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The European Tyre and Rim
Technical Organisation

Correlation and Alignment of measurement methods

ETRTO/ETRMA – August 2022

Question & Definitions

Let's suppose we have a reference test method

Ref : T° meas. by liquid dilatation



New candidate test methods are proposed

Candidate:



Infrared



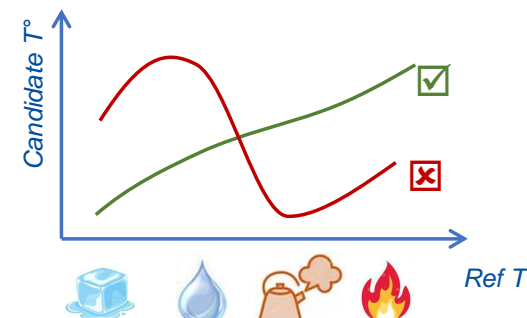
Electronical thermocouple



Bimetallic strip

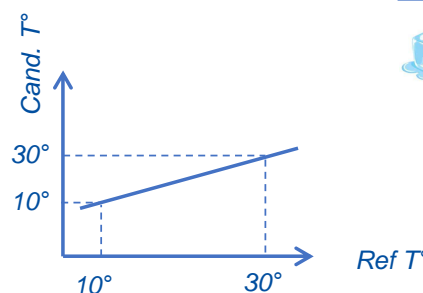
Are we sure that the candidate method is a reliable measurement ?

➔ Method CORRELATION



Once correlated, how can we convert the test results?

➔ Result ALIGNMENT



We need to correlate candidate test methods

The objective is to remove tire with high abrasion from the market

The risk is to use a method which is not relevant

➔ *Tires with high abrasion in reality would be allowed*

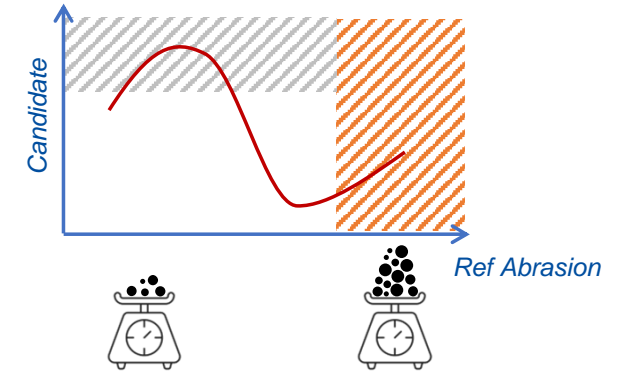
➔ *Tires with low abrasion in reality would be forbidden*

The stakeholders would be questioned on the representativity of the method

➔ *public image risk*

The other risk : to refuse a candidate method although it is relevant

➔ *industrial efficiency risk*



We need to align candidate test methods

To be sure that the threshold is the same for all test center

The objective is to avoid “favorable” test center, where tire homologation would be easier

Correlation requests more experiments than alignment

Correlation results can be used for alignment

Correlation experiments

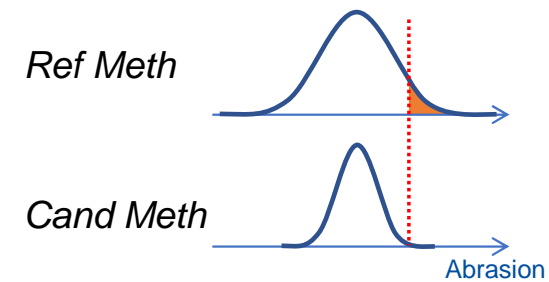
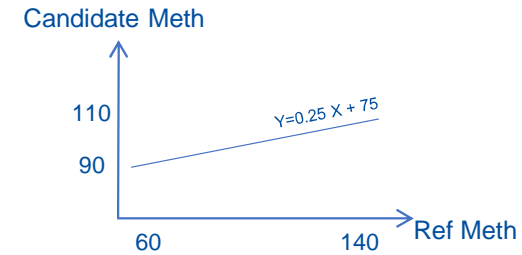
For abrasion, 9 tires, 5 repetitions recommended ()*

