Analysis of High Damping Underlayer Materials for Brake Pads and its Effects on NVH Performance

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FRAS-LE Friction Materials

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Objectives

- Development of experimental underlayer materials with high viscoelastic behavior (elastomers based).

- Characterization of mechanical and dynamic properties of these materials and its effects on pads properties.

- Verify the influence of these underlayers on the brake system's noise performance on SAEJ2521.

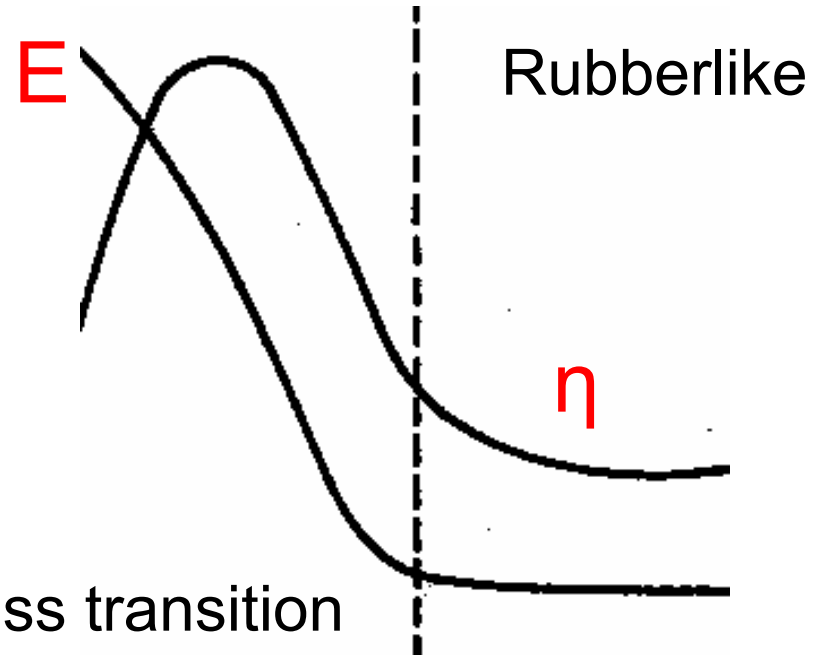
- Identify which characteristics have a most relevant impact on noise performance.

Experimental underlayer materials

- Underlayer SBR (Tg*=-50ºC; Td**=110ºC)
- Underlayer NBR (Tg=-40ºC; Td=125ºC)
- Underlayer EPDM (Tg=-60ºC ; Td=150ºC)

* Tg = Glass transition temperature.

** Td = Degradetion temperature.



Underlayer materials formulation

	SBR	NBR	EPDM
Elastomer	39,3%	39,3%	39,3%
Fibers	22,7%	23,2%	23,1%
Fillers	35,2%	35,4%	35,7%
Others	2,9%	2,2%	1,9%

Experimental Underlayer Materials

(elastomeric matrix)

	Friction	A	B
Elastomer	14,5%	11,4%	31,4%
Fibers	9,2%	14,9%	17,9%
Fillers	44,5%	56,4%	14,9%
Resin	13,2%	17,1%	19,0%
Others	18,6%	0,2%	16,8%

Standard Friction Material & Underlayer Materials

(phenolic matrix)

Evaluated properties of the samples

- Quasi-static Young modulus characterization (E_{zz} and E_{xy})
- Dynamic Young module characterization ($Edin_{xy}$)

Materials' bulk

- Compressibility
- Natural frequency - in different temperatures (first four modes)
- Loss factor associated to the first four modes - in different temperatures
- SAE J2521

Sample pads

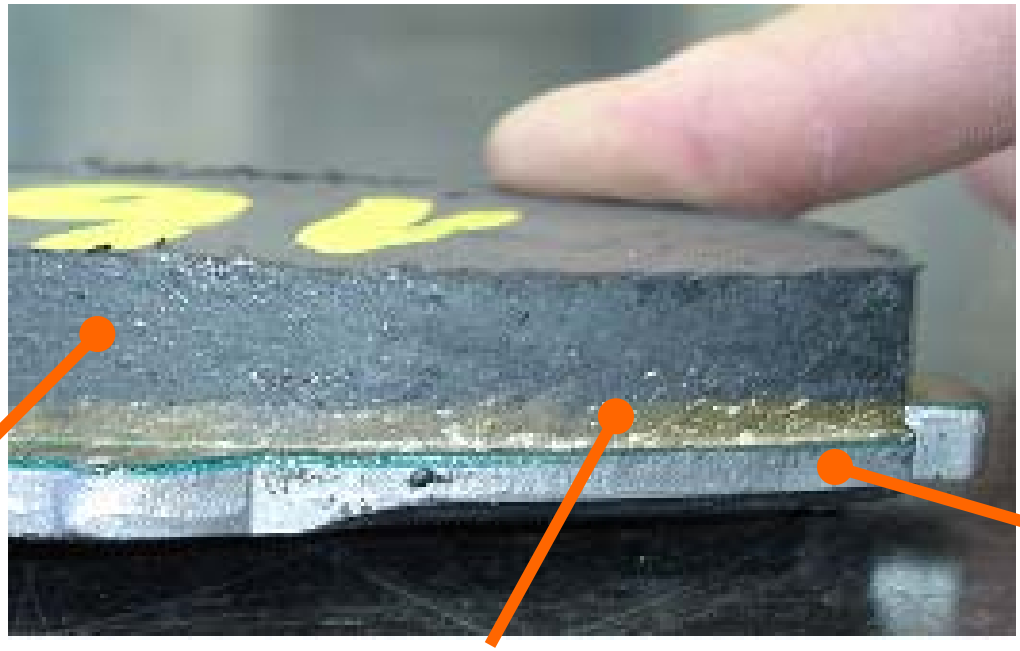
Samples fabrication

- All composites were pressed on a single cavity mold to produce blocks of material which were cut in small parts and used on mechanical characterization tests.

- The pressing process were developed to obtain the minimum number of defects on the composite matrix (porosity, bubbles,…).

Samples fabrication

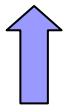
Fifteen pads were produced using each underlayer material (3mm layer) below the friction material.



Quasi-static Young modulus

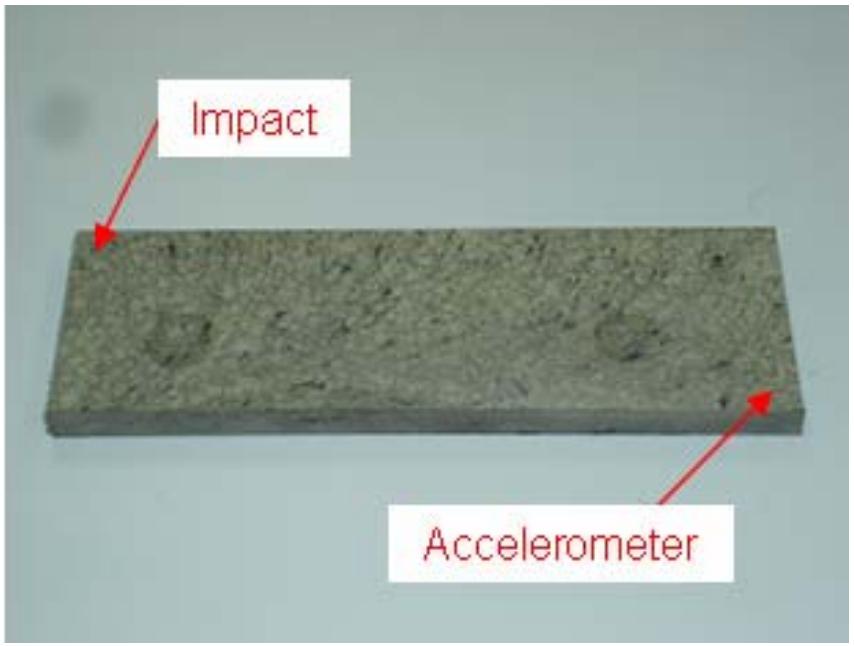
Compression assay performed on a universal testing machine.

