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Road vehicles — Brake lining friction materials — Dynamometer metal pick-up generation procedure for disc brakes

Véhicules routiers — Matériaux de friction des garnitures de freins — Procédure de génération de métal aggloméré sur freins à disque par dynamomètre

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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 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

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

Metal pick-up (MPU) is a phenomenon/issue observed in automotive disc brakes during the braking process. Worn metallic particles may agglomerate under specific conditions and embed in the friction material. It may deteriorate brakes' appearance by scoring (grooves) on the surface of brake discs. MPU is also suspected to be a root cause of brakes NVH (noise, vibrations and harshness) issues as brake squeal or wire brush.

There is no single mechanism for creation of MPU in the automotive brakes so it cannot be only one specific condition for testing it. While the so-called NAO (non-asbestos-organic) friction materials are sensitive to high temperature and pressures, low metallic materials may create MPU under wet conditions or even more under the saltwater influence.

This document describes and covers all known critical conditions for generating MPU, it specifies which conditions are critical for a given friction material type. The methods described apply not only in the development of the material composition, but also in the selection of the materials for new brake applications and optimization of components for a recognised MPU issue.

This document includes three test procedures:

1. MPU generation under water/saltwater influence (typical for low metallic friction materials);
2. MPU generation at low temperatures and low brake pressures (typical for low metallic friction materials);
3. MPU generation at high brake temperatures and brake pressures (typical for NAO friction materials).

Road vehicles — Brake lining friction materials — Dynamometer metal pick-up generation procedure for disc brakes

1 Scope

This document describes test procedures for assessing the influence of pressure, temperature and water/salt water on the generation of metal pick-up (MPU) for a given friction material in combination with a specific brake disc. There are multiple tests to investigate the MPU generation issue for different types of friction materials (so called NAO and low metallic materials) under critical environmental and working conditions: influence of water and salt water, high temperatures and high pressures and low temperatures and low pressures.

This document supports the friction material development process and selection of friction materials for new brake applications.

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 611, *Road vehicles — Braking of automotive vehicles and their trailers — Vocabulary*

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

ISO 15484, *Road vehicles — Brake lining friction materials — Product definition and quality assurance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 611, ISO 15484 and the following 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
MPU
metal pick-up
disc material agglomeration or compaction of high hardness on or in the pad material surface

Note 1 to entry: The MPU shapes could be different (flakes, grains with different aspect ratio, colloquially called "fishes") and have different sizes (up to several millimetres).

3.2
groove
mechanical disc surface defect in the circumferential direction caused by *metal pick-up (MPU)* (3.1) collected in the pad material with a depth of more than several tens of micrometres

3.3
friction value
μ
average by time of all *instantaneous friction values* (3.4)

Note 1 to entry: See Formula (1) for calculation and evaluate after the brake application reaches 95 % of the set point value (pressure or deceleration) until it falls below 95 % of the set point level.

3.4
instantaneous friction value
*μ**
ratio of instantaneous output torque to instantaneous input pressure at any specific point in time

Note 1 to entry: For calculation, see also Formula (1).

3.5
step
sequence number of labelling the different *sections* (3.6) during the test

Note 1 to entry: 1to entry: Sequence number ensures the test conduction in the prescribed order.

3.6
section
group of similar brake applications under similar conditions or following a specific logic

Note 1 to entry: The brake applications can be stopped.

Note 2 to entry: The specific logic can be increasing brake pressure, increasing initial speed, or increasing brake temperature.

3.7
brake stop
brake application where the brake slows down the test inertia until the equivalent linear speed is 0,5 km/h

Note 1 to entry: Project dependent the final speed can be increased to 5 km/h max.

3.8
brake snub
brake application where the brake slows down the test inertia to an equivalent linear speed above 5 km/h

3.9
burnish section
series of *brake stops* (3.7) or *brake snubs* (3.8) to condition the friction couple by developing a steady coefficient of friction and create friction film and brake dust between the brake pads and disc

3.10
water and salt water section
series of *brake snubs* (3.8) while water or salt water is added between pads and disc surface

Note 1 to entry: Water sections are used to create *metal pick-up (MPU)* (3.1) and evaluate friction level under wet conditions.