Alignment experiments

For abrasion,

5 tires, 3 repetitions recommended ()*

() see later in this document*





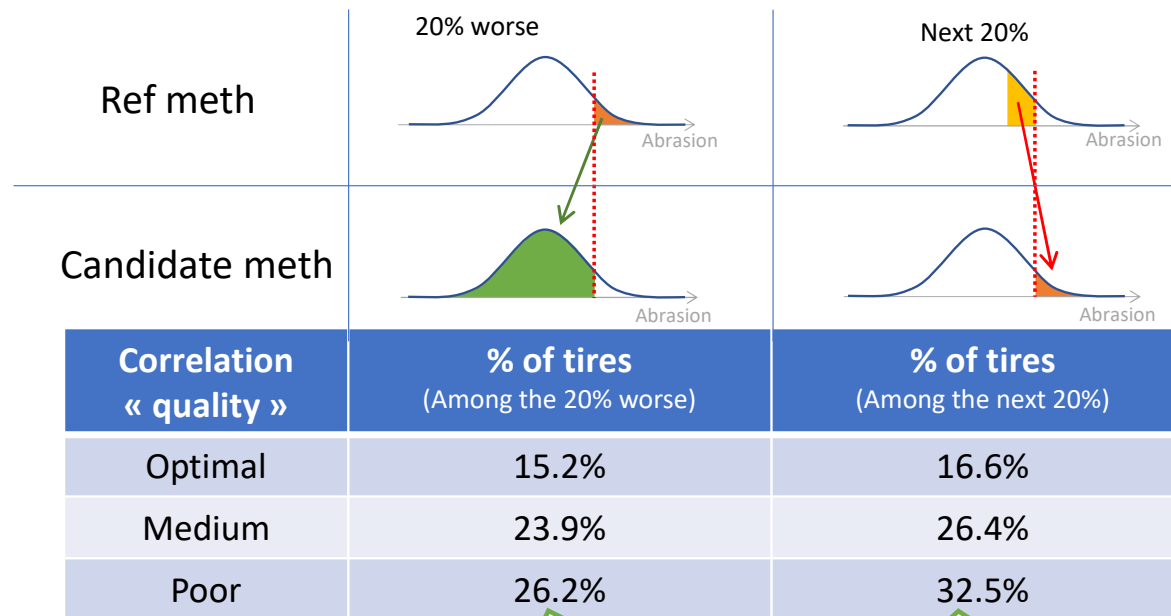
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Process to correlate a candidate method

Why do we need to correlate the methods ?

To avoid inversion in tire homologation depending on the test method



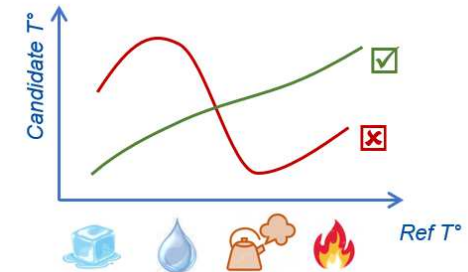
Made with 20 000 random simulations

Among the 20% of tires that **do not fulfill** an abrasion threshold on the ref method, which share **respect it** on a **candidate method**

Among the next 20% of tires that **barely pass** an abrasion threshold on the ref method, which share **do not pass it** on a **candidate method**

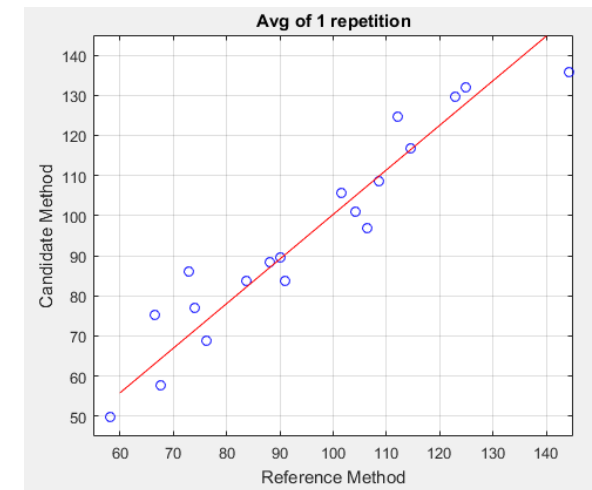


What means “Correlate” a method ?



