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Plain bearings — Dynamic adhesion test method for DLC coated parts under lubricated condition

Paliers lisses - Méthode d'essai d'adhérence dynamique sur des composants revêtus de DLC dans des conditions de lubrification

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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 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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This document was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 7, *Special types of plain bearings*.

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

Reducing the mechanical loss in engines is one of the effective ways to improve the fuel efficiency of automobiles. To reduce the friction coefficient between engine parts, diamond-like carbon (DLC) coatings can be applied for plain bearings as well as other sliding parts such as valve lifters and piston rings.

Since DLC hard coatings have high internal stress due to its coating process under high temperature and the difference of the coefficient of thermal expansion between DLC and engine parts, the quality control of the adhesion strength between coatings and base materials of specific parts after the coating process is very important. As there is no appropriate official test, automobile manufacturers or part suppliers must validate the adhesion strength by using a specially designed test facility using actual engine parts. In order to further spread the DLC coatings to mechanical parts of engines in the future, a test method can be used to easily evaluate the adhesion strength of the coatings.

The purpose of this document is to provide a test method for evaluating adhesion strength of DLC coatings. The test method specified in this document is a test apparatus equipped with a simple ball-on-disk that has a correlation with conventional engine evaluation results and a relatively inexpensive acoustic emission measurement machine without using actual parts.

The positioning of this test method in the process of parts evaluation performed by automobile manufacturers or part suppliers is shown in Annex A. The correlation between results obtained by the test method specified in this document and results obtained by the test method using conventional engine parts is described in Annex B.

Plain bearings — Dynamic adhesion test method for DLC coated parts under lubricated condition

1 Scope

This document specifies a procedure to measure the adhesion strength of diamond-like carbon (DLC) coatings specified in ISO 20523 by detecting acoustic emission signals using ball-on-disk method under the lubricated condition. DLC is normally coated on metal or ceramic.

The test results are not applicable when the DLC coated parts operate in an unlubricated environment.

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 683-17, *Heat-treated steels, alloy steels and free-cutting steels — Part 17: Ball and roller bearing steels*

ISO 1101, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 21920-2, *Geometrical product specifications (GPS) — Surface texture: Profile— Part 2: Terms, definitions and surface texture parameters*

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
ball-on-disk method
test method in which the sliding contact between fixed balls and rotating disk specimen

3.2
acoustic emission
AE
physical vibration caused by sudden movement within a material subjected to physical stress, often symptomatic of a defect

3.3
adhesion strength
load of diamond-like carbon (DLC) coating delamination detected by sharp signal increment of *acoustic emission* (3.2)

4 Specimens

4.1 General

Ball and disk specimens having the dimensions described later are prepared. To load equally on each ball, three balls shall be applied. In the ball-on-disk test, a bearing ball is fixed and used. The disk can be used as a substrate for a DLC film for testing. All appropriate details regarding the ball and disk specimens shall be provided, such as their dimensions, surface finish, material type, composition, microstructure, and processing.

4.2 Ball specimen

The ball specimen shall be 9,525 mm in diameter, made of 100Cr6 material as specified in ISO 683-17, and is recommended to be the equivalent to G28 or more as specified in ISO 3290-1. The hardness of the ball is HRC 62-67.

4.3 Disk specimen

The thickness of the disk specimen is 2,5 mm or more. The thickness of the DLC film is 0,1 µm to 10 µm. In order to set the sliding radius of the ball to 9 mm, the diameter of the test specimen is 28 mm or more. If the disk has a hole inside, the acceptable inner diameter is 12 mm or less. The surface of the disk shall be flat and parallel within 0,02 mm as specified in ISO 1101. The roughness of the test surface shall be less than 0,02 µm Ra as defined in ISO 21920-2. The hardness of the substrate is recommended to be HRC 60 or more, or 700 HV or more.

