SAE INTERNATIONAL

37TH ANNUAL
BRAKE COLLOQUIUM
& EXHIBITION

Friction ICS

An innovative and integrated system for EOL pad quality control

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Brembo S.p.A.

Everything brake science and technology

Overview

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   - Ultrasonic E_z measurements and validation
3. End-of-Line Pad Quality Control
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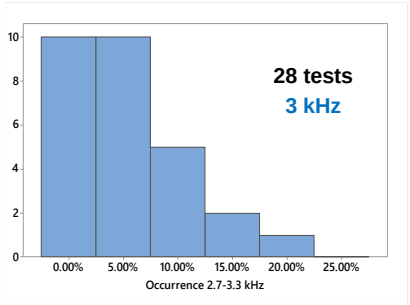
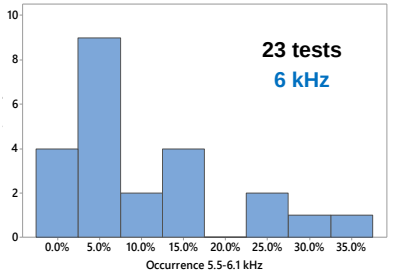
1. Introduction
Brake pads variability

Backplate and friction material dispersion in terms of geometrical properties and mechanical/physical/chemical features could have severe impacts over various quality aspects:

- Brake pad
  Friction material porosities, cracks, chunks and non-uniformities could lead to breakage and delamination
- Caliper assembly
- Performance
  Scarce backplate flatness and parallelism can cause residual torque, pedal feeling and fluid absorption issues
- NVH
  number of squeal frequencies, squeal occurrence levels, judder behavior

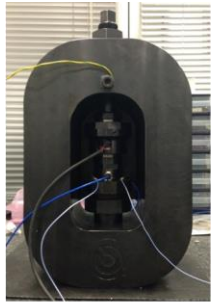
Squeal occurrence variability with different pads (same code, same batch)





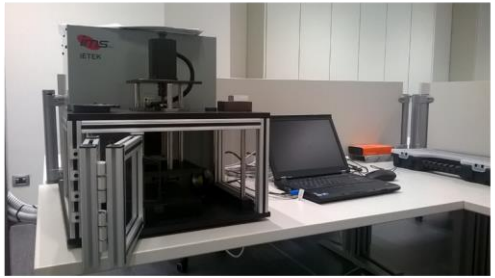
2.1 Out-of-plane Stiffness

Brembo Shake® vs UT measurement with iETEK



patented

EKS
Technical Standard



ims INDUSTRIAL MEASUREMENT SYSTEMS, INC.

Mechanical piezoelectric actuation

Samples:	specimens (20x20/30x30 mm^2)
Frequency range:	0.5-4 kHz
Sample area:	400-900 mm^2
Static preload:	5-40 bar
Testing time:	90 min/sample

Ultrasonic measurement

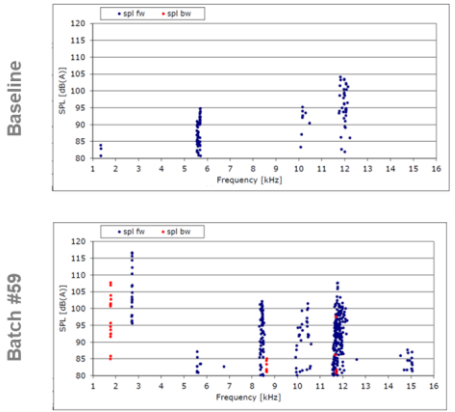
Samples:	full pad / specimens (30x30 mm^2)
Frequency range:	0.2-1 MHz
Sample area:	170 mm^2
Static preload:	100-800 N (6-47 bar)
Testing time:	1 min/sample

2.2 Out-of-plane Stiffness

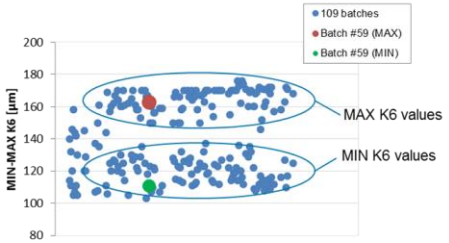
Troubleshooting case study with Shake® and iETEK

