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Paints and varnishes — Adhesion of coatings

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 documents 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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

Introduction

The determination of the adhesive strength is one of the most important preconditions for evaluating the protective function of coatings.

This document offers a helpful overview for the selection of the test method most suitable for each individual case in regard to the evaluation of the adhesive strength.

Paints and varnishes — Adhesion of coatings

1 Scope

This document summarises the common methods for evaluating the adhesive strength of coatings on a substrate, which can be another coating beneath or the substrate itself. The test methods and evaluation methods are described in Clauses 4, 5, and 6. In the case of standardized test methods the respective standard is referenced in regard to procedure and evaluation. Annex A compares the methods in the synoptic Tables A.1, A.2, and A.3.

Often the adhesive strength cannot be sufficiently evaluated by means of a single method.

The purely physical methods for measuring the adhesive strength are such in which mechanical quantities (e.g. force or torsion moment) are measured directly.

All other methods are based on the evaluation of behaviour under mechanic stress according to practical conditions. For these methods the viscoelastic properties have a wide influence on the evaluation of the adhesive strength, so that it can only be tested comparatively within one method.

Each method has its specific application. An unsuitable method can lead to false information. All of the test methods for the evaluation of the adhesive strength require a certain routine of the test person, especially in regard to identifying the separation line. For most of the test methods the test results, among other things, depend on the film thickness of the coating to be tested. In addition, for several methods differences between tests on a test sheet and in practice can occur, due to different roughness of the substrate.

Effects of delamination caused by weathering or corrosion influences are not subject of this document.

In case cohesion failures predominantly occur during an adhesive strength test, this is no measure for the adhesive strength. However, information can be given on the protective effect of the coating against corrosion.

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 4618, *Paints and varnishes — Terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4618 and the following apply.

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

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

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

3.1
adhesion
phenomenon of attachment at the interface between a solid surface and another material caused by molecular forces

Note 1 to entry: Adhesion should not be confused with cohesion.

[SOURCE: ISO 4618:2014, 2.7]

3.2
cohesion
forces that bind a film or coat into an integral entity

Note 1 to entry: Cohesion should not be confused with adhesion.

[SOURCE: ISO 4618:2014, 2.55]

3.3
adhesion failure
detachment of a coating from the substrate caused by external forces

Note 1 to entry: The substrate can be another coating beneath or the working material.

3.4
cohesion failure
loss of coherence within a coating caused by external forces

3.5
adhesive strength
force required to detach a coating from a substrate or another coating

[SOURCE: ISO 4618:2014, 2.8]

3.6
wet adhesive strength
adhesive strength (3.5) immediately after previous exposure to moisture

3.7
separation line
interface in which *adhesion failure* (3.3) occurs

3.8
failure pattern
entirety of the visual coating defects, which are caused by an *adhesive strength* (3.5) test

3.9
failure pattern assessment
classification of a *failure pattern* (3.8) by means of criteria or reference patterns

3.10
failure pattern analysis
quantitative evaluation of a *failure pattern* (3.8) with specification of the relative percentages of area for *adhesion failure* (3.3) and *cohesion failure* (3.4) as well as the separation line(s)

3.11
main separation line
separation line with the largest area

3.12
repeatability conditions
conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time

[SOURCE: ISO 5725-1:1994, 3.14]

3.13
repeatability limit
r
the value less than or equal to which the absolute difference between two test results obtained under *repeatability conditions* (3.12) may be expected to be with a probability of 95 %

[SOURCE: ISO 5725-1:1994, 3.16]

3.14
reproducibility conditions
conditions where independent test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment

[SOURCE: ISO 5725-1:1994, 3.18]

3.15
reproducibility limit
R
the value less than or equal to which the absolute difference between two test results obtained under *reproducibility conditions* (3.14) may be expected to be with a probability of 95 %

[SOURCE: ISO 5725-1:1994, 3.20]

