ensure that variability in the properties of the erodent are minimised.

It is well known that the results of gas borne particulate erosion depend critically on the shape, size and size distribution of the erodant. For this reason, if it is important to compare the results of one test with another, batches of the same erodent should be used in both tests.

It is important that the erodent 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 desirable in some circumstances to use a reference test-piece 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 or erodent. 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.

3 TEST

3.1 SUMMARY OF TEST SYSTEM

A schematic of a typical test system is shown in Figure 1

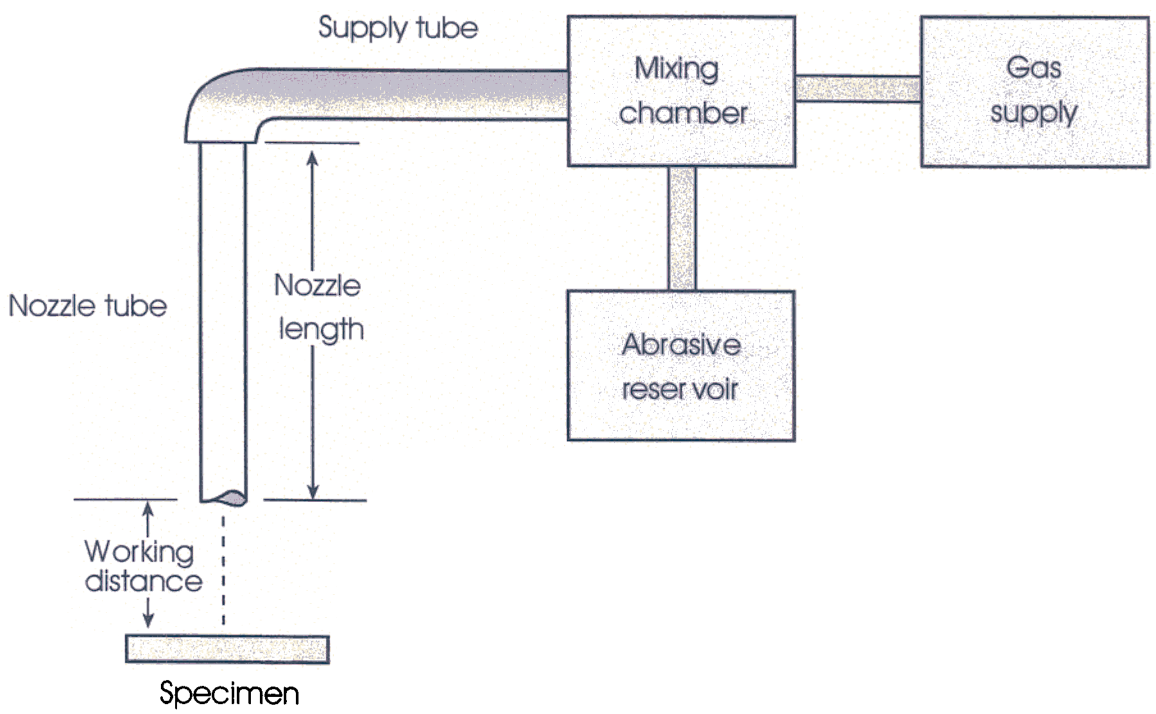

Figure 1, Schematic diagram of gas blast erosion system (from reference 1).

The erodent is fed from a hopper into the erodent feed system that introduces the erodent into the gas flow by means of a venturi suction device. The erodent particles are accelerated in the nozzle by the gas and emerge to hit the test-piece that is clamped at a well defined distance and angle from the end of the nozzle.

The test-piece and nozzle are enclosed in a sealed chamber that is provided with vacuum extraction to ensure that fine particulate material is removed safely.

3.2 NOZZLE

The length and diameter of the nozzle are both important parameters which affect the final particle velocity and divergence of the erodent particle stream on leaving the nozzle. The ASTM Standard recommends the use of a nozzle 50 mm long with a bore of 1.5 mm, but this suffers from considerable contact of erodent with the particle stream and a short nozzle life with a divergent particle stream. Other workers (eg [2]) use longer nozzles with a diameter of about 5 mm. To achieve an acceptable particle velocity distribution a length: diameter ratio of at least 25 is recommended.

3.3 VENTURI

The venturi is a critical element of the test system as it controls the way particles are fed into the gas stream for acceleration in the nozzle. The design of venturis is beyond the scope of this procedure; the reader is referred back to test system manufacturers for further information.

3.4 ERODENT FEED MECHANISM

The erodent can be fed to the venturi by a number of different methods. These include

- a vibrating feed
- a screw auger
- a vacuum feed coupled with a slotted rotating disc.

The essential feature of all these methods is that the erodent is fed steadily and in a well controlled way to the venturi. All of these methods have been shown to be effective in giving good control of feed rates.

3.5 VACUUM EXTRACTION

It is important that a vacuum extraction system is fitted to ensure that used erodent and debris are collected and can subsequently be disposed of safely.

