# Frictional couple emissions: evaluation procedure from the REBRAKE project

Ispra, 8 November 2017

**45th PMP Meeting**

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# Agenda

- Background
- The REBRAKE project
- The REBRAKE work cycle
- The dyno-bench
- Testing procedure
- Outcomes

# The REBRAKE Project

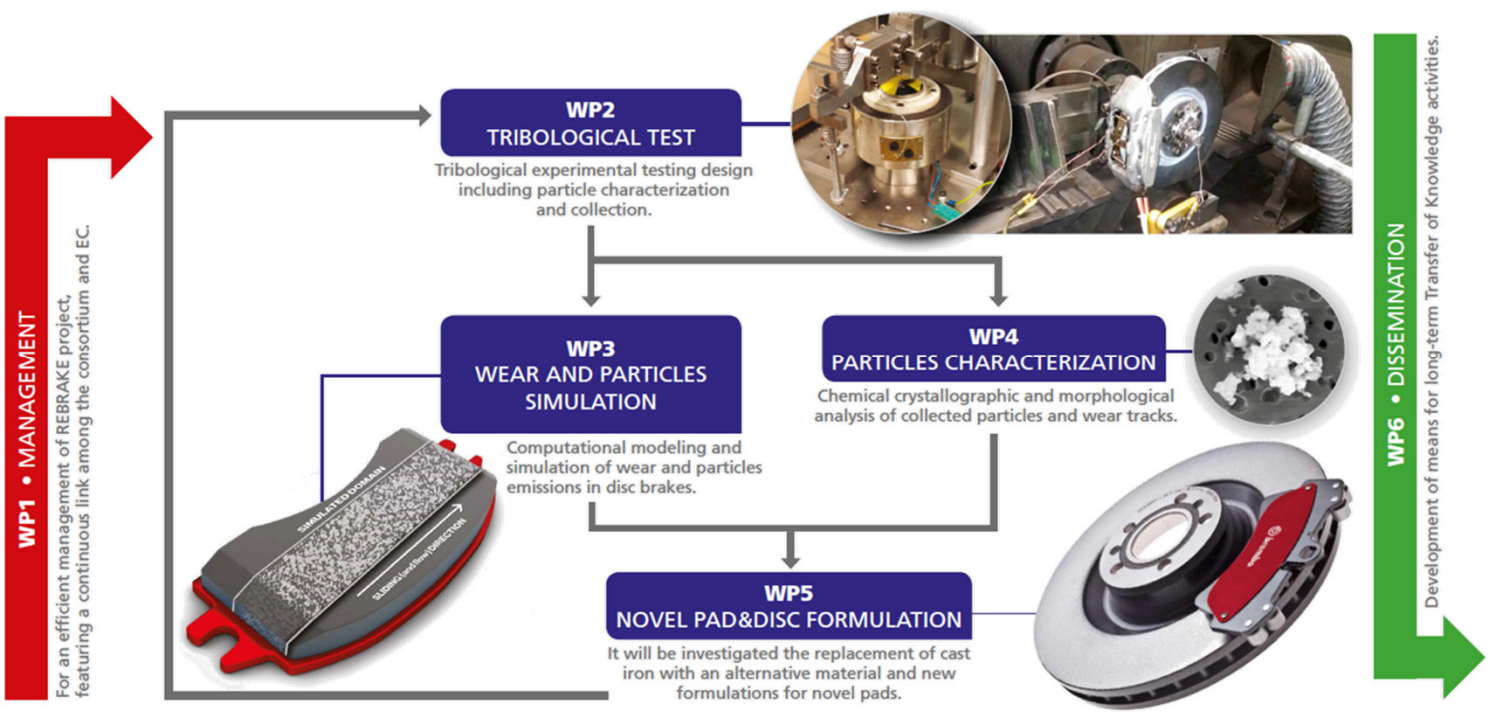
## Aim:

| | |
|---|---|
| 1. | **At least 50% particulate matter (PM10) mass reduction from brake wear, in compliance with the EU2020 thematic strategy of 47% reduction of particulate matter by 2020;** |
| 2. | Deeper comprehension of the physical and chemical phenomena underlying the brake wear process, including higher comprehension and analysis of characteristics coarse, fine and UFP particles. |