Correlate the candidate method means :

- Check if we can say : candidate method gives the same evaluation than reference method
- Within given limits : how perfect do we want the correlation to be ?
- The measurement dispersion has to be considered ...
- NB : align a method = to set-up conversion formula :
 - $Candidate\ Method_{correlated} = a \times Candidate\ Method_{raw\ meas} + b$



What means “Correlate” a method ?

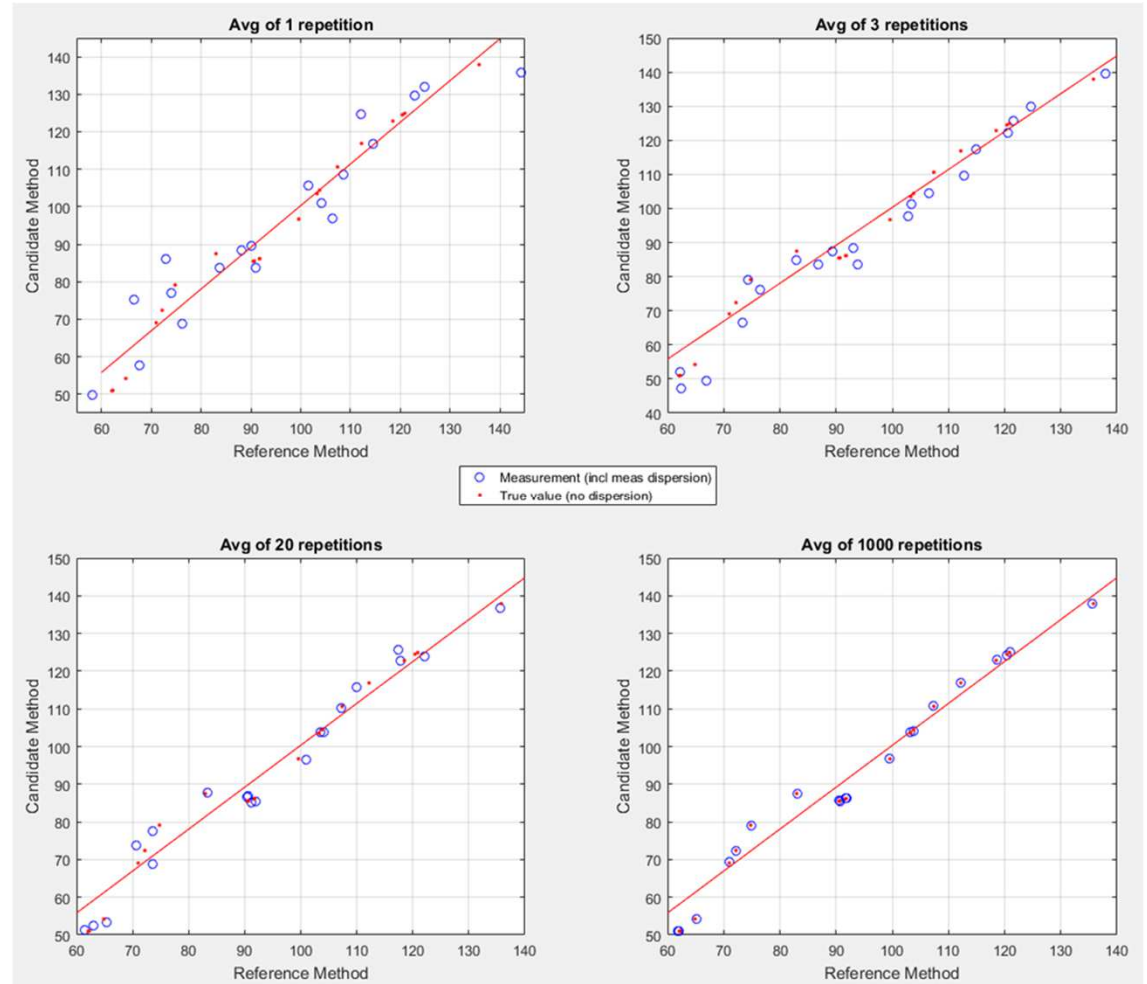
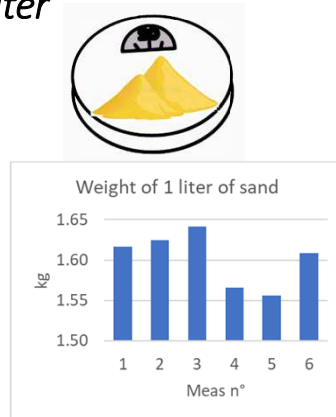
Impact of the measurement dispersion :