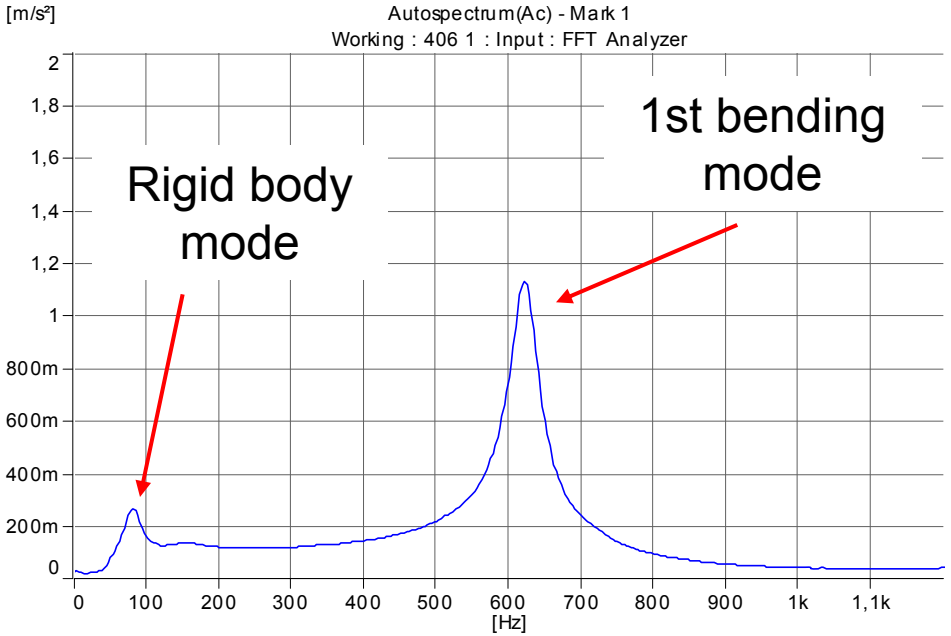
	Ez [Mpa]	*Exy* [Mpa]	*Exy/Ez*	
Friction	1684,9	3203,5	1,90	Higher modulus
A	1970,3	3592,7	1,82	
B	705,7	1439,2	2,04	
SBR	228,8	336,8	1,47	Lower modulus
NBR	189,7	243,1	1,28	
EPDM	176,2	229,5	1,30	