3.11
heat and pressure section
section (3.6) of test procedure with a series of *brake snubs* (3.8) at elevated initial brake disc temperatures (above 300 °C) and increased brake pressure (up to 50 bar/5 MPa) to simulate heavy braking or overloaded conditions

3.12
low load and pressure section
section (3.6) of test procedure with a series of *brake snubs* (3.8) to generate a significant amount of wear debris at low load and brake pressure

4 Symbols and abbreviated terms

4.1 Symbols

Symbol	Definition	Unit
A_p	Total piston area	mm^2
I	Test inertia reflected at the brake	kg·m^2
$M_{d,brake}$	Measured torque	N·m
P	Applied pressure	kPa
$p_{threshold}$	Threshold pressure or minimum pressure required to develop braking torque	kPa
R_{eff}	Brake effective radius	mm
R	Dynamic tyre effective rolling radius	m
V_p	Prescribed or braking speed for the brake application	km/h
Z	Deceleration	m/s^2
μ	Average by time friction value for disc brakes	—
μ^*	Instantaneous friction value for disc brakes	—
η	Brake efficiency	%

4.2 Abbreviated terms

DTV Disc Thickness Variation

IBT Initial Brake Temperature (disc)

GVM Gross Vehicle Mass

LRO Lateral Run-Out

MPU Metal Pick-Up

NAO Non-Asbestos Organic

NVH Noise, Vibration and Harshness

5 Test conditions and test preparation

5.1 Inertia for the brake testing

Use inertia calculated based on the real brake force distribution for a deceleration level of 0,3 *g* (2,94 m/s^2) and GVM vehicle mass conditions.

Option: if the nominal brake force distribution is not known, use the following approach:

— front inertia: calculate the inertia for the front axle using 75 % of half the gross vehicle mass, and the tyre rolling radius;

— rear inertia: calculate the inertia for the rear axle using 25 % of half the gross vehicle mass and the tyre rolling radius.

5.2 Pressure ramp rate

The pressure ramp rate shall be 3 MPa/s for all brake applications.

5.3 Maximum pressure

The maximum pressure applied to the brake can be lower than that specified in this document to accommodate specific brake configurations or brake system design parameters.

5.4 Sampling rate

The sampling rate shall be at least 100 Hz for pressure and torque.

5.5 Initial brake temperature

The initial brake temperature shall be the real-time temperature on the disc at the start of the brake application.

5.6 Brake temperature measurement

One thermocouple shall be at the centre of the friction path (0,5 ± 0,1) mm deep in the outer face of the disc or drum contact face. The initial brake temperature shall be measured using the disc thermocouple.

Additional thermocouple(s) can be in the centre of the outer pad recessed 1 mm into the friction material. If a slot through the centre is present, the thermocouple shall be at least 5 mm left or right from the slot (on the radial centre line). Change the thermocouple location towards the trailing (check if trailing or leading edge) edge of the lining if slots, calliper fingers or other brake features interfere with placing the thermocouple in the exact centre of the pad.

5.7 Cooling air conditioning

For specific cooling air definition (speed, temperature, humidity) for every test type (wet, heat and pressure, low temperature and low pressure) refer to the Tables 1 to 4.

Tolerances for cooling air parameters:

— temperature: value ±2 °C (mandatory);

— humidity: ±5 % (optional);

— air speed: ±3 km/h or equivalent air volume (mandatory).

5.8 Cooling air velocity or volume

The cooling air velocity or volume shall be specified in km/h or m^3/h, as measured in the duct. The duct outlet shall be nominally (300 to 400) mm away from the test hardware. For more details for determining the approximate relationship between air volume, air speed, duct size and duct outlet distance to the brake, see Annex B.

5.9 Exhaust conditions

Use exhaust power shall be higher than cooling air power to keep a light under pressure in the test cabin.

5.10 Conditioning settings for temperature and absolute humidity (humidity ratio)

The cooling air conditioning for temperature (mandatory) and absolute humidity (optional) shall be reported as the average of all brake events taken at the start of the brake application. The nominal cooling air temperature is (20 ± 2) °C and the absolute humidity is 7,29 g/kg (8,68 g/m^3) measured at sea level. Use the appropriate psychometric chart to find operating limits at temperatures other than 20 °C, or elevations other than sea level.

NOTE Nominal cooling air conditions are equivalent to (20 ± 2) °C and (50 ± 5) % relative humidity (RH).

5.11 Dynamometer rotational speed between brake applications

For specific dynamometer cooling speed for every test type (wet, hot with pressure, low temperature and low pressure) refer to the Tables 1 to 4.

5.12 Orientation of brake set-up

Use a knuckle fixture style as default. A universal fixture (plate) is an acceptable option; see Figures 1 and 2.

NOTE Reference SAE J3152 for further details on the fixture styles.