- For each “tire” measured
 - To average an increasing number of repetitions reduces the dispersion
 - With an infinity of repetition, we get the “True value”

Ex : 6 weight measurements of 1 liter of sand

Difference can come from :

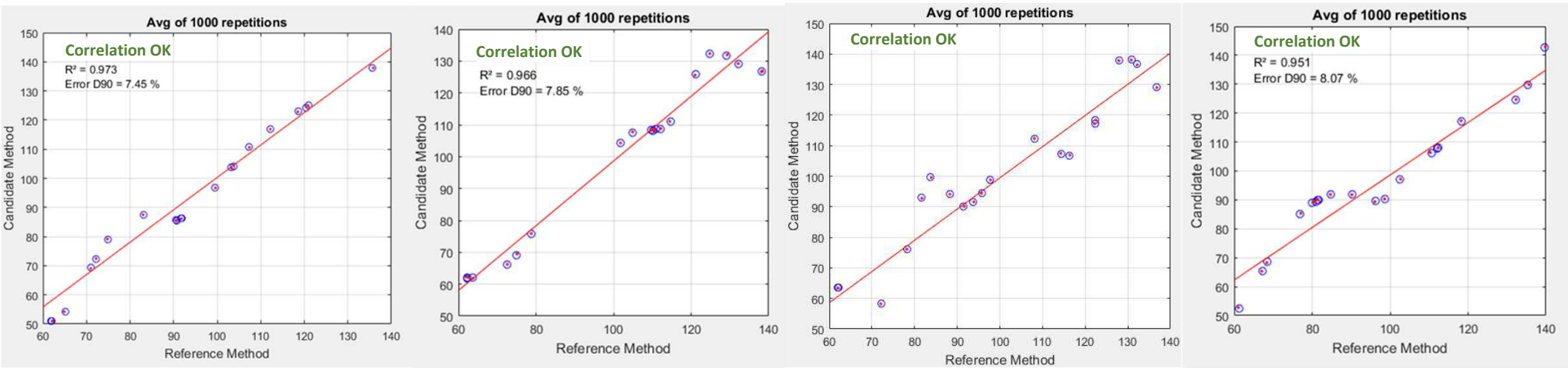
- ▶ The process to take 1 liter
- ▶ The scale itself
- ▶ Humidity
- ▶ Variation in sand granulometry
- ▶ ...



What means “Correlate” a method ?

How to decide if a candidate method is correlated vs the reference ?