Orthotropic behavior

Dynamic Young modulus - ASTM E 1876-97

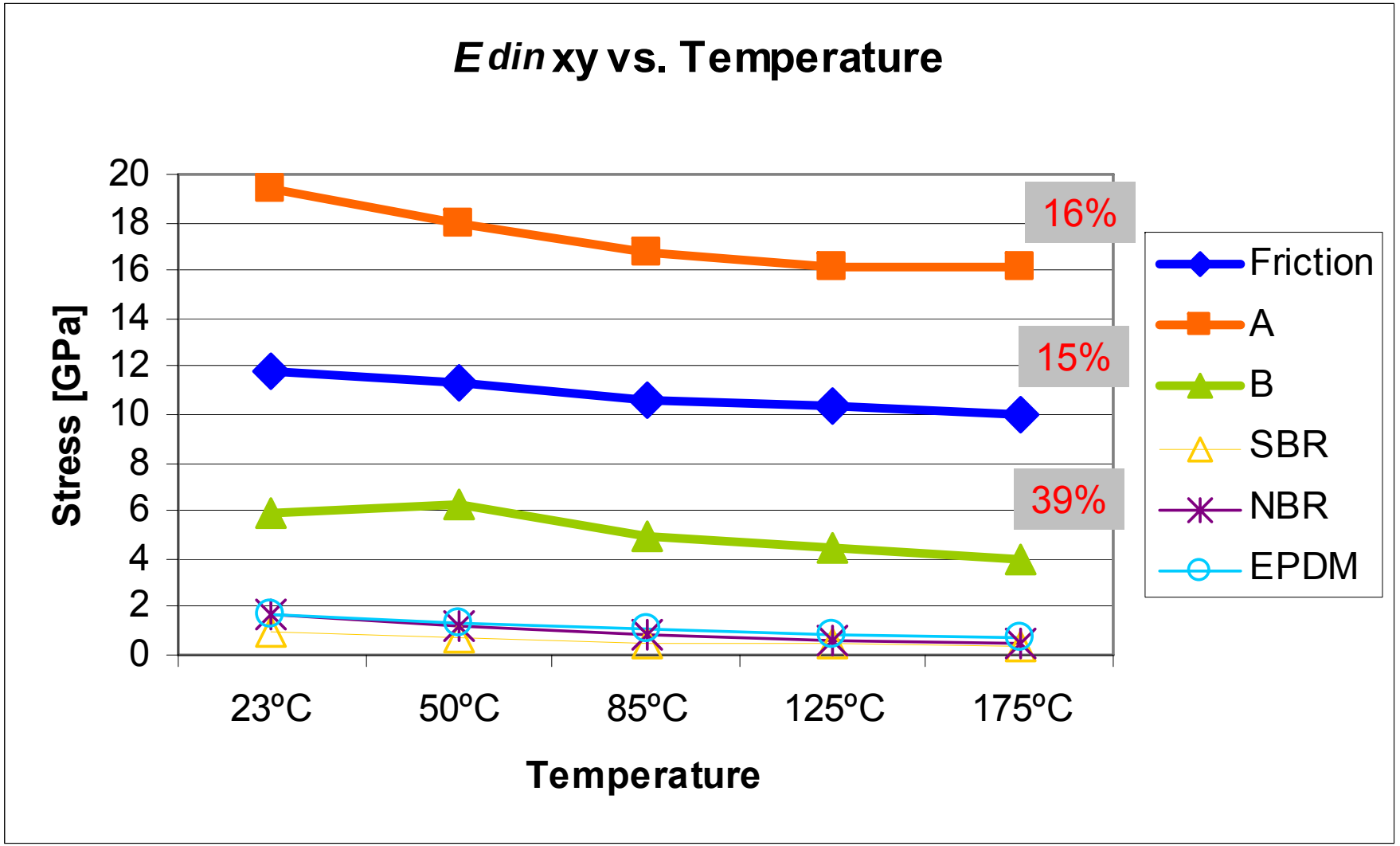




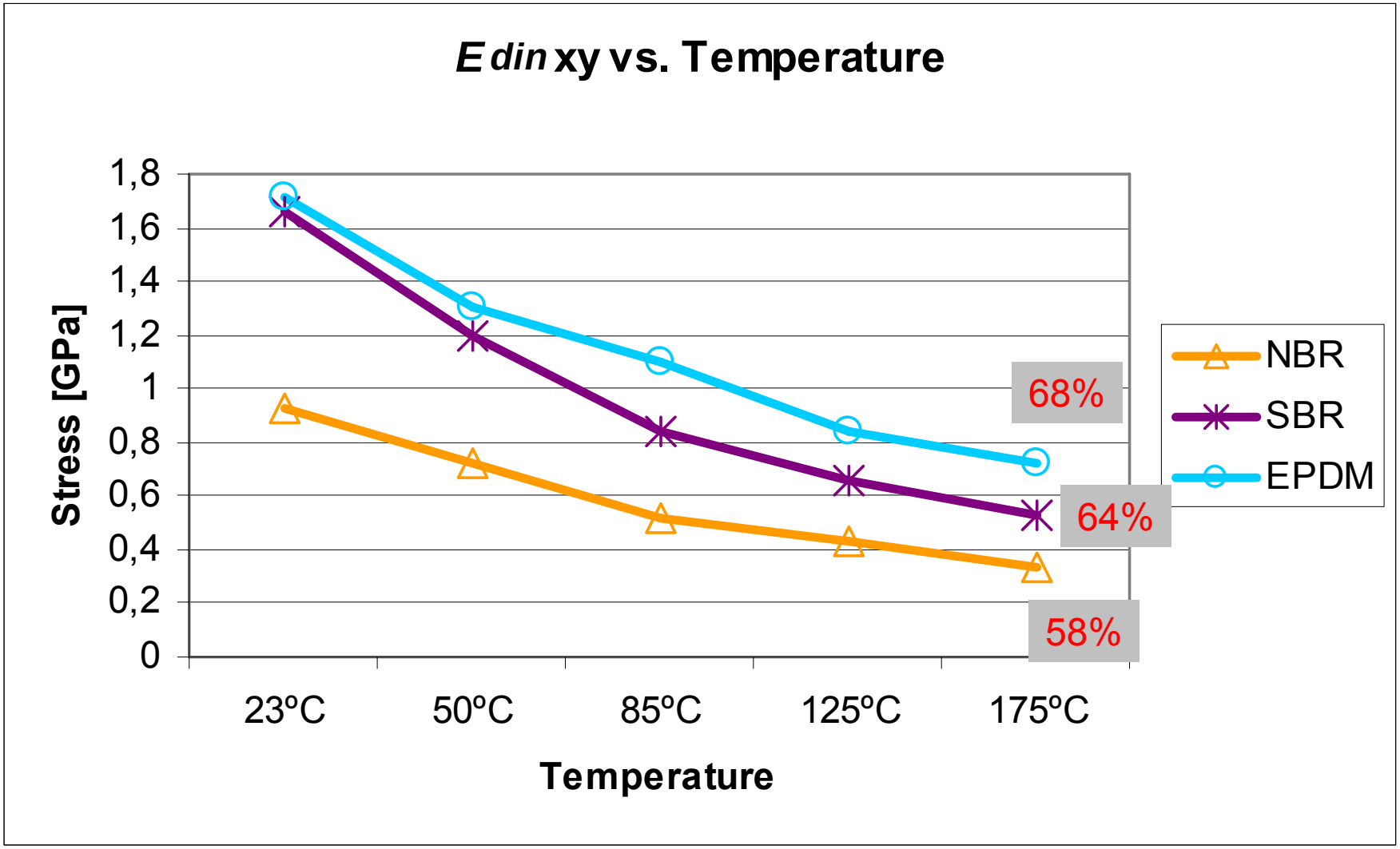
$$E_{din} = 0{,}9465m\left(f_f{}^2 / b\right)\left(L^3 / w^3\right)T_1$$