SAE BCE 2015

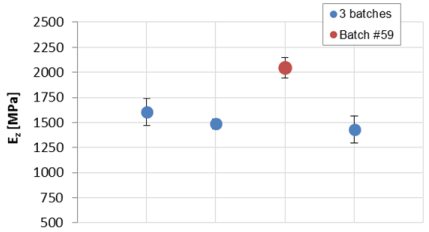
NVH Dyno



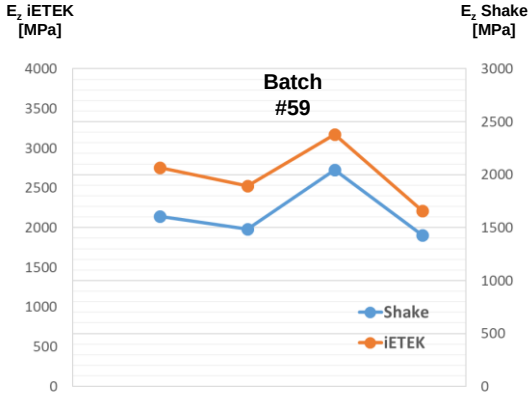
Compressibility



Shake



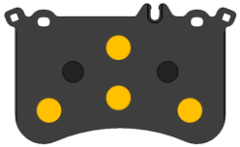
iETEK

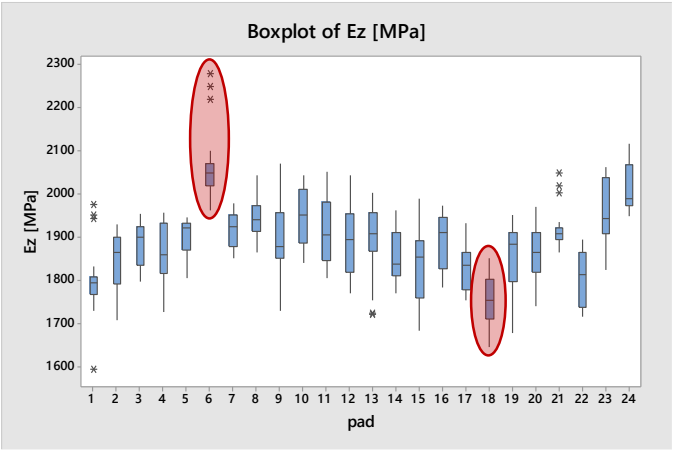


- high correlation between Shake E_z and iETEK E_z
- iETEK vs Shake E_z ratio between 1.3 and 1.6 depending on friction material type

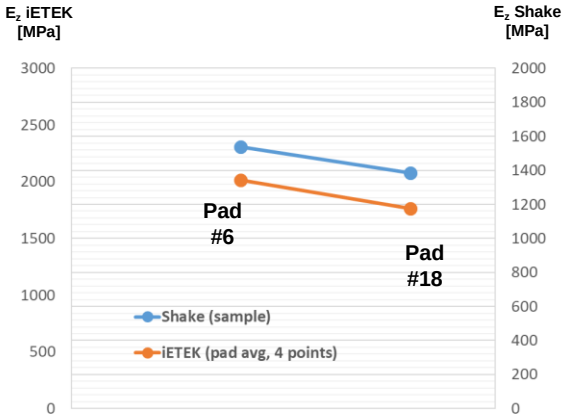
2.3 Out-of-plane Stiffness
Ultrasonic E_z measurements and validation