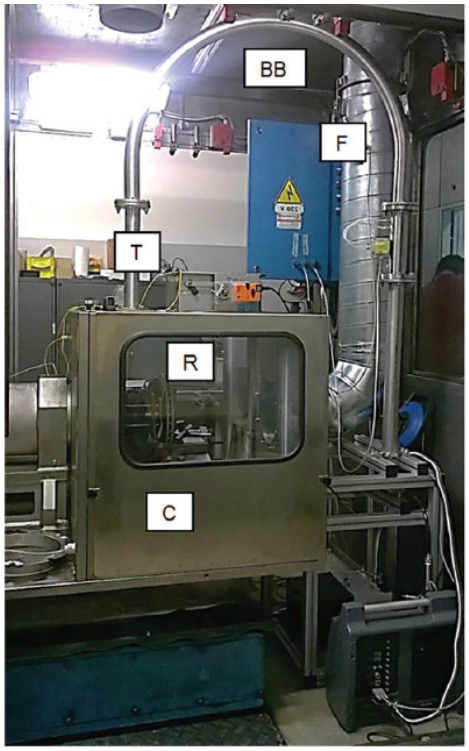
## Consortium:

- **Project effort: 211 men-months, Total funding: € 2.061.716,43**
- **Project lenght: 48 months; starting March 2013, 1st**

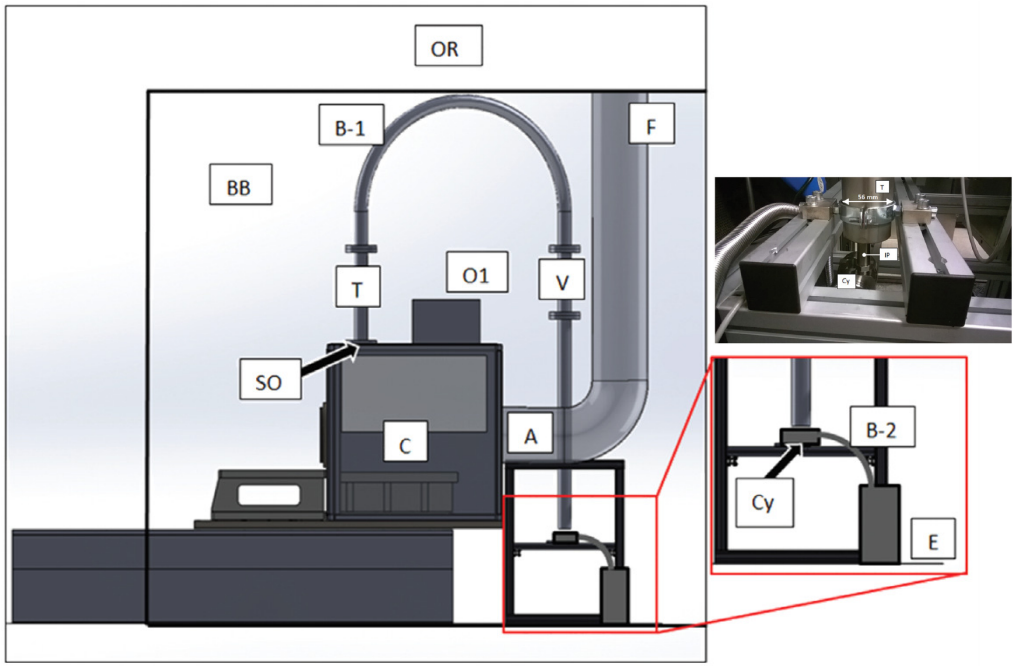
# The REBRAKE Work Cycle



# The Dyno-bench




**A photograph of the novel bench design.** BB: bigger box (door open); F: inlet tube from which clean air enter; T: outlet tube; R: rotor; C: dust-box chamber