5 Apparatus

5.1 Testing equipment

Adhesion strength test using ball-on-disk testing equipment shall consist of the following:

a) the disk holder, for securing a disk specimen;

b) the ball holder, for fixing ball specimens;

c) the equipment, for driving the disk while pressing the ball against the disk with stepwise load;

d) the equipment, for measuring the friction force;

e) the oil bath maintaining lubrication and its temperature;

f) the oil heater, for controlling the oil temperature;

g) the acoustic emission (AE) sensor, for detecting delamination of DLC coating;

h) the AE sensor holder, for detecting AE by way of ball specimens;

i) the equipment, for amplifying AE signal;

j) the equipment, for counting AE events;

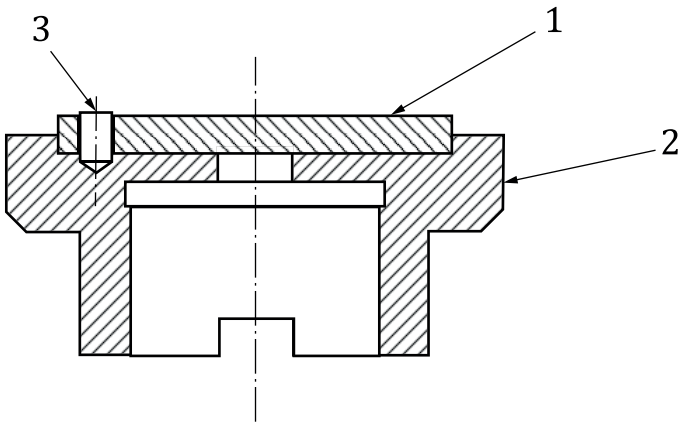
k) the ancillary devices for the above.

5.2 Specification of ball-on-disk equipment

The test equipment should have a capability to apply the load up to 5 kN, and speed at least 100 min^{-1}.

5.3 Sample of disk holder

The disk holder shall rotate in a horizontal plane. The eccentricity of the rotating axis shall be less than 0,02 mm and the fluctuation at the contact point in the direction perpendicular to the disk shall be less than 0,02 mm. The example of assembly is in Figure 1. The concentricity between the upper frame centre and the centre of disk holder shall be aligned in the assembled condition.



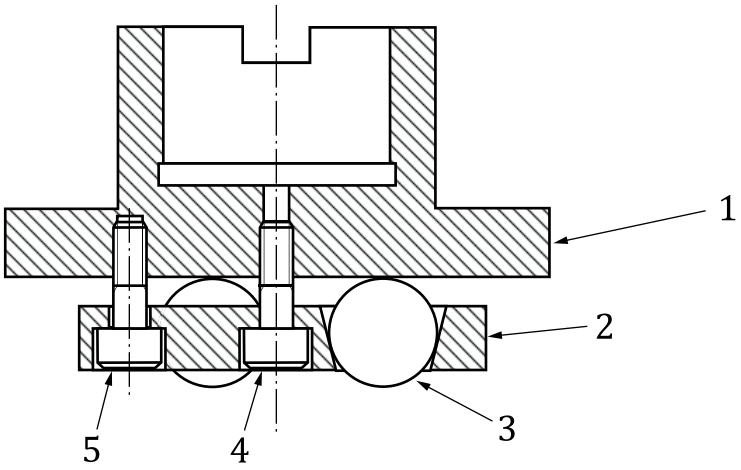
Key

1 disk
2 disk holder
3 pin to prevent from disk rotation

Figure 1 — Sample of disk holder

5.4 Sample of ball holder

A schematic of assembly is shown in Figure 2. The ball holder shall fix the ball specimens to ensure the sliding motion between the ball specimens and the disk specimen. It is necessary to prevent from the ball specimen rolling. Bolt tension shall be given to bolts in Figure 2 to fix the ball specimens to their holder in the test condition. The ball holder also should have a high rigidity because of the high stresses at the contact point between balls and their holder. In order to align orbitals of three balls, the concentricity of the upper frame centre and the centre of pitch circle diameter of the ball specimens shall be aligned in the assembled condition.