IMS iETEK



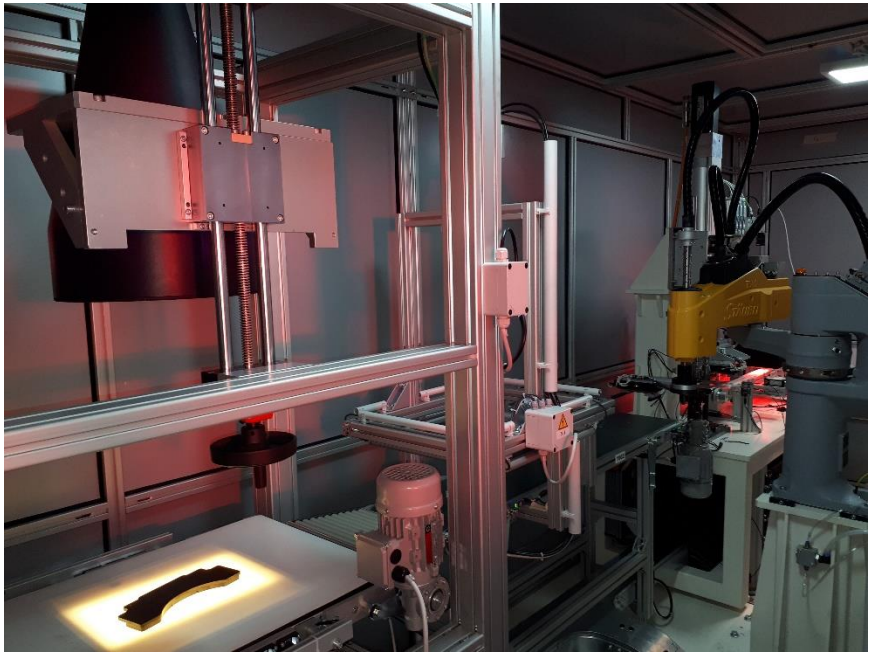


Brembo Shake



- The correlation between Shake measurement on pad samples and iETEK on full pads has been verified over several applications
- The differences in terms of NVH performances between high and low E_z pads should be verified over wider datasets

3.1 End-of-Line Pad Quality Control
Friction ICS Introduction

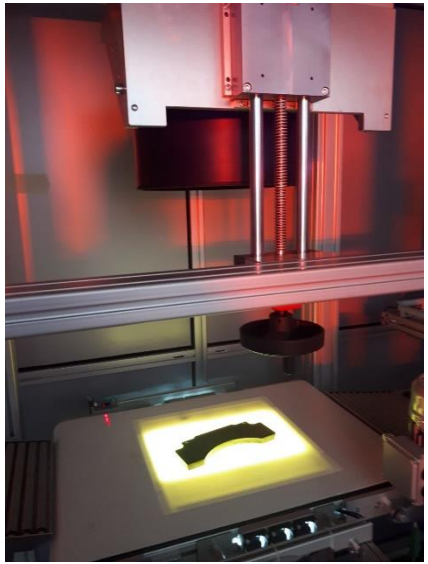


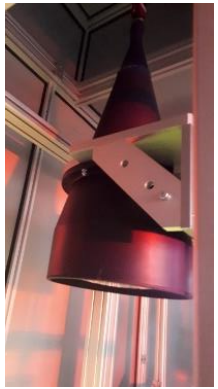
- 100% EOL control
- Fully automated pad handling system through:
    1. Backplate dimensional control
    2. Rapid iETEK
    3. Backplate and friction material thickness measurement and control
    4. Serial number marking with NOK control indication
- Total cycle time < 10 s

Developed by:

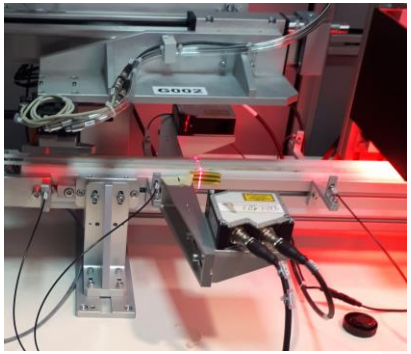
MAGYC

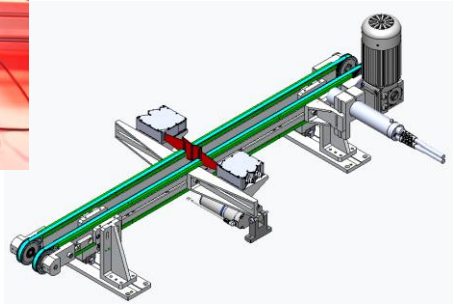
3.2 End-of-Line Pad Quality Control
Pad dimensional control