3.6 CONTROL OF PARTICLE VELOCITY

The gas jet velocity is adjusted by varying the pressure of the gas feed to the nozzle. As the gas jet velocity is increased, the particle velocity will also increase. The differential gas pressure between the test chamber and the gas feed should be measured with a calibrated manometer.

Typically particle velocities in the range of about 40-200 ms^{-1} can be achieved with this type of system, but there are some systems that are capable of higher particle velocities [3].

3.7 CALIBRATION OF PARTICLE VELOCITY

Accurate measurement of impact velocity is essential in any quantitative erosion test.

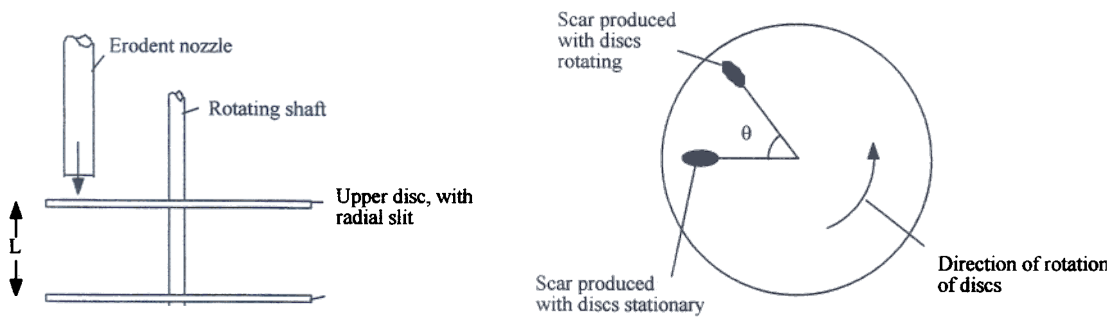

Figure 2 Double disk method for particle velocity measurement.

A common method is the rotating double disk method [4] illustrated in Figure 2. Two disks are rotated on a common shaft, and the stream of erodent particles is arranged to strike the upper disk which has a thin radial slot cut in it. The lower disk is coated with a thin paint or dye film to show where particles strike it. Two erosion scars are formed: one with the disks stationary, with the particles passing through the slit in the upper disk, and the other with the disks rotating at a known speed. The angular displacement θ between the two scars is measured, and can be used to calculate the time taken for the particles to travel the distance *L* between the disks, and hence their velocity, *V*. The velocity is given by

$$V = \frac{L\omega}{\theta}$$

where ω is the angular velocity of the rotating disks. In practical examples of this device, a high rotational speed is needed to achieve reasonable displacement of the scars and thus accuracy of measurement of the angle θ. Values between 3000 and 10000 revolutions per minute are common, with a distance *L* of about 20 to 40 mm. The method is well suited to use in an gas-blast erosion test, since velocity calibration can be carried out under exactly the same conditions of particle feed rate and air pressure as used in the erosion test. However,, the random error in measuring velocity in this way is ± 10% and there can also be a systematic error due to the aerodynamic influence of the rotating disks on particle stream, which may be 10% or even greater for very small particles of low density.

Another relatively simple method, which is well suited to use with the gas-jet method, involves measuring the time of flight of the particles between two transverse light beams a short distance apart [5].

3.8 CALIBRATION OF MASS FLOW RATE

There are two methods that can be used to calibrate the mass flow rate. These are to collect erodent in an erodent trap enclosed around the nozzle for a known period of time or to measure the time taken to use a known mass of erodent. Both of these are subject to some error in determining the time period, so it is advisable to use a fairly large mass of erodent in these measurements (say 20 g).

Normally the mass flow rate can be altered by adjusting the erodent feed mechanism. The calibration of mass flow rate should be carried out for all flow rates used in experiments, although normally this calibration is not of major importance as the amount of erodent used in an experiment is controlled by weighing known aliquots of erodent.

TEST TEMPERATURE

For tests at ambient temperatures (e.g. between 18 and 25 °C), small variations in the test temperature do not have a major effect.

4 TEST PROCEDURE

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

Test-pieces are normally clamped on a table in the test-piece chamber that can be rotated to a set angle with respect to the nozzle. The angle shall be adjusted to give the current angle of incidence of erodent with the test-piece surface.

NOZZLE POSITION

The nozzle should be positioned so that the tip of the nozzle is the required distance above the test-piece surface.

The stand-off distance influences the size of the eroded area, which gets larger as the stand-off distance increases due to spread of the erodent stream.

4.5 The test-piece chamber is closed, the vacuum extraction system started, and the gas flow started at the appropriate pressure to give the required particle velocity.

4.6 START OF TEST

The test is started by introducing the first aliquot of erodent into the feed mechanism.

4.7 FINISH OF FIRST STAGE OF TEST

After the first aliquot of material has been consumed, the test system should be switched off and the test-piece removed.

4.8 TEST-PIECE CLEANING AND REWEIGHING

The test-piece should be cleaned by the same procedure given in 4.1 and then reweighed.