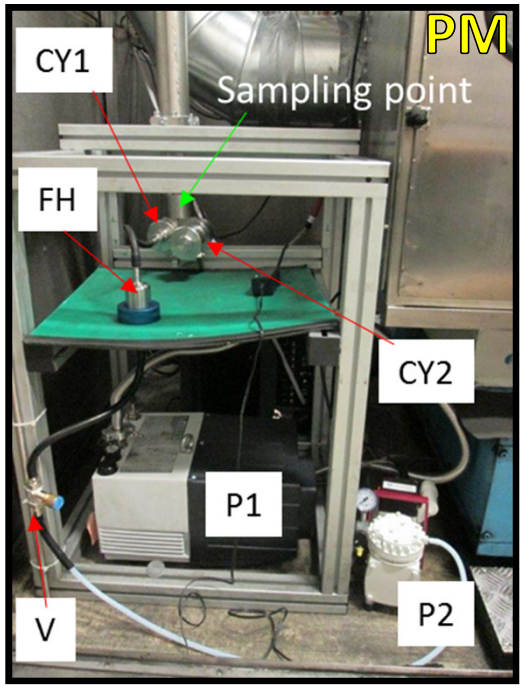

**Schematic diagram of the test stand.** OR: outdoor room; B-I: 0.4m bend tube; F: flow measurement point and filter; BB: bigger box; T: tube; OI: first outlet gap; V: Venturi flow measurement tube; SO: sampling outlet; C: dust-box chamber; A: Air inlet opening; Cy: Cyclone; B-2: 90°, 0.1m bend tube; E: ELPI+® cascade impactor

**Source:** 2015, Proc IMechE Part D: J Automobile Engineering, p. 1–8

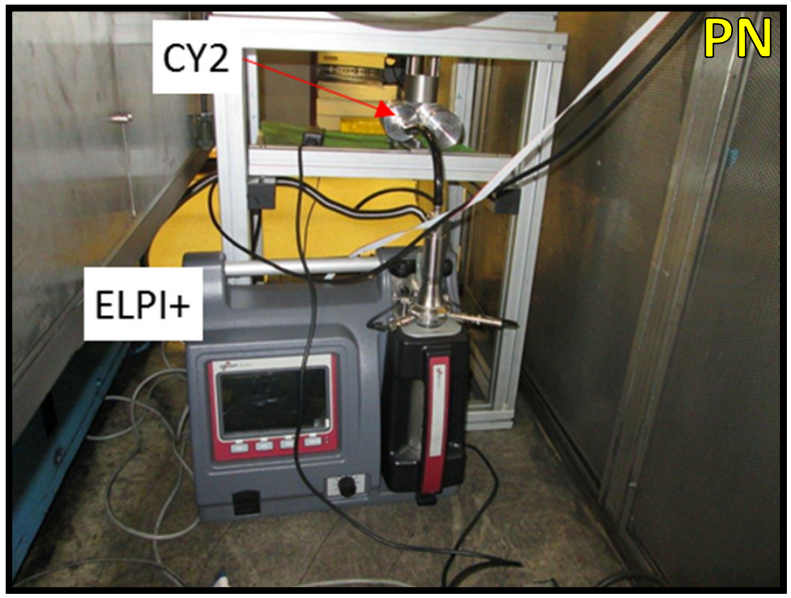
# The Dyno-bench - parameters

| Parameter | Dyno Bench |
|---|---|
| **Wear** | Measured after test (weights/thickness) |
| **Pressure** | Applied |
| **Torque** | Torque transducer |
| **Friction** | calculated |
| **Disc Temperature** | 1 k-type thermocouple |
| **Pad Temperature** | 2 k-type thermocouples (one for each pad) |
| **Sliding velocity** | Imposed/measured |
| **Flow rate** | Imposed (1 full exchange every 3s) |
| **PM/PN** | Elpi+ (with collection)/47mm filter (Quartz) |

# The Dyno-bench – Particles sampling




**Particle mass measurement.** CY1-2: cyclones; FH: Filter Holder; P1:ELPI+ pump; P2: filter holder pump; V: valve for airflow regulation.