$$T_1 = \left[1 + 6{,}585(w/L)^2\right]$$

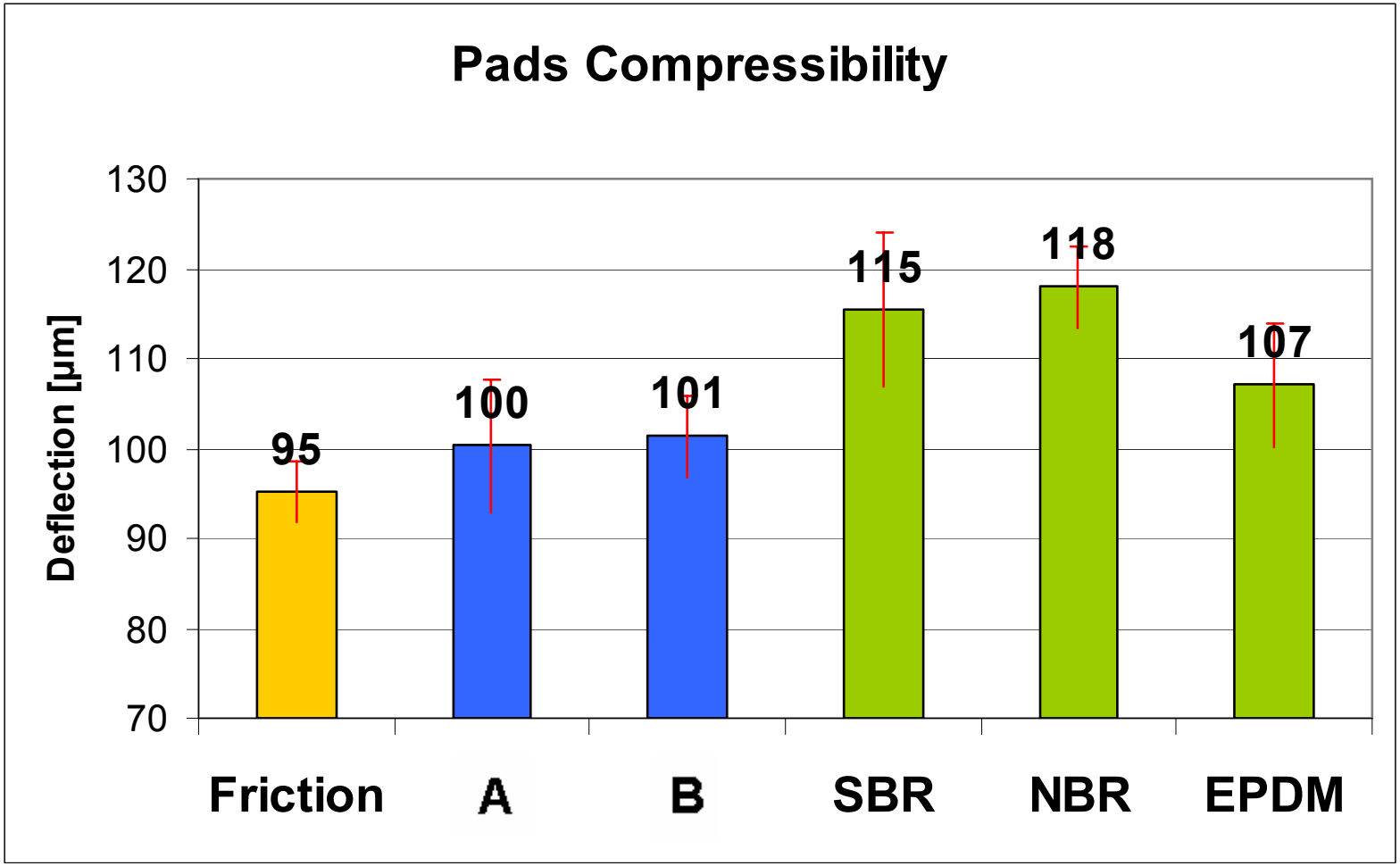
Materials dynamic $E din_{xy}$



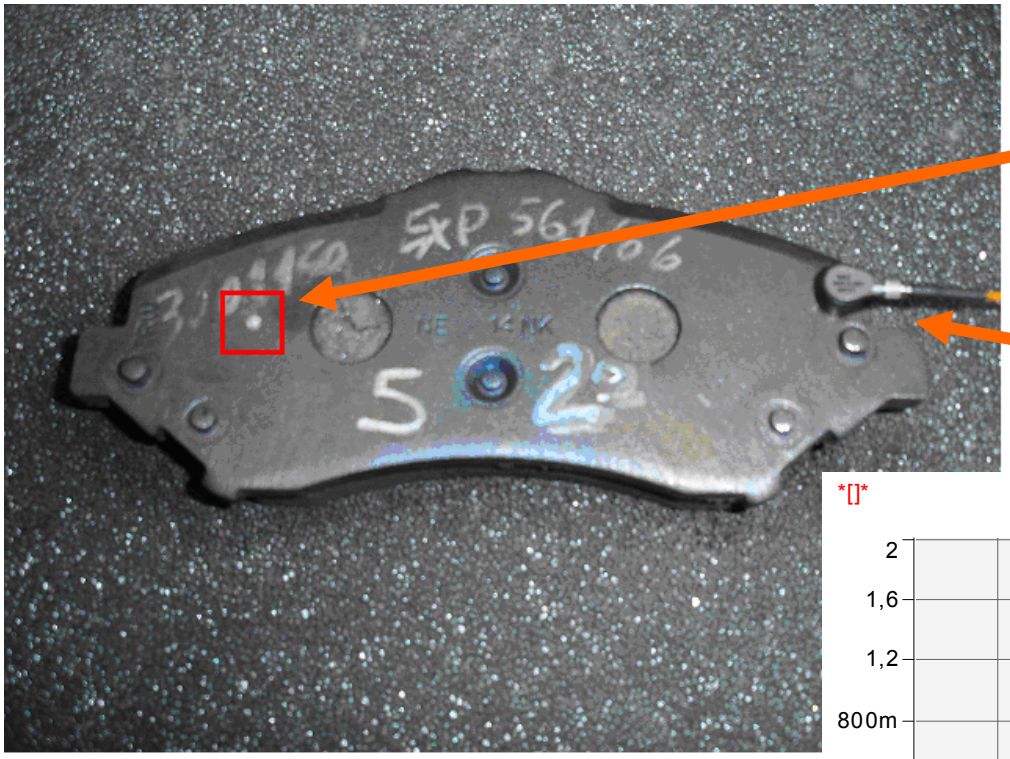
Elastomeric materials dynamic $E_{din_{xy}}$