Key

1 upper frame
2 ball holder
3 ball specimen
4 bolt centre
5 bolt outer

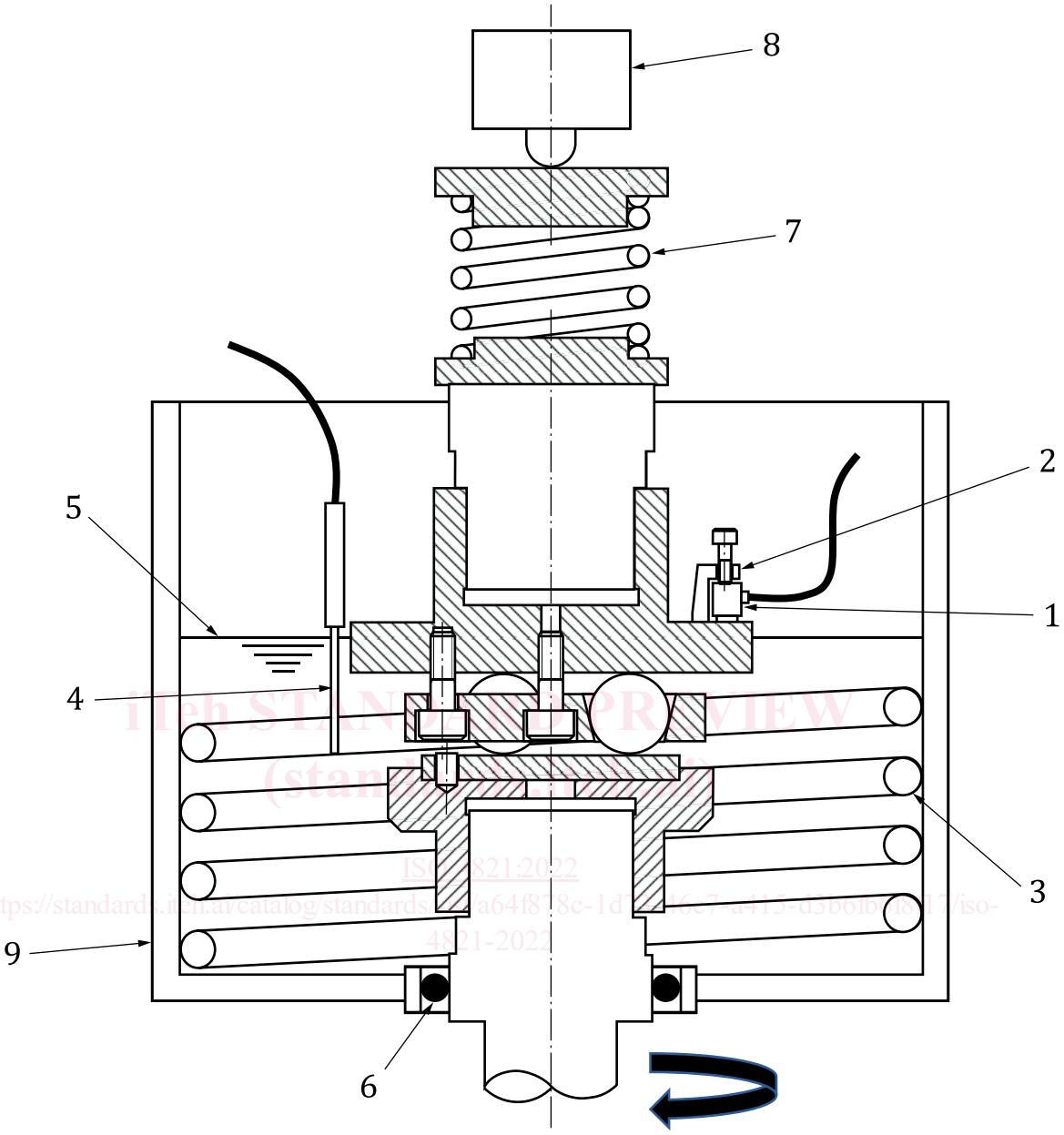
Figure 2 — Sample of ball holder

5.5 Oil bath and equipment for controlling oil temperature

The lubrication is maintained by either oil bath or circulation type. Figure 3 shows an example of the oil bath system. It is permitted to have an arrangement "upside down", i.e. the rotating part on top.

The level of lubricant is that at which the test piece is completely immersed.

The temperature of oil in the oil bath is controlled by a heater to within 2 °C of the set temperature at 80 °C.



Key

1	AE sensor	6	oil seal
2	AE sensor holder	7	load spring
3	oil heater	8	load cell
4	thermocouple	9	oil bath
5	lubricant		

Figure 3 — Oil bath and equipment for controlling oil temperature

5.6 AE sensor and its holder

The range of the frequency covered by the AE sensor should be 10 kHz to 1 000 kHz (see ISO 12713). The sensor surface contacts on the upper frame. An example of the AE sensor holder and its assembly are also shown in Figure 3. The level of the lubricant is lower than the location of the AE sensor for the protection.