4 Adhesive strength tests without scratch/cut

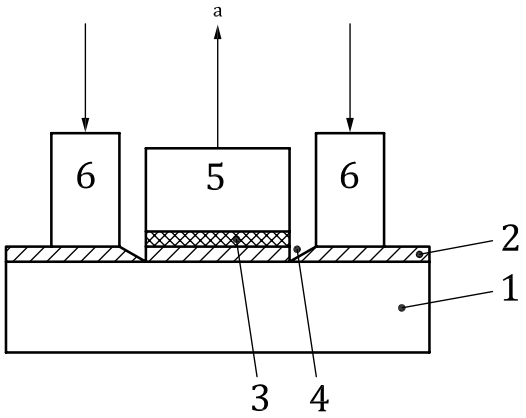
4.1 Tests with mechanical stress application on the coating

4.1.1 Pull-off test

— Principle

A uniformly increasing tensile force is applied to a test cylinder (metal cylinder of diameter 20 mm), which is adhered to the coating, until the test cylinder is pulled off. The pull-off strength is determined by calculating the tensile force to pull off the test cylinder and the area of the test cylinder.

The principle of the pull-off test is illustrated schematically in Figure 1.



Key

1 substrate
2 coating
3 adhesive film
4 free punch
5 test cylinder
6 outer ring to support the test panel
a The pull-off direction.

Figure 1 — Principle of the pull-off test

— Application

The pull-off test is generally applicable.

— Procedure

— Attach the test cylinder to the coating by means of a previously tested adhesive.

— Cut the coating around the circumference of the test cylinder using a suitable tool through to the substrate (see Figure 1).

— Attach the test specimen to the test apparatus so that it is supported and the test cylinder is connected to the pulling unit, centred and without being wedged.

— Carry out the pull-off process with a uniformly increasing tensile force and measure when the test cylinder is pulled off.

— Evaluation

The test result is the pull-off strength (MPa) = the tensile force when pulling off the test cylinder divided by the area of the test cylinder.

Specify the result of the failure pattern analysis (see the procedure specified in 6.2.1).

— Precision

Precision data are not available at present.

— Reference

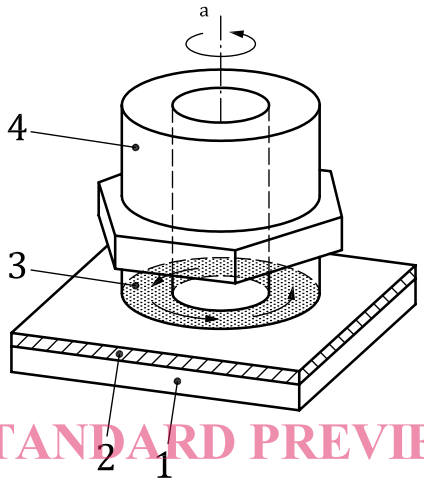
The pull-off test is specified in ISO 4624 and ISO 16276-1.

4.1.2 Twist-off test

— Principle

By means of a motor-driven test apparatus a uniformly increasing torsion moment is introduced to a test cylinder (a metal cylinder of a 12 mm or 15 mm diameter and a 6 mm drill), which is adhered to the coating, until it is twisted off. The adhesive strength ("shear strength") can be read directly from the test apparatus as shear stress (N/mm^2 = MPa).

Figure 2 illustrates the principle of the twist-off test in a schematic diagram. Figure 3 shows the minimum distance between the test cylinders for repeated tests.



Key

1 substrate
2 coating
3 adhesive
4 test cylinder
a The axis of rotation.

Figure 2 — Principle of the twist-off test

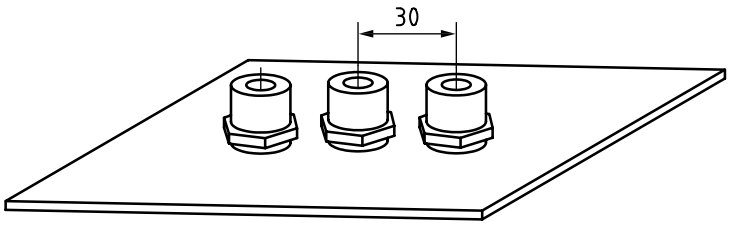


Figure 3 — Minimum distance between the test cylinders

— Application

The twist-off test is generally applicable.