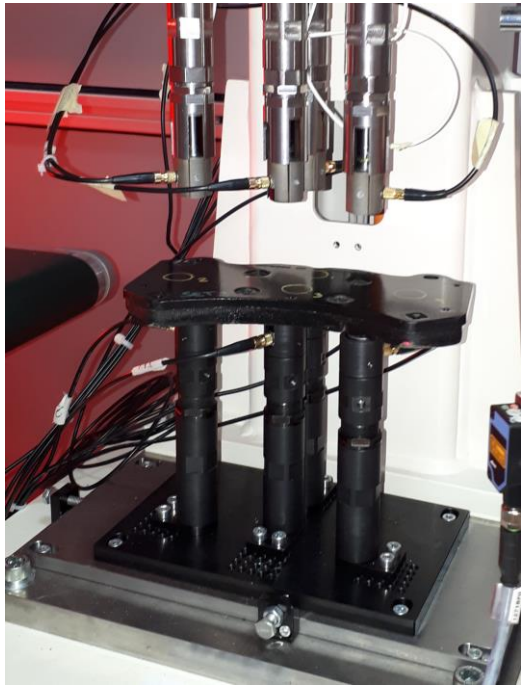
- Dimensional control of up to 5 geometrical features of the pad backplate by means of a telecentric lens





- Double laser scanning system for high-accuracy thickness measurements of backplate and friction material
- Thickness data are used both for E_z calculation and pad dimensional control

3.3 End-of-Line Pad Quality Control
Rapid iETEK

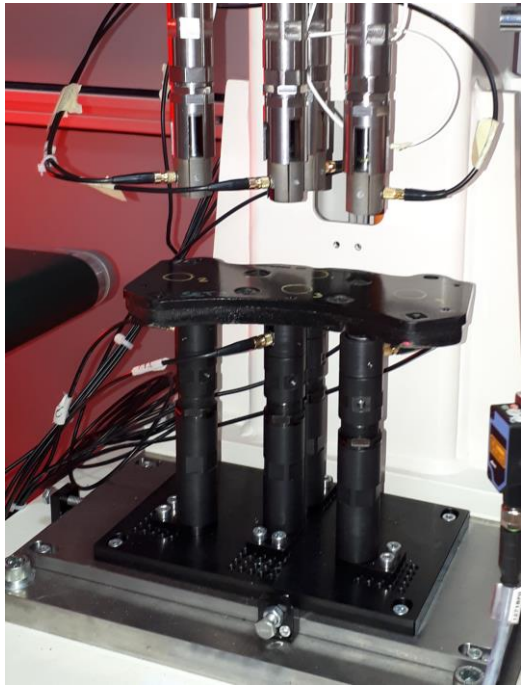


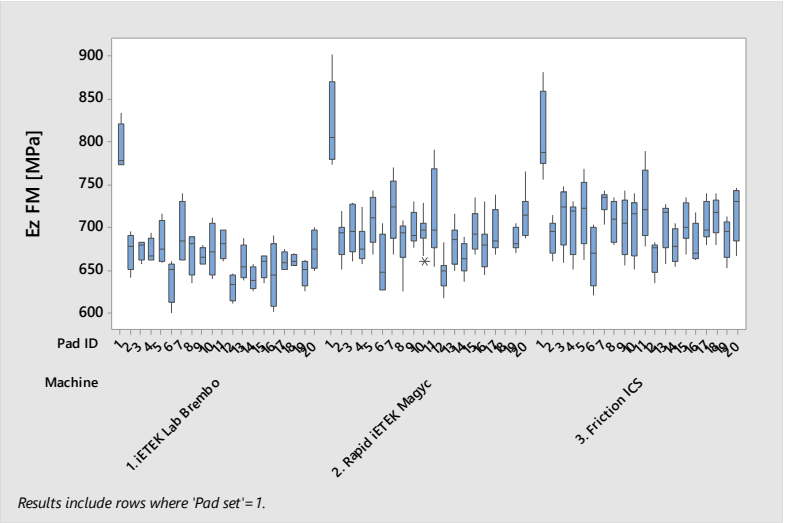
- 4 measurement points for friction material out-of-plane stiffness
- Automatic pad placement and upper UT probes movement
- Real-time controlled preload on each UT probe (600 N)

- Measurement time < 0.2 s
- Total time < 2 s
  (load - measure - unload)

In collaboration with:

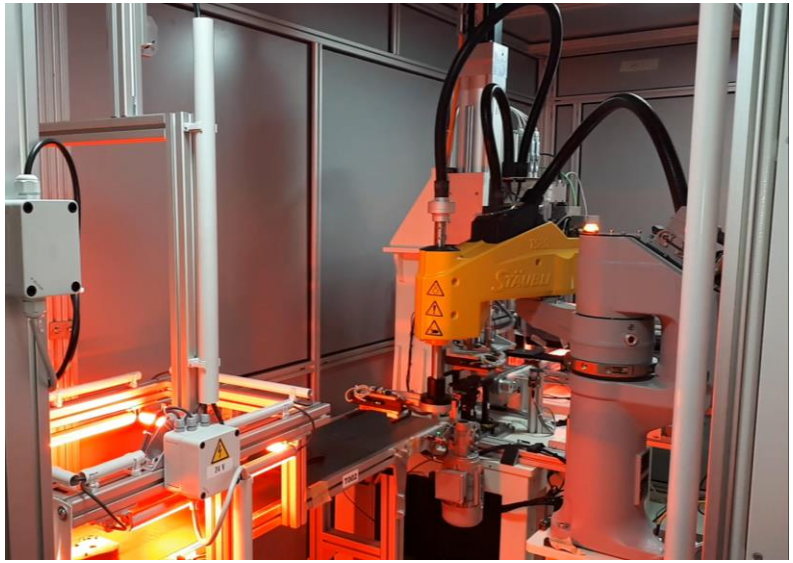
3.3 End-of-Line Pad Quality Control
Rapid iETEK

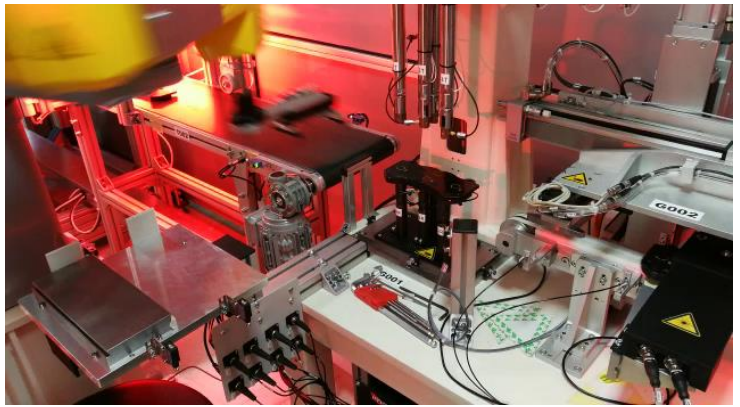




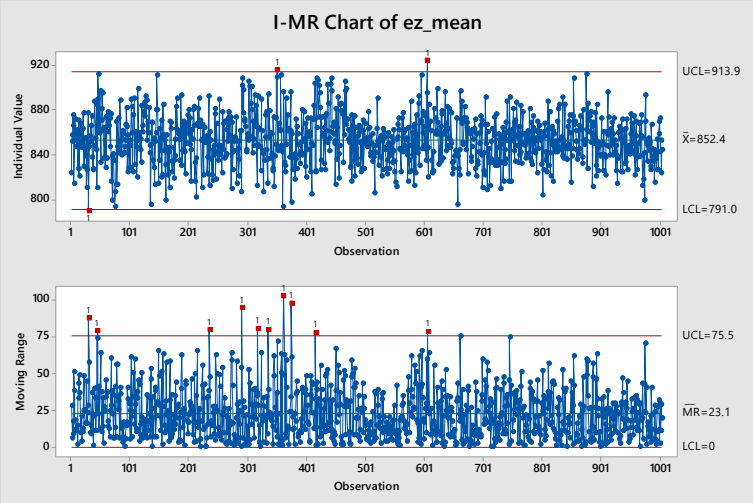
- Very good level of correlation between Lab iETEK and Rapid iETEK through all the development stages

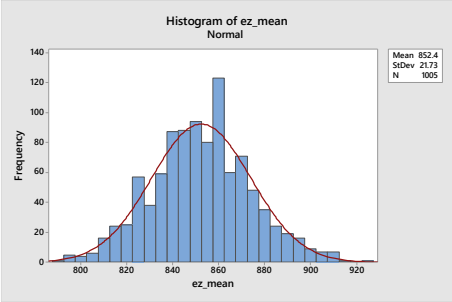
3.3 End-of-Line Pad Quality Control
Friction ICS