Pads Compressibility

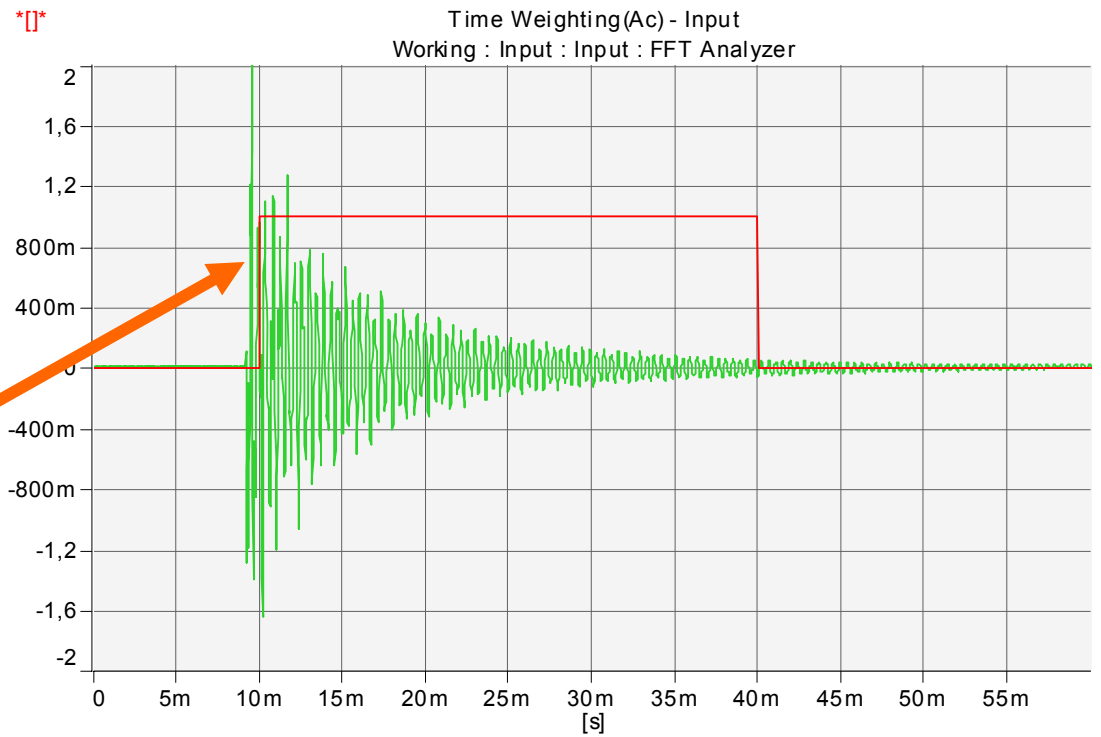


Pads dynamics characterization



Excitation

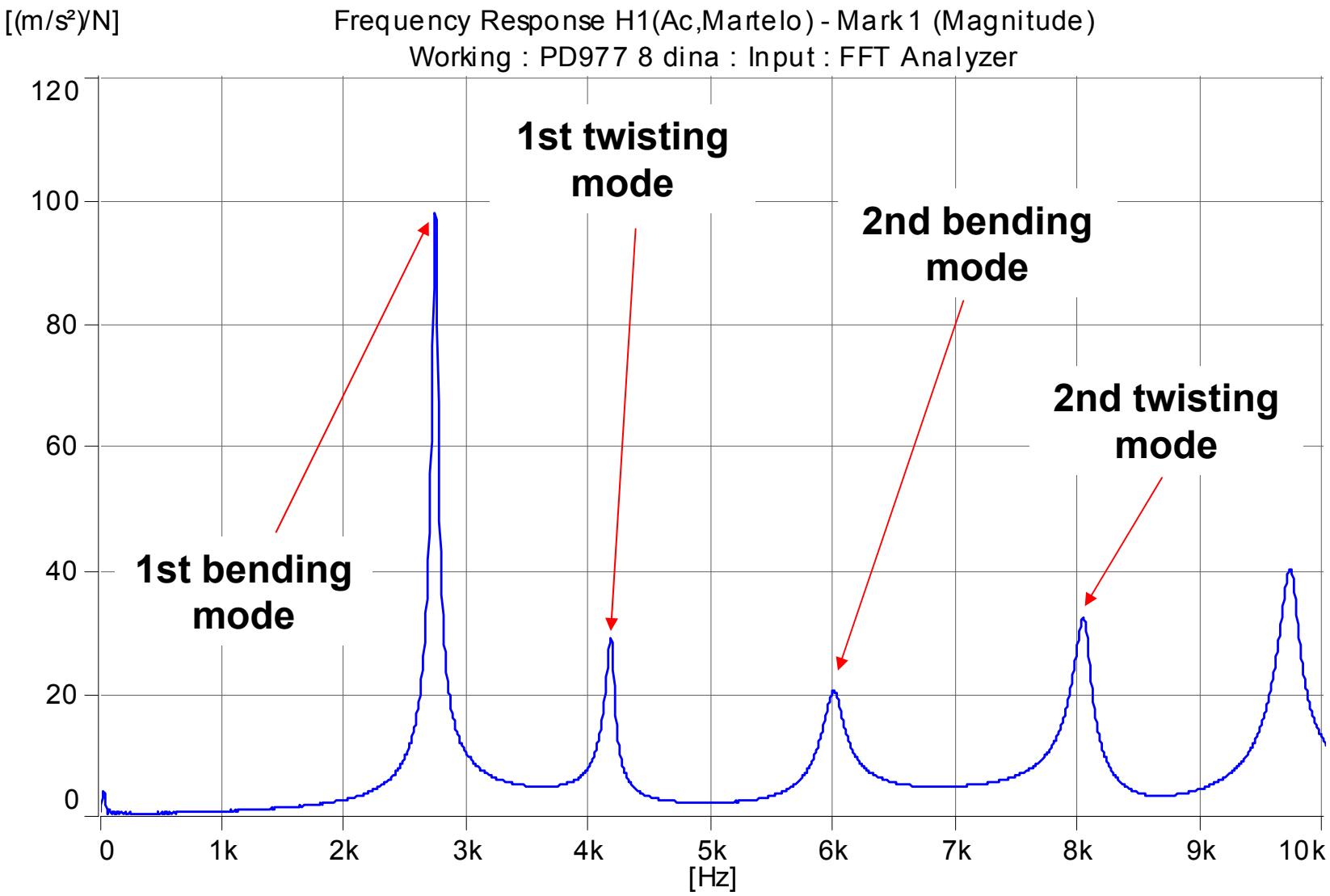
Accelerometer



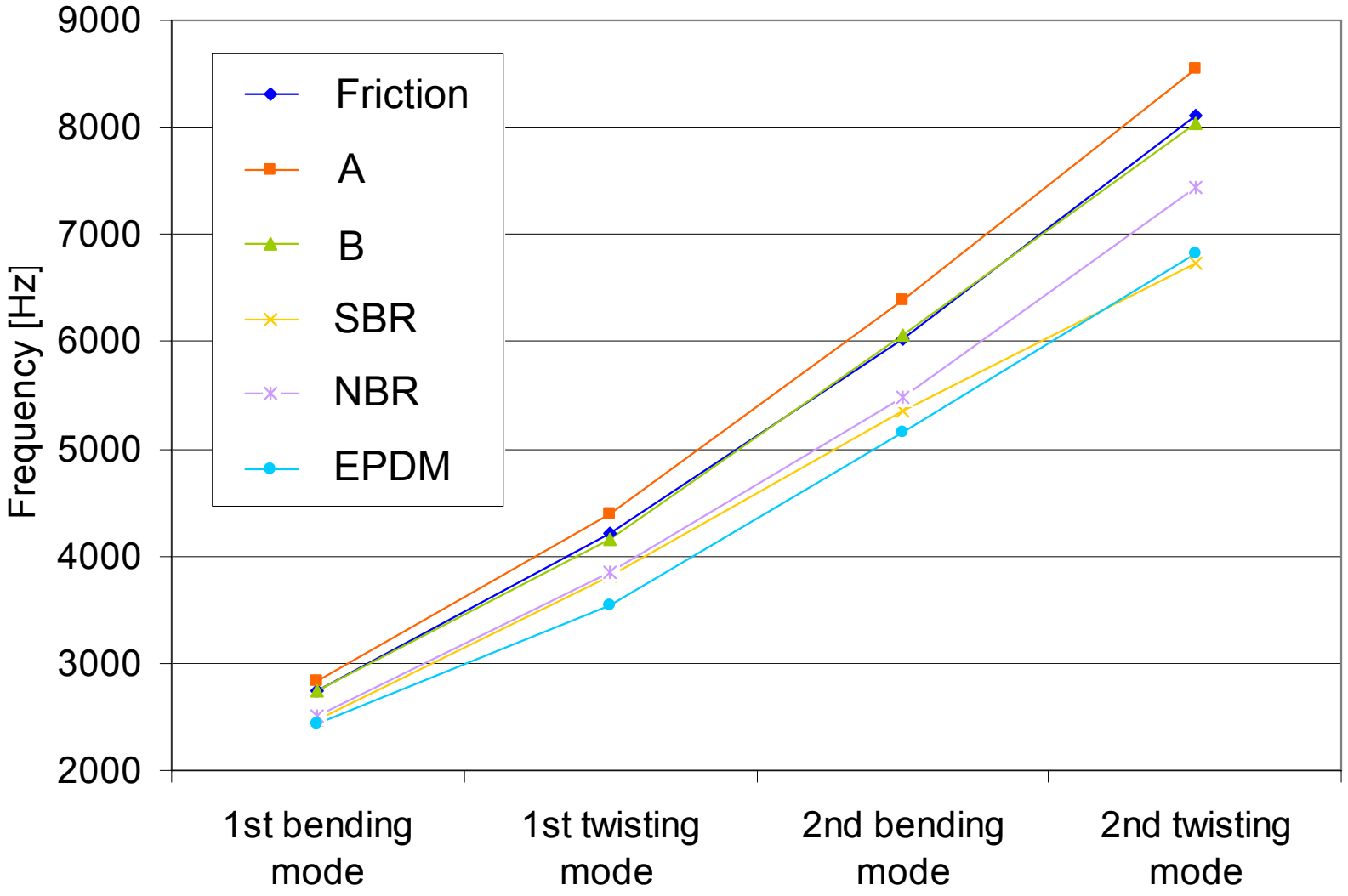
Accelerometer's transient window

(10 to 40ms)