4.9 COMPLETION OF TEST

Steps 4.1, 4.2, 4.5, 4.6, 4.7, and 4.8 should be repeated until the required total mass of erodent has been used. Normally at least 5 steps are used.

5 ANALYSIS OF RESULTS

5.1 TABULATION

The values of mass measured in 4.2 and 4.8 are tabulated 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 (Figure 3 [6]).

5.2 CALCULATION OF EROSION RATE

Normally a linear relationship is observed between the test-piece mass loss and the mass of erodent. However, an initial incubation time is often observed before this linear relationship is seen (Figure 3). Regression analysis should be used to obtain an erosion 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.

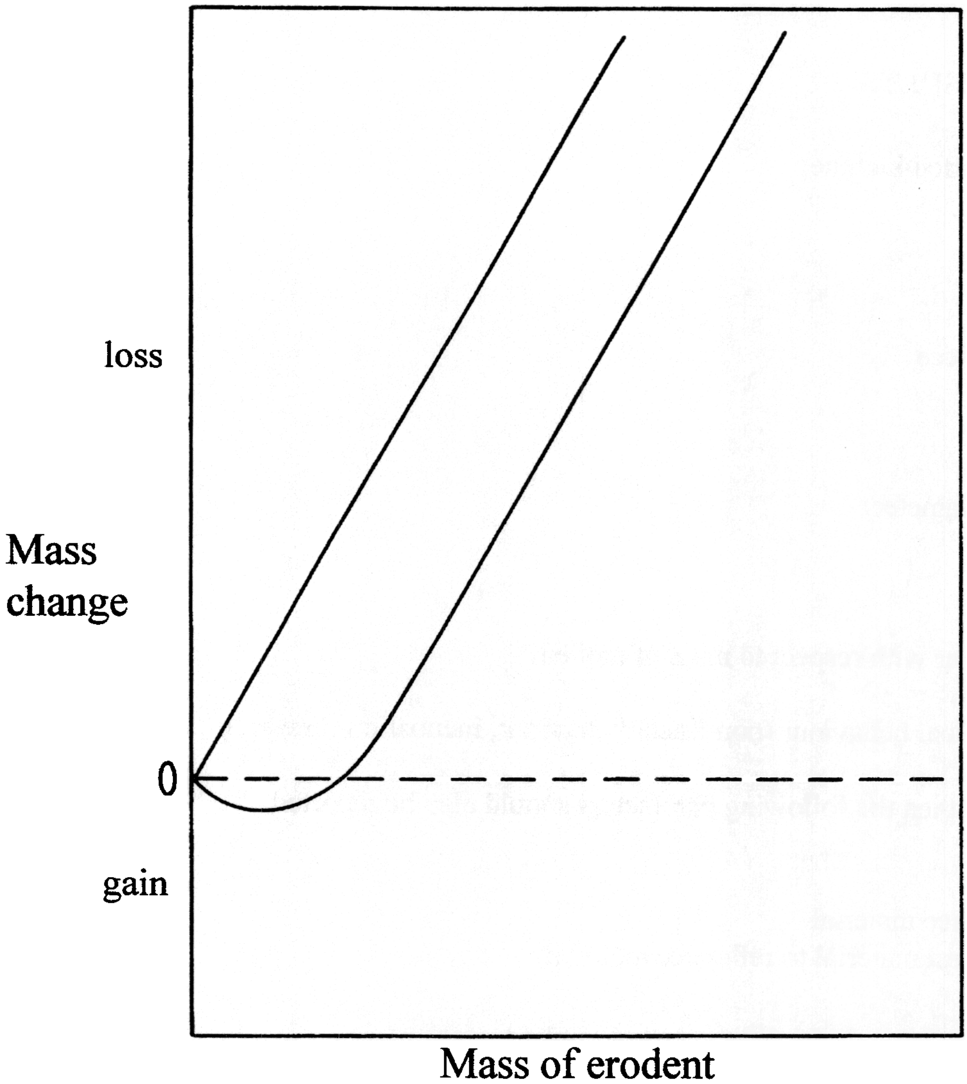

Figure 2 Typical dependence of mass lost from a specimen on the total mass of erodent particles that have struck it. In many cases, the mass loss increases linearly with mass of erodent from the start of the test, but under some conditions there may be a significant incubation period where the wear rate is different from the final steady state value, and in some cases the specimen gains mass.

5.3 USE OF A REFERENCE MATERIALS

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
Erodent material
Erodent size
Mass of erodent used
Nozzle size (internal diameter)
Nozzle length
Angle of incidence
Velocity of erodent
Graph of volume of wear with respect to mass of erodent
Erosion 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.

Erodent	220 μm silica
Impact velocity	75 ms^{-1}
Impact angles	20 and 90 °

8 REFERENCES

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6) I. M. Hutchings, Tribology: Friction and Wear of Engineered Materials, Edward Arnold, 1992

9 ACKNOWLEDGEMENTS

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