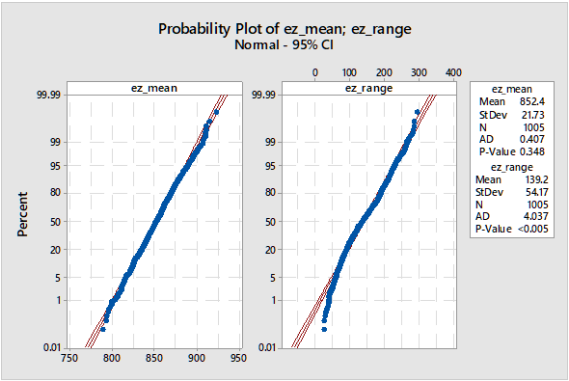


3.3 End-of-Line Pad Quality Control
Preliminary results





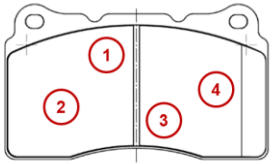
- Out-of-plane pad stiffness = average of E_z among the 4 measurement points

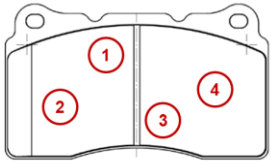


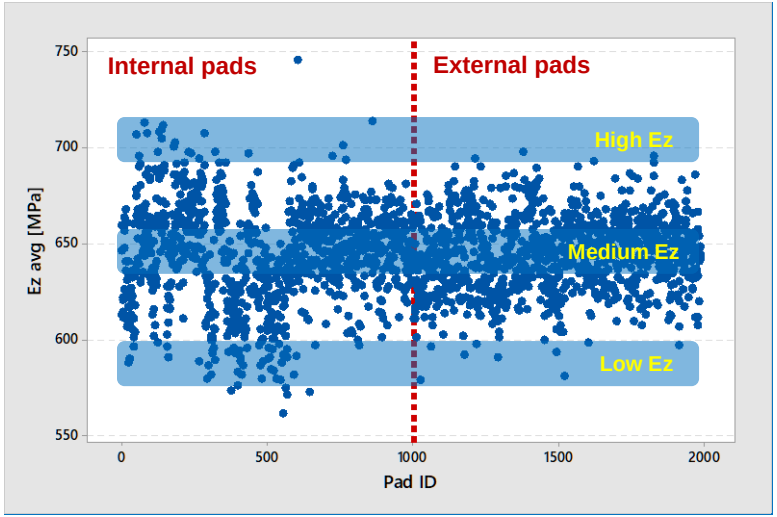
- The first extensive test of the system (1000 pads, same batch) shows a very good distribution of Ez (Individuals Moving Range SPC analysis and normality tests are both OK)