Figure 1 — Example of a knuckle fixture

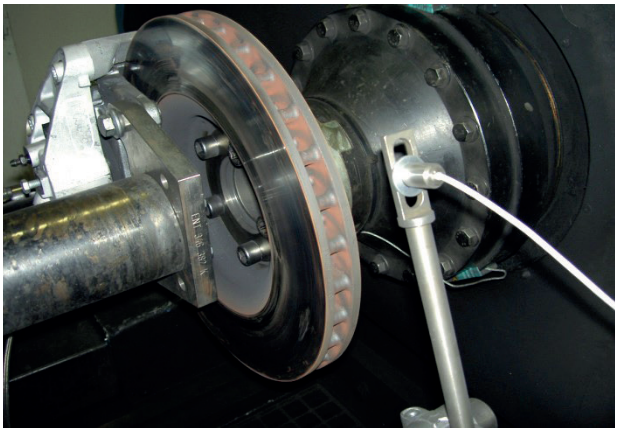

Figure 2 — Example of a universal fixture

The position of the brake on fixture is as on the vehicle as defined by knuckle; in case of universal fixture the vehicle position is preferable. Keep the orientation during the project duration.

5.13 Direction of air relative to the brake set-up

The test report shall document the airflow inlet regarding direction (vertical or horizontal) and orientation relative to the vehicle side under test (from forward, rear, top or bottom). Keep the same orientation during the project duration.

5.14 Wear measurement

Wear measurement is optional. If measured, initial and final disc and lining thickness and mass shall be measured and recorded. Measurements shall be made with following accuracy:

— lining: 0,01 mm (with ball head) and 0,1 g;

— disc 0,001 mm and 0,1 g.

5.15 Disc lateral run-out

Initial lateral run-out (LRO) shall be set to 50 µm or less when measured 10 mm from the outer diameter on the outboard friction surface of the brake disc.

5.16 Caliper, disc or drum and pads condition

The brake disc used for the test shall be new and original equipment (OE) level. Generally, use new calipers. Used calipers are acceptable if agreed for a specific project.

5.17 Hot brake applications

Control the hot brake applications by pressure and initial brake temperature.

5.18 Water specification

Use city water/tap water, preferably with a water container for water temperature conditioning to (15 to 25) °C. The temperature shall be at the same level for the entire duration of the project, per 5.7. Lower temperatures are acceptable (down to 7 °C).

5.19 Specification of nozzles for water spraying

The nozzles shall have a flow rate of (0,55 ± 0,1) l/min. The spray angle and spray width of the nozzle is: 90°. Other angles and width are possible if required by dyno design or available space.

The water spray pattern shall impact the disc surface equally over its full width. The spray nozzle shall produce a flat, bar-shaped spray pattern on the target surface.

See Clause 6 for the description of the nozzle setup.

5.20 Saltwater specification

5.20.1 Recommended solution

Use a 5 % solution of sodium chloride (NaCl) per Annex D. See 5.18 for the water specification.

5.20.2 Alternative solutions

The test may use (but it is not recommended) a solution with commercial-grade salt with the following composition:

— at least 96 % of NaCl;

— less than 0,5 % of each of the following components: calcium chloride, calcium sulphate, calcium carbonate, magnesium chloride, magnesium sulphate, and potassium chloride;

— a 5 % solution, see 5.18 for the water specification.

5.20.3 Other solutions

The test can use other salt compositions.

EXAMPLE De-icing salt used in Germany: NaCl 92,1 % -$MgCl_2$ 7,9 %: solution 5 % in water.

5.21 Noise and vibration (NVH) measurements

Noise and vibration recording is optional. Simultaneous measurement should help to identify noise events caused by MPU.

Setup for NVH measurement:

— sampling frequency: at least 44 kHz;

— position of the microphone: 0,5 m above and 0,1 m outboard of the hub;

— position of the accelerometer: leading side of the anchor bracket;

— use Hanning windows with 50 % overlap, for noises up to 20 kHz with 800 spectral lines of resolution.

Brake event is noisy when the frequency difference measured by the microphone and accelerometer is not greater than 25 Hz.

5.22 Data collection

It is necessary to configure the data collection system of the inertia dynamometer to collect automatically and in real-time the following values:

a) time,

b) shaft rotational speed (vehicle equivalent speed),

c) hydraulic pressure,

d) brake torque,

e) brake disc temperature,

f) brake fluid displacement,

g) cooling air temperature,

h) cooling air speed and airflow,

i) absolute humidity of cooling air,

j) means to identify the specific section and brake application.