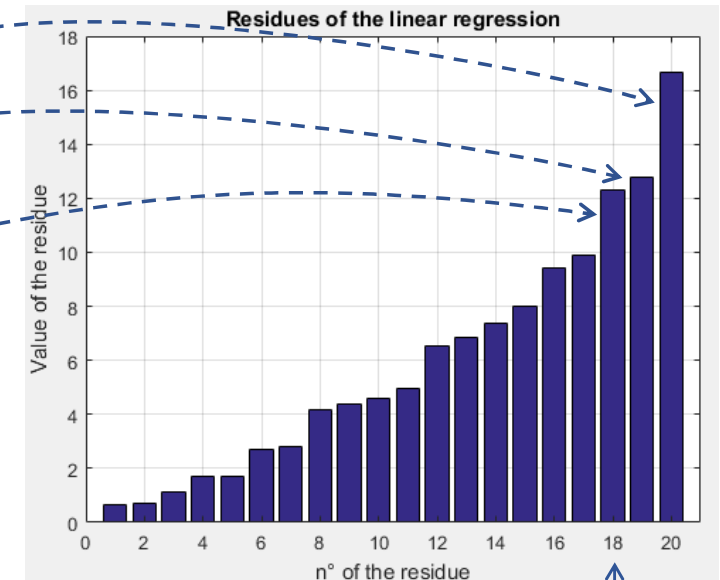
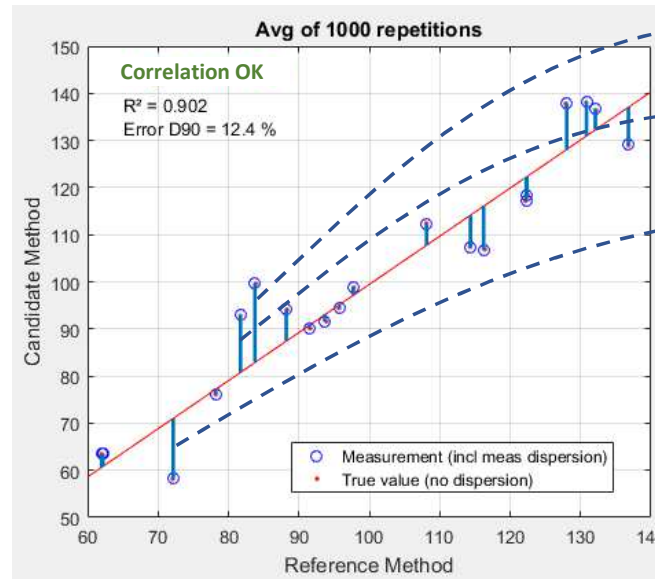
- It is a matter of choice, statistical criteria can help
 - $\sigma_{Cand} \leq 1.5 \times \sigma_{Ref}$ ($\approx 1.5 \times 5\% = 7.5\%$) \rightarrow like in RR regulation
 - R^2 of linear regression
 - Residues of regression : last decile of abs(residue) (D90) (more stable than max which is too sensitive)



What means “Correlate” a method ?

Focus on residues of regression

❖ Residues of regression :