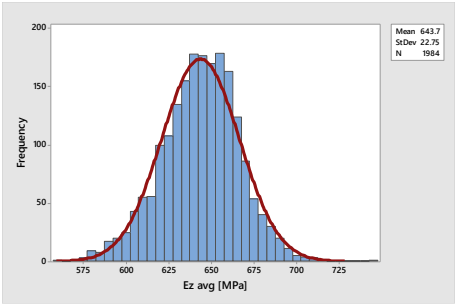
4. Quality Control Process Validation

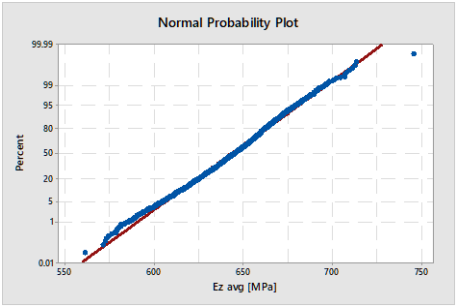
NVH Dyno Tests - Pad selection







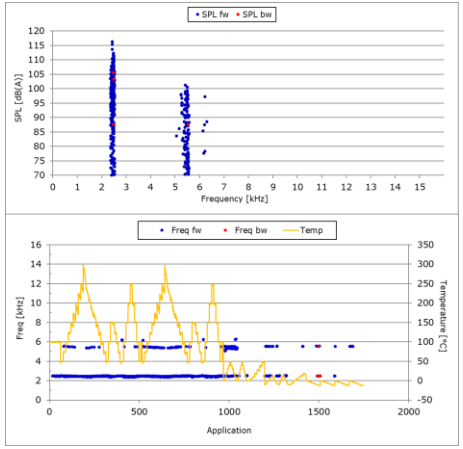




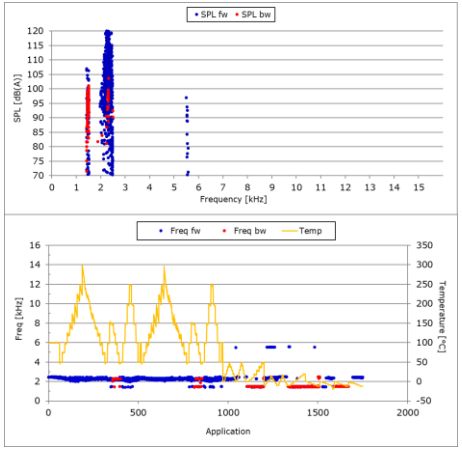
- E_z values of internal and external pads are normally distributed
- For NVH dyno test sets of pads with high, medium and low values of E_z have been selected

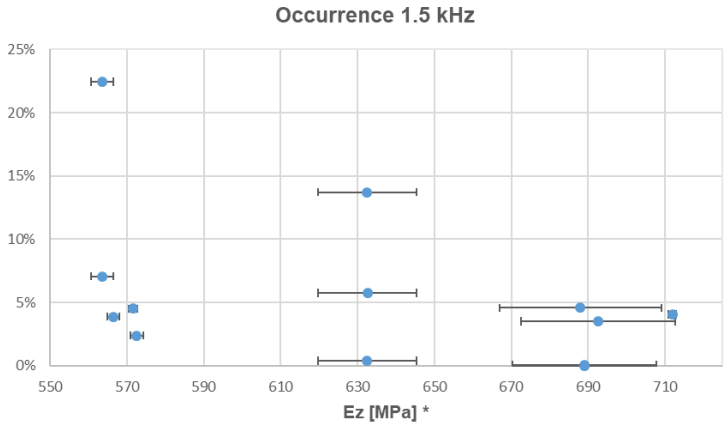
4. Quality Control Process Validation
NVH Dyno Tests - Results

High E_z

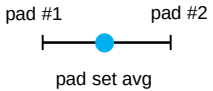


Low E_z





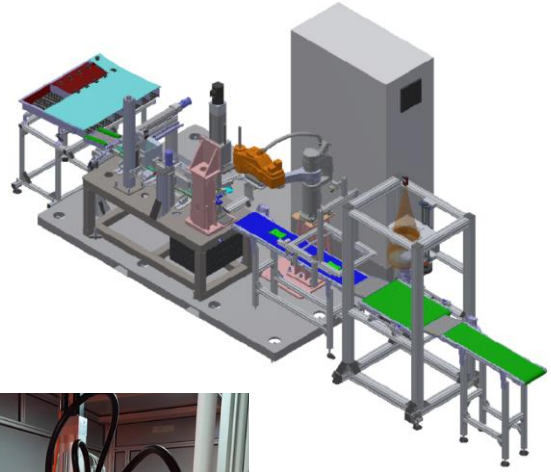
- Sets of pads with higher E_z levels show lower and less variable occurrence at 1.5 kHz



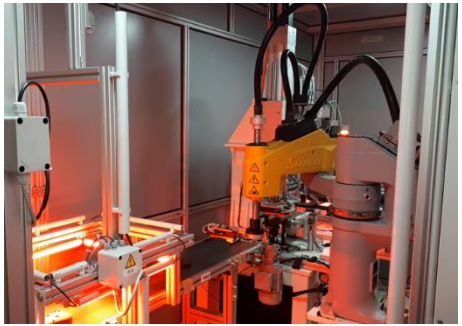
* Pad E_z is the average value among the 4 measurement points

5. Summary and future developments

- An innovative control system for brake pads has been developed and placed at the end of production line featuring:
  - Backplate dimensional control
  - Out-of-plane stiffness measurement
  - Backplate and lining thickness measurement and control
- Pads with different values of out-of-plane stiffness (E_z) has been selected among an entire batch and tested on dyno: as seen in the past years the results show a possible correlation between Ez and occurrence for specific instabilities



- Future activities include:
  - NVH dyno testing on several applications to gain experience about E_z influence on squeal
  - Definition and validation of specific NVH oriented E_z limits for each application
  - E_z driven modification of pad formulation and production process to optimize NVH performance of friction materials



Thanks for your attention

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NVH Methodologies