— Procedure

— Use a sufficiently thick substrate (minimum 0,7 mm) or a substrate with reinforcement adhered to the backside in order to avoid deformation during testing.

— Adhere the test cylinder to the coating using a previously tested adhesive. For repeated tests observe a minimum distance between the test cylinders (see Figure 3).

— Attach the test apparatus at the hexagon bolt of the test cylinder (see Figure 2) and secure the test panel against twisting.

— Start torsional stress and read the shear stress from the apparatus when the test cylinder is twisted off.

— Evaluation

The test result is the shear stress (N/mm^2 = MPa), which is read from the apparatus and interpreted as the twist-off strength.

Specify the result of the failure pattern analysis (see the procedure specified in 6.2.1).

— Precision

Precision data are not available at present.

— Reference

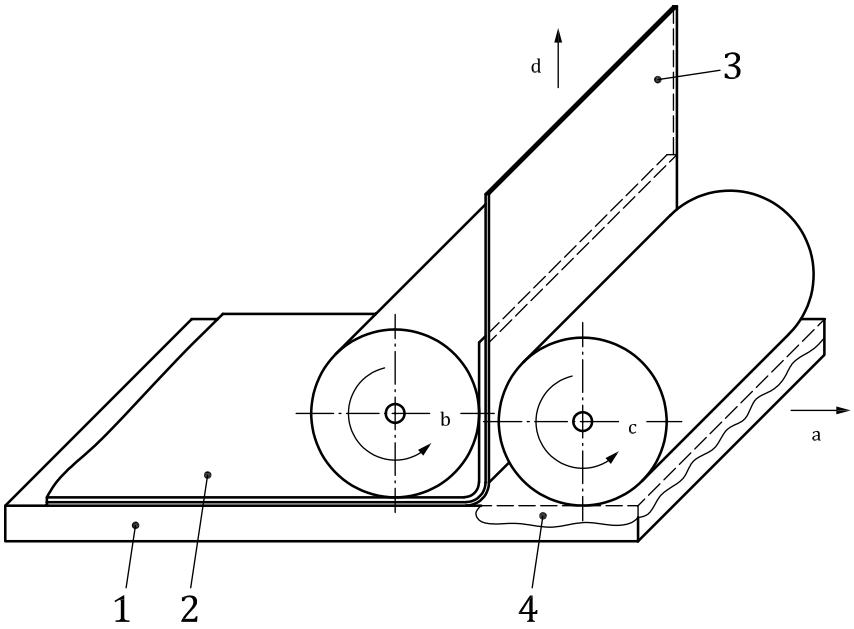
The twist-off test is specified in Reference [50].

4.1.3 Peel-off test 1

— Principle

A fabric specified by material, thread size, and mesh size is bedded into a newly applied coating material. After curing of the coating a tensile tester grabs the overlapping fabric, and due to continuous tensile force at 90° the coating is peeled off from the substrate. The peel strength is determined as the force required for peeling off and referring to the width of the test specimen.

Figure 4 schematically shows the peel-off process and the function of a 90°-peel-off apparatus.



Key

1 substrate
2 coating
3 fabric
4 tape (uncoated end of the test panel)
a The direction of movement of the test panel.
b The direction of rotation of the pressing roller on the coating.
c The direction of rotation of the pressing roller on the uncoated test panel.
d The direction of peel-off (tensile tester).

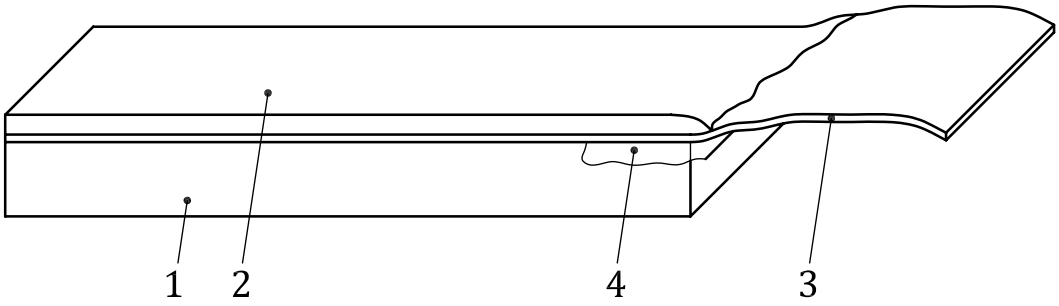
Figure 4 — Principle of the peel-off test 1

— Application

The peel-off test 1 is preferably carried out on automotive coatings.