**Particle number measurement.** CY2: ELPI+ cyclone; ELPI+: Low-Pressure Cascade Impactor.

# Testing procedure – Overview

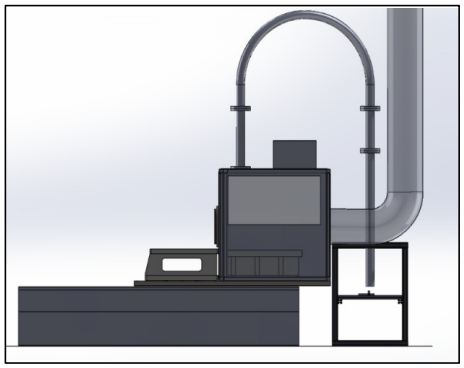
Allows sampling of representative samples for the entire particle size range

47mm quartz filter set-up

Dyno bench assembly

$m_{pad\_in}$ [g]
$m_{disc\_in}$ [g]

ELPI+ set-up



Dyno bench test cycle

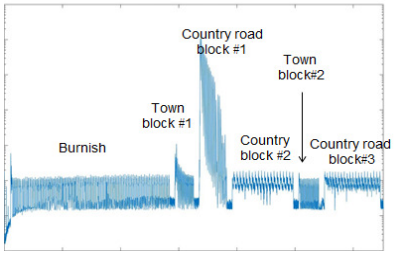
PM10 values

$PM_{10}[g] = w_{test\_fin} - w_{filter\_in}$

Wear values

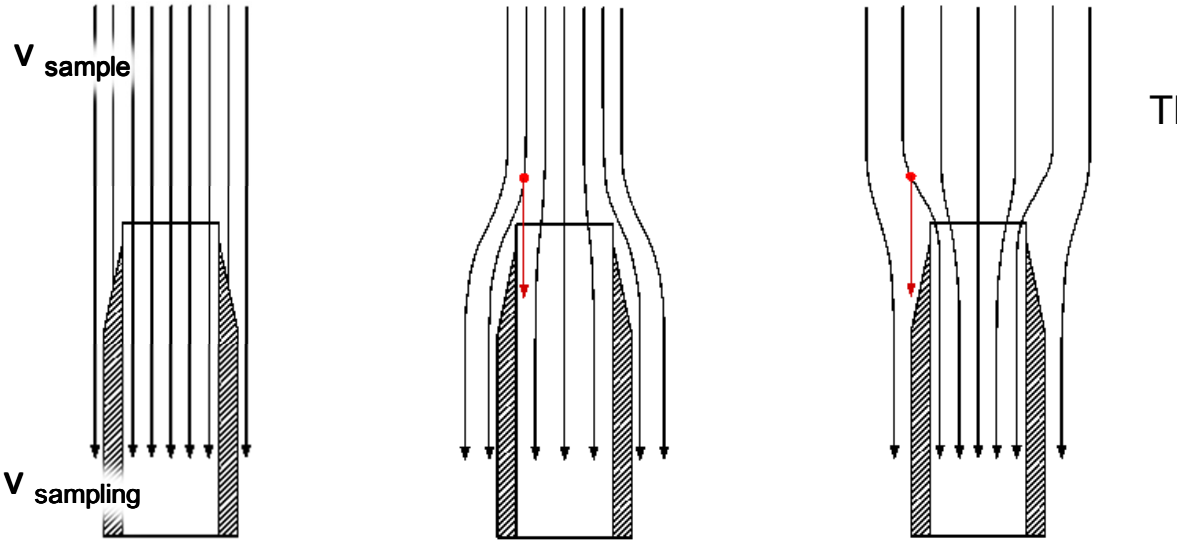
$\Delta m_{pad}[g] = m_{pad\_fin} - m_{pad\_in}$
$\Delta m_{disc}[g] = m_{disc\_fin} - m_{disc\_in}$

PN values



# Testing procedure – Isokinetic sampling

Needed to have a representative sample for the entire particle size range




**Isokinetic sampling**

$v_{sample} = v_{sampling}$

**Super isokinetic sampling**

$v_{sample} > v_{sampling}$

**Sub-isokinetic sampling**

$v_{sample} < v_{sampling}$

The following conditions need to be verified:

- $v_{sample} = v_{sampling}$
- Laminar flow
- Streamlines have to be parallel to the sampling probe

**Source:** Hinds (1999)

# Testing procedure – PN measurement

An Electrical Low Pressure Impactor (ELPI+®) measures particles number on-line. A cyclone filters all the particles bigger than 10µm.