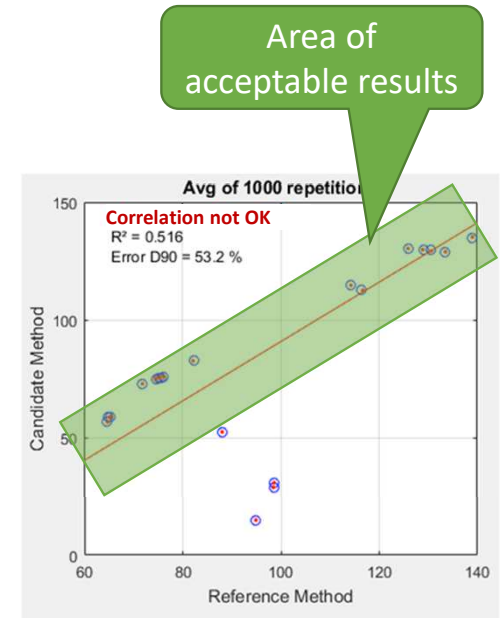
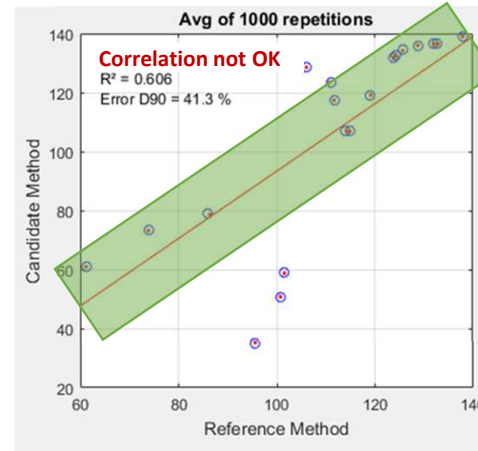
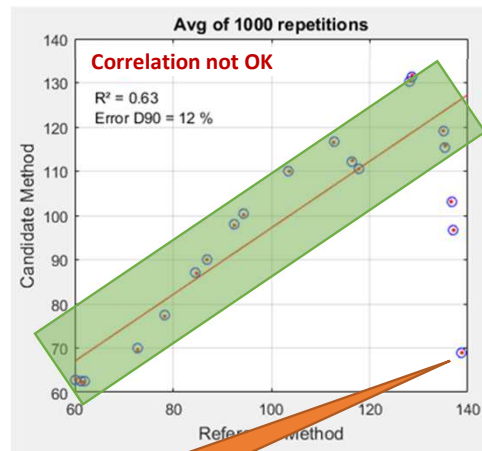
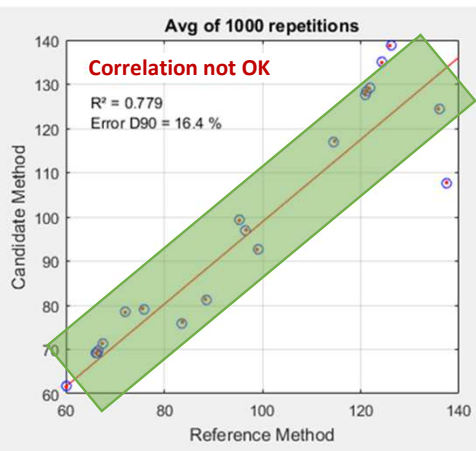
❖ last decile of residues (D90)

- If N points available, we take the $0.9 \times N$ th \rightarrow for 20 points, $0.9 \times 20 = 18$ th point
 - If less than 10 points, we take the before last point
- The D90 value is more stable than max, which is too sensitive

What means “Correlate” a method ?

How to decide if a candidate method is correlated vs the reference ?

- Example of clearly not-correlated cases



Inversion of abrasion :
140% on Ref method
70% on candidate

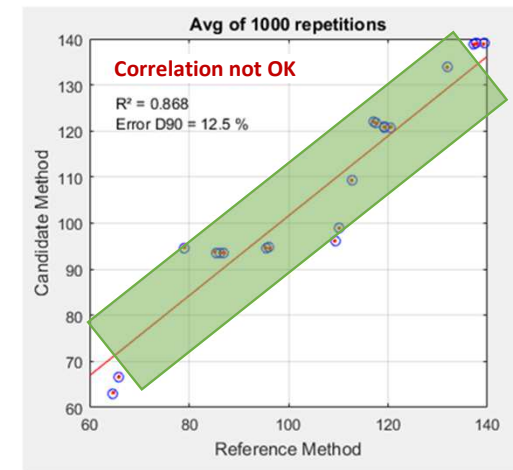
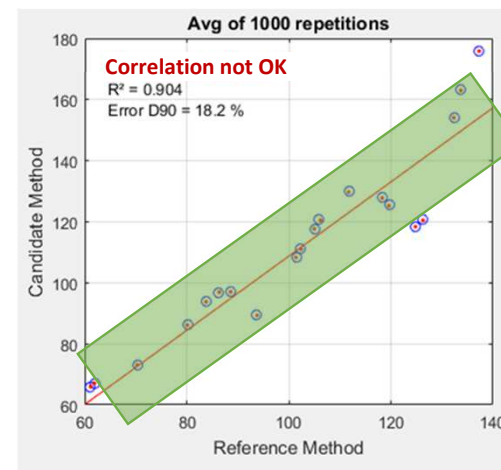