— Procedure

— Coat the test panel (dimensions 15 mm × 100 mm) sparing a 10 mm wide strip at the edge of the narrow side. Subsequently bed the fabric so that it remains for about 50 mm uncoated and overlaps at the uncoated end of the test panel (see Figure 5).



Key

1 substrate
2 coating
3 fabric
4 tape (uncoated end of the test panel)

Figure 5 — Test panel with coating and fabric

— After drying/hardening of the coating mount the test panel into a tensile tester equipped with a 90°-peel-off apparatus (see Figure 4) and clamp the free end of the fabric.

— Start the peel-off process and record the tensile force (peel strength) required for peeling off.

— Evaluation

Determine the mean peel strength over a peel-off distance of at least 50 mm for five test specimens, disregard the beginning and the end of the test.

The test result is the mean value (with standard deviation) from the five individual determinations, which is designated as the peel strength (N/15 mm width of test specimen).

Specify the result of the failure pattern analysis (see the procedure specified in 6.2.1).

— Precision

Precision data are not available at present.

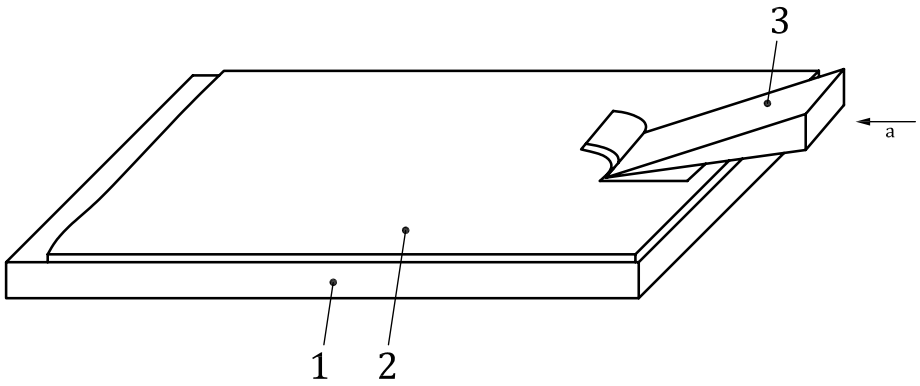
— Reference

The peel-off test 1 is specified in Reference [47].

4.1.4 Peel-off test 2

— Principle

The coating is peeled off from the substrate under specified conditions by means of an electrically driven test apparatus. The force is determined which is required for peeling off and which refers to the width of peeling off. Figure 6 illustrates the peel-off process in a schematic diagram.



Key

1 substrate
2 coating
3 peel-off tool
a The peel strength.

Figure 6 — Principle of the peel-off test 2

— Application

The peel-off test 2 is generally applicable.

— Procedure

— Specify the peel-off tool (cutting angle/width), setting angle, peel-off speed and peel-off distance.

— Mount the test panel into the peel-off apparatus and start the peel-off process.

— During testing record the force (peel strength) required for peeling off.

— Evaluation

Determine the mean peel strength over the peel-off distance, disregard the beginning and the end of the peel-off process.

The test result is the mean peel strength divided by the width of the peel-off tool (N/mm).

— Precision

Precision data are not available at present.

— Reference

The peel-off test 2 is specified in Reference [35].

4.2 Tests with continuous deformation of test specimens

4.2.1 Bend test with a wedge-shaped conical mandrel

— Principle

The test panel is deformed from the direction of the substrate side by pressing in a wedge-shaped conical mandrel of specified geometry. The smallest radius of the mandrel is determined for which no defect of delamination in the deformed area is detectable.