Particles are collected on aluminum foils to allow subsequent chemical characterization

# Testing procedure - PM measurement

A 47mm Quartz filter is used for mass measurements

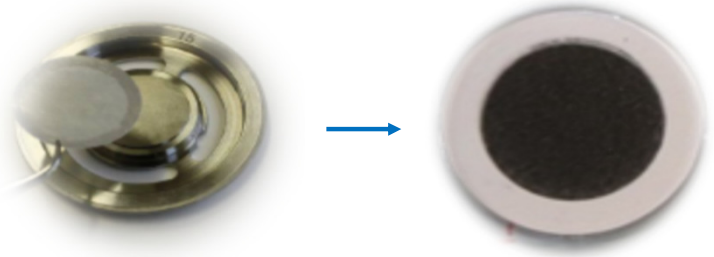
**24h Filters Conditioning and weighing**


$$w_{test} = w_{filter} + w_{PM10}$$

**Assembling**

$w_{filter}$

**Testing**



$$\boldsymbol{PM10\ [g] = w_{test} - w_{filter}}$$

# Testing procedure – P2 cycle

Modified SAE J2707 – Part B:

- wear procedure
- it considers only urban driving conditions
- reduced number of stops
- cleanings are introduced between blocks

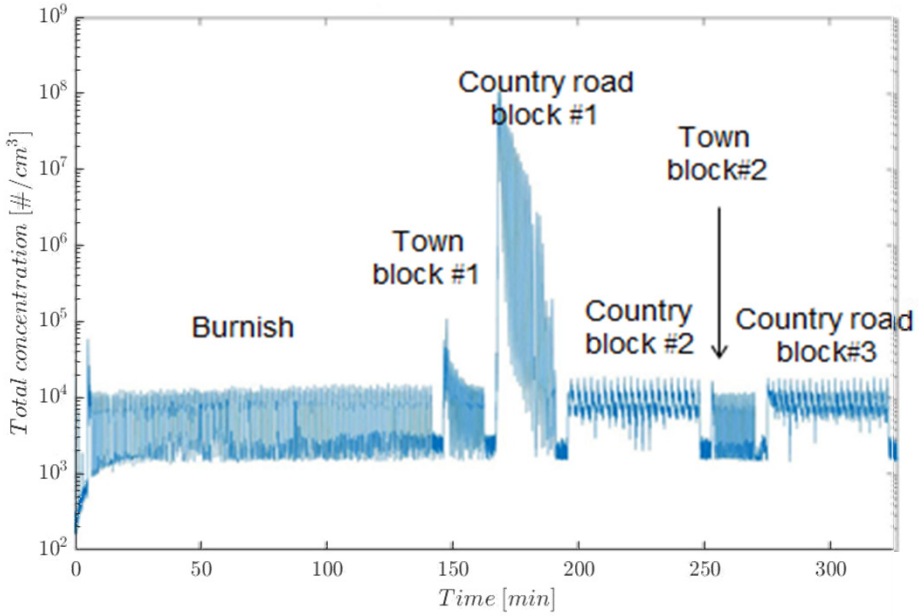
| Block | Initial speed [km/h] | Final speed [km/h] | Init disc temp. [°C] | Decel [g] | No. of stops |
|---|---|---|---|---|---|
| **Burnish** | 50 | 4 | 100 | 0.25 | 100 |
| **5min cleaning** | | | | | |
| **Town block #1** | 50 | 4 | 150 | 0.25 | 20 |
| **5min cleaning** | | | | | |
| **Country road block #1** | 80 | 4 | 200 | 0.35 | 20 |
| **5min cleaning** | | | | | |
| **Country road block #2** | 100 | 4 | 125 | 0.4 | 20 |
| **5min cleaning** | | | | | |
| **Town block #2** | 50 | 4 | 150 | 0.25 | 20 |
| **5min cleaning** | | | | | |
| **Country road block #3** | 100 | 4 | 125 | 0.4 | 20 |