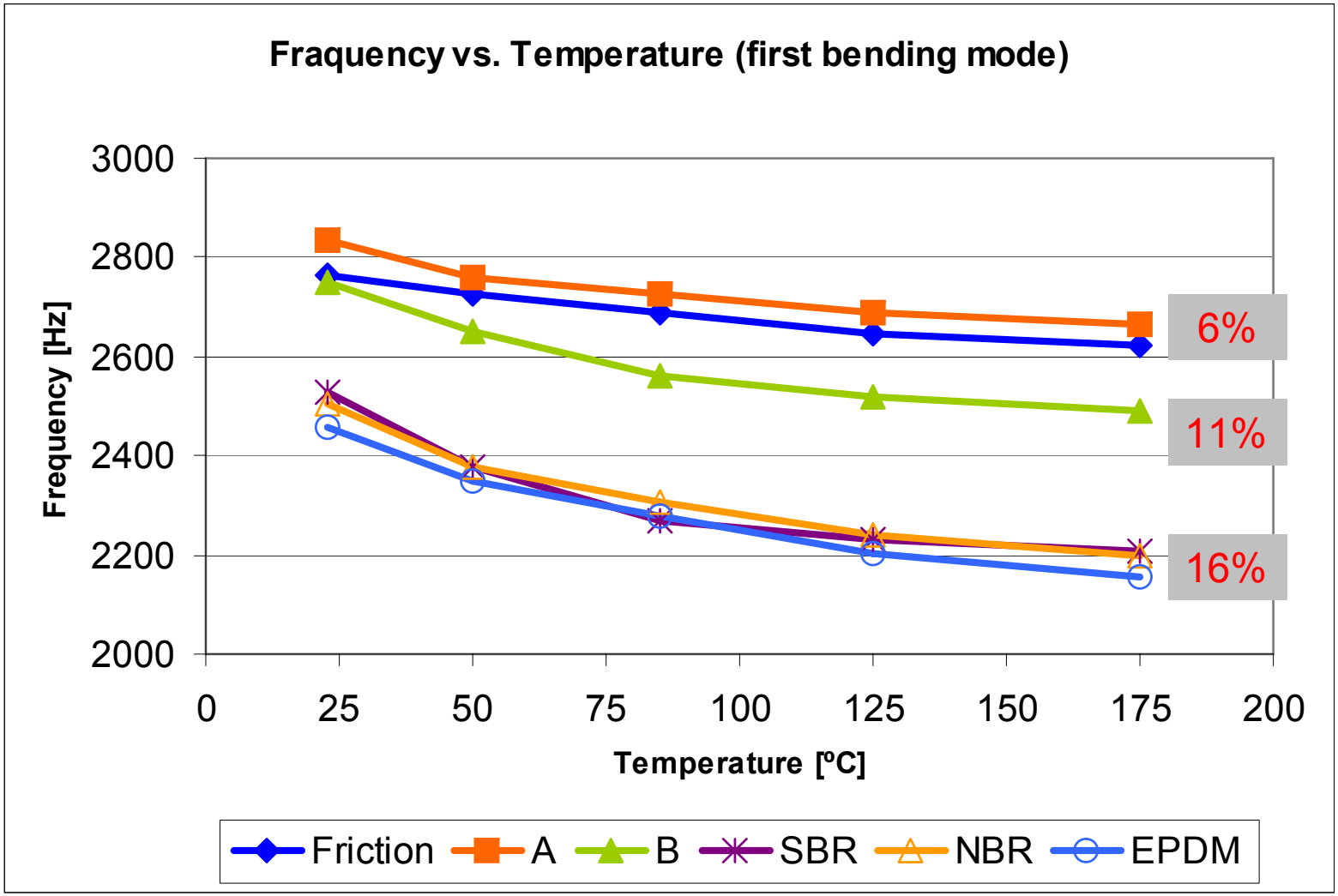
Pads Vibration modes



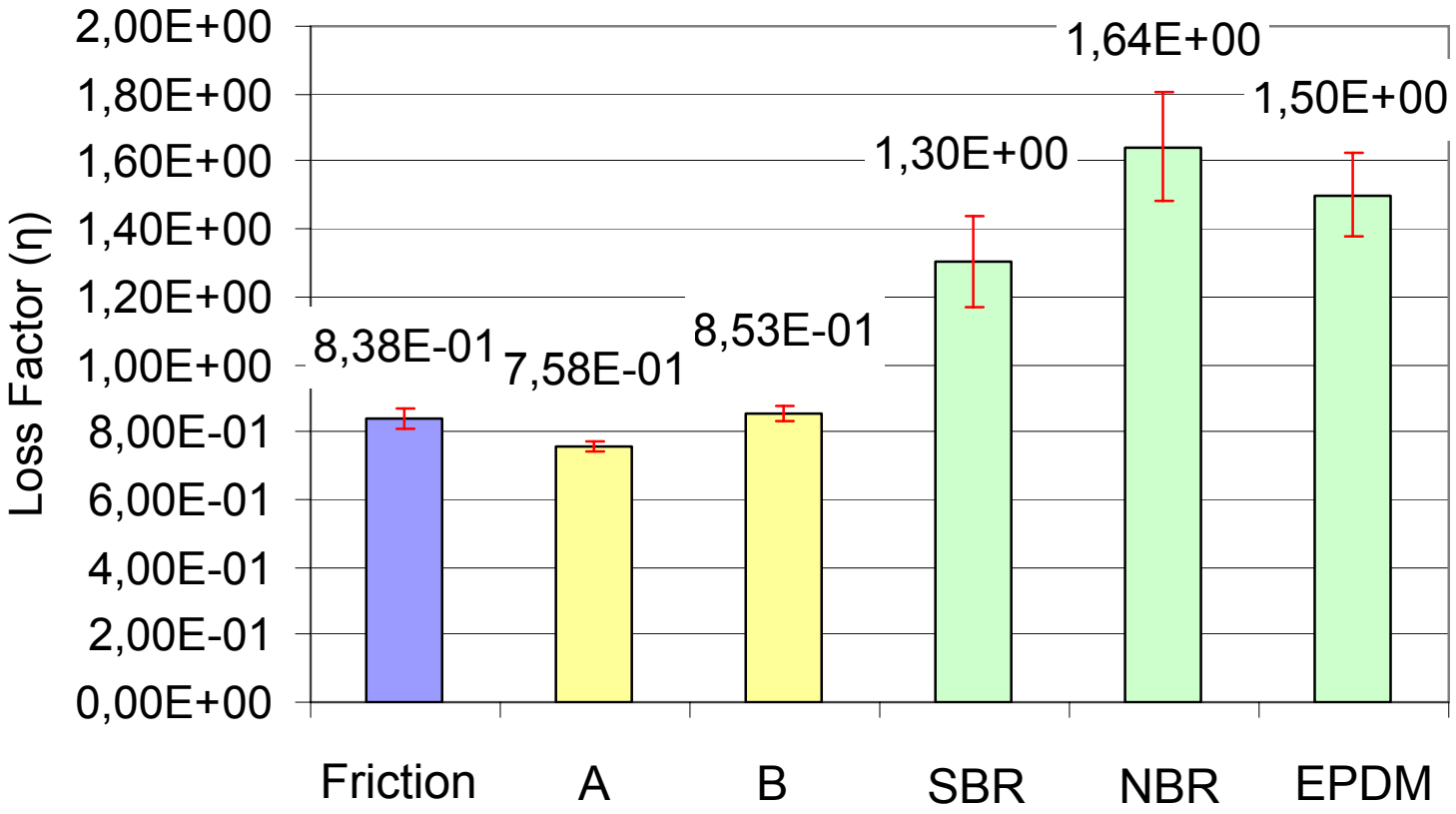
Frequency – first four modes – 23ºC



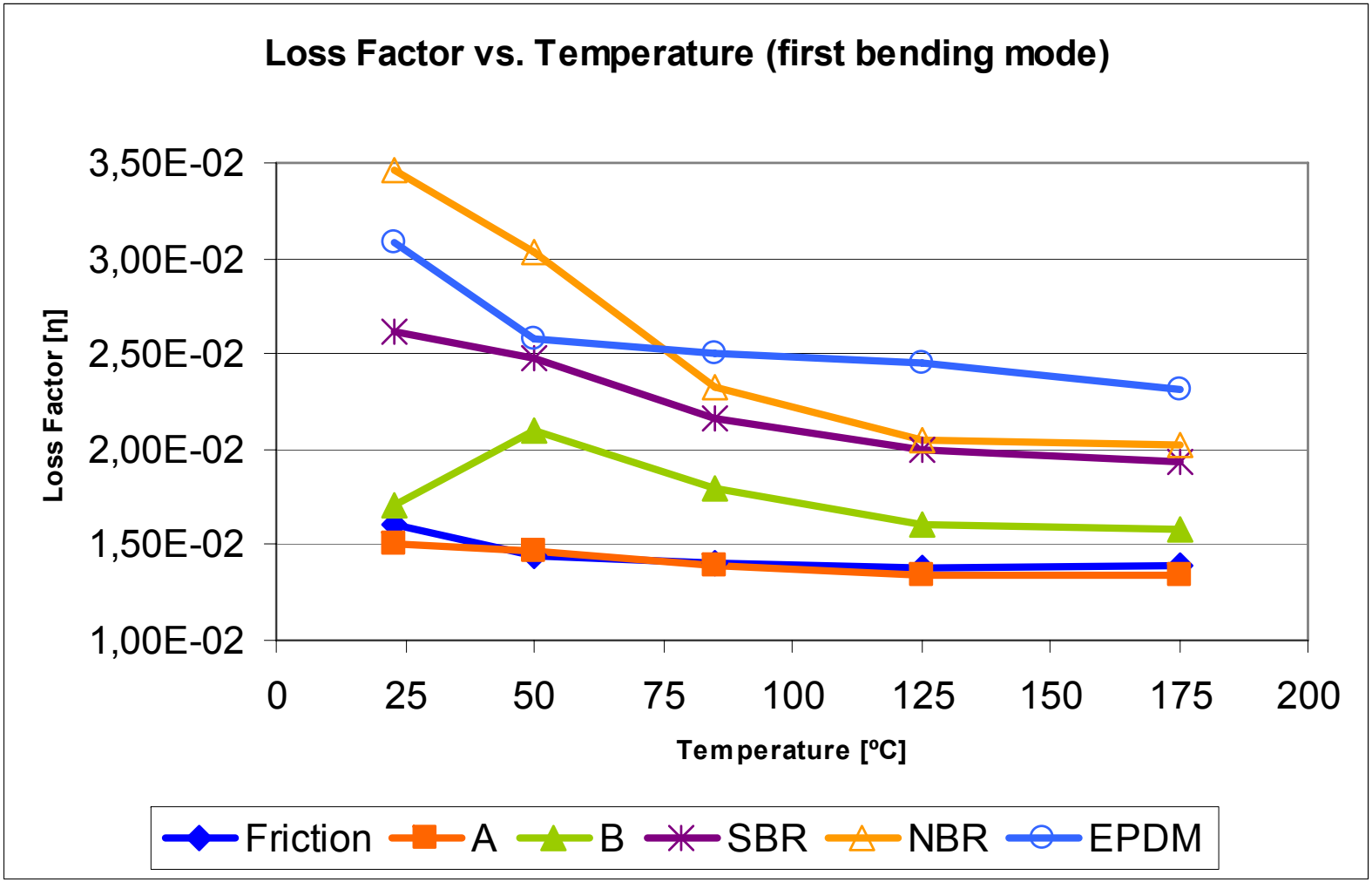
Frequency behavior with temperature



Loss factor - first bending mode – 23ºC



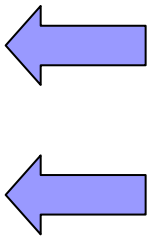
Pads behavior with temperature



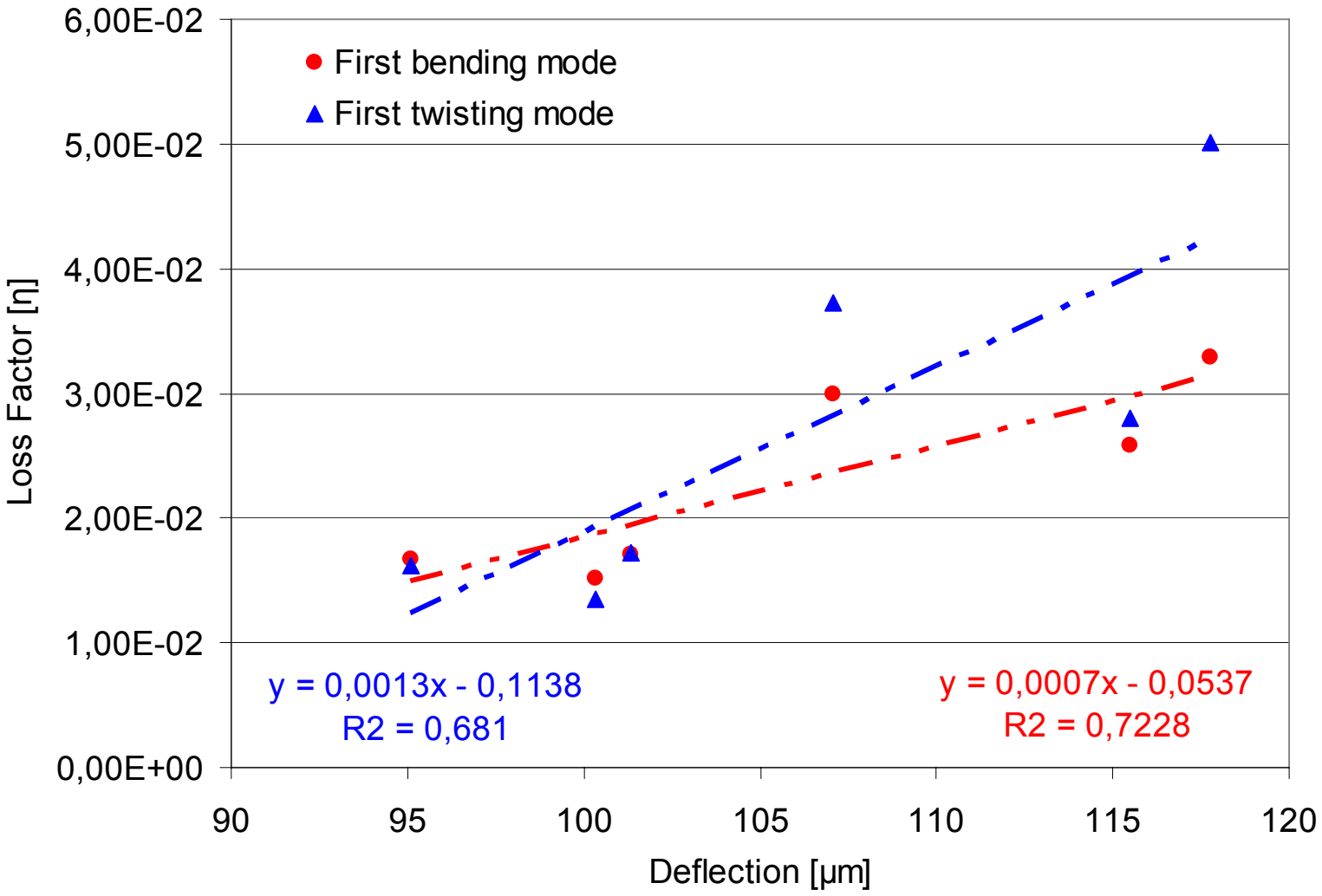