# Testing procedure – P5 cycle

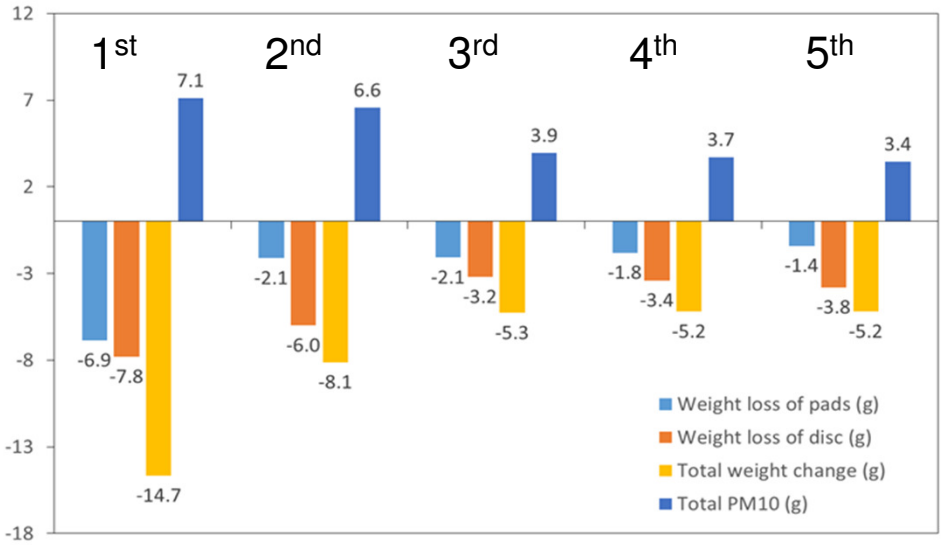
| Specific energy [J/kg] | Section | Block | $v_{initial}$[km/h] | $v_{final}$ [km/h] | $T_{disc\_initial}$[°C] | Dec. [g] | No. of stops |
|---|---|---|---|---|---|---|---|
| | 5' Cleaning | | | | | | |
| | 25 J/kg | 1.1 | 36 | 26 | 70 | 0,16 | 2 |
| | | 1.2 | 36 | 26 | 90 | 0,16 | 18 |
| | | 1.3 | 36 | 26 | 110 | 0,16 | 83 |
| | | 1.4 | 36 | 26 | 130 | 0,16 | 56 |
| | | 1.5 | 36 | 26 | 150 | 0,16 | 24 |
| | | 1.6 | 36 | 26 | 170 | 0,16 | 8 |
| | 75 J/kg | 2.1 | 52 | 28 | 70 | 0,23 | 5 |
| | | 2.2 | 52 | 28 | 90 | 0,23 | 16 |
| | | 2.3 | 52 | 28 | 110 | 0,23 | 22 |
| | | 2.4 | 52 | 28 | 130 | 0,23 | 25 |
| | | 2.5 | 52 | 28 | 150 | 0,23 | 12 |
| | | 2.6 | 52 | 28 | 170 | 0,23 | 8 |
| | 125 J/kg | 3.1 | 57 | 5 | 70 | 0,25 | 2 |
| | | 3.2 | 57 | 5 | 90 | 0,25 | 3 |
| | | 3.3 | 57 | 5 | 110 | 0,25 | 6 |
| | | 3.4 | 57 | 5 | 130 | 0,25 | 8 |
| | | 3.5 | 57 | 5 | 150 | 0,25 | 1 |
| | 175 J/kg | 4.1 | 70 | 17 | 110 | 0,31 | 1 |
| | | 4.2 | 70 | 17 | 130 | 0,31 | 2 |
| | | 4.3 | 70 | 17 | 170 | 0,31 | 1 |
| | 225 J/kg | 5.1 | 79 | 20 | 110 | 0,24 | 1 |
| | 5' Cleaning | | | | | | |

# Outcomes

## PN - Particle number (#/cm³)




## PM - Particle mass (g)



# Thank you!


www.rebrake-project.eu

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