Pads behavior with temperature

Variation of the loss fator between ambient temperature (23ºC) and 175ºC.

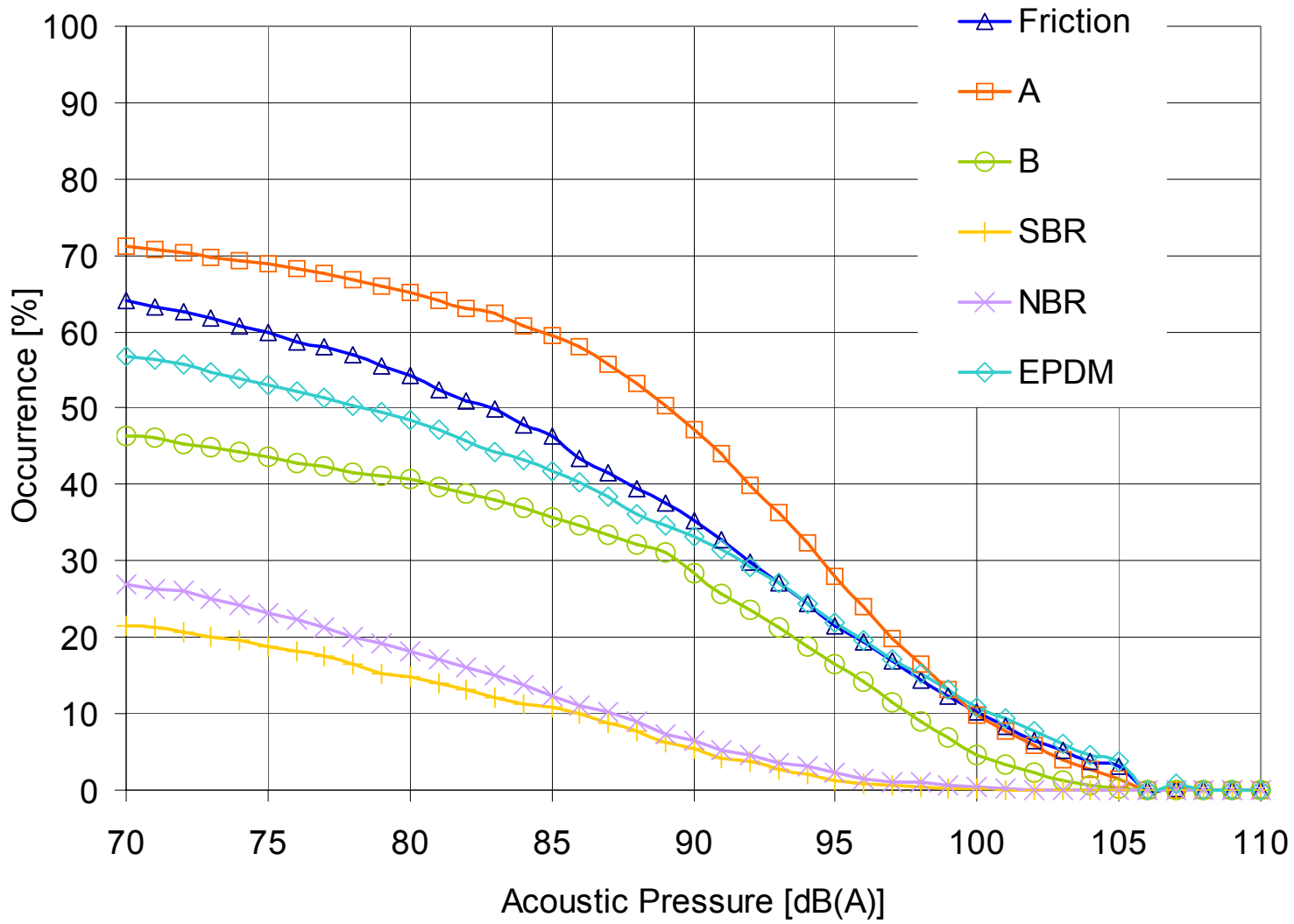
	1st Bending mode	2nd Bending mode	1st Twisting mode	2nd Twisting mode
Friction	-14%	-16%	-24%	-24%
A	-10%	-29%	-21%	-27%
B	-8%	-29%	-15%	-14%
SBR	-26%	-46%	-34%	-38%
NBR	-41%	-62%	-61%	-61%
EPDM	-25%	-43%	-46%	-47%



Compressibility vs. loss factor (23ºC)



SAE J2521 results



SAE J2521 results vs pads properties

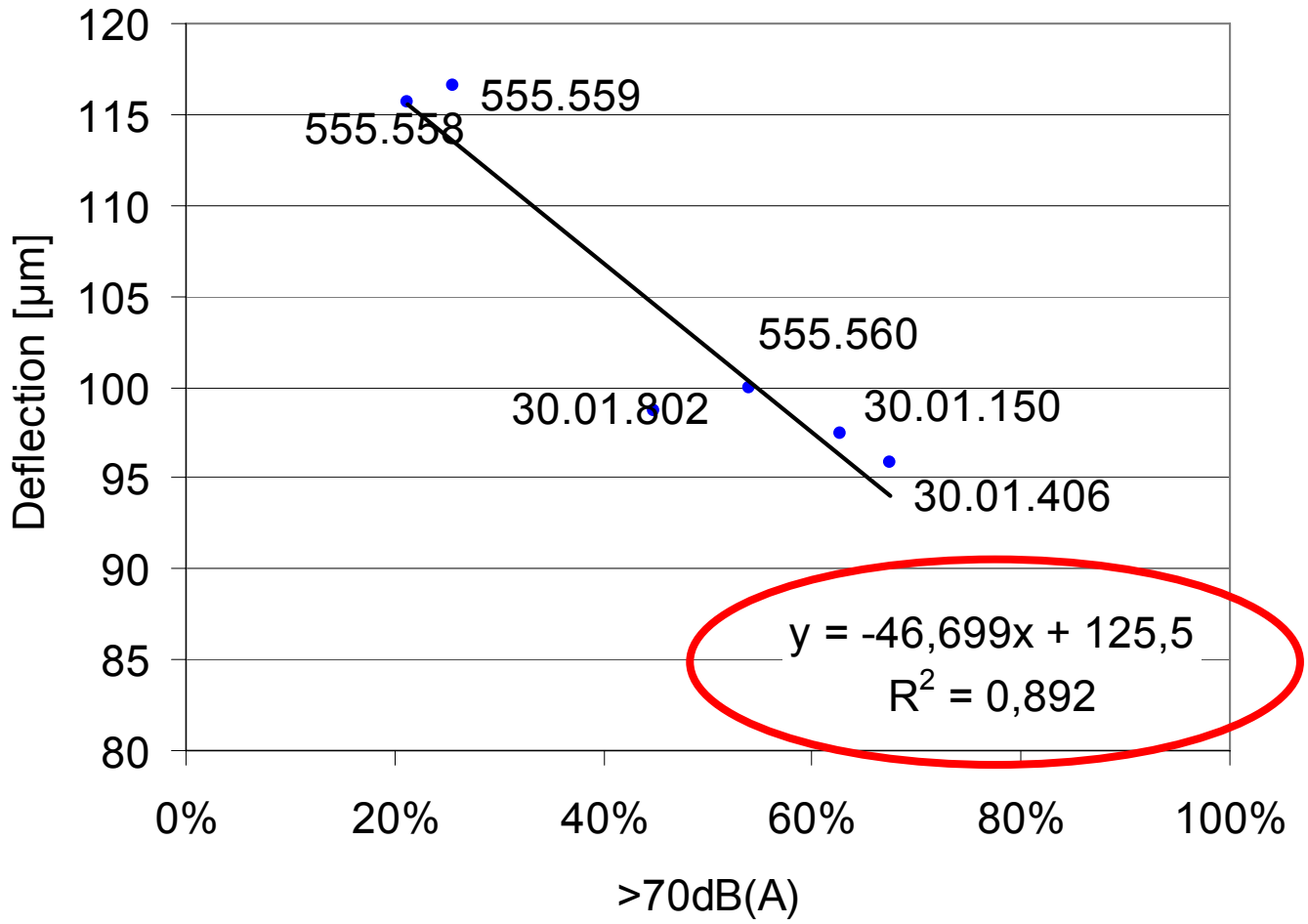
	Defletion [µm]	"η" 1st Bending mode	"η" 1st twisting mode	Squeal noise occurrences
Friction	97	1,71E-02	1,68E-02	63%
A	96	1,49E-02	1,32E-02	67%
B	99	1,71E-02	1,78E-02	45%
SBR	116	2,93E-02	3,11E-02	21%
NBR	117	3,34E-02	5,19E-02	26%
EPDM	100	2,88E-02	3,66E-02	54%

$y = -0{,}0539x + 0{,}0526$ $R2 = 0{,}4835$

$y = -0{,}032x + 0{,}0381$ $R2 = 0{,}5942$

No valid correlation could be established between noise occurrence and loss factor at ambient temperature.

SAE J2521 results vs pads properties



Compressibility vs Noise occurrence

Conclusions

- The increase of pad's intrinsic damping (300% max) was achieved by the addition of underlayers with elastomeric matrix, materials NBR, SBR and EPDM.
- The use off this high damping underlayers was verified to be an option to modify the resonance frequency of standard pads by changing its structural stiffness.
- Damping characteristics were verified to be very sensitive to temperature variations although this sensitiveness depends on the type of viscous-elastic material.

Conclusions

- No correlation between the calculated loss factors for pad's first two vibration modes and noise occurrences at SAE J2521 test could be found.
- A correlation between compressibility test results and noise occurrences was established, showing that higher values of compressibility reduce the noise occurrence propensity.
- The modification in compressibility, at this work, was made by changing underlayer materials instead of change some component on friction bulk.

Thank you!

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May, 10th and 11th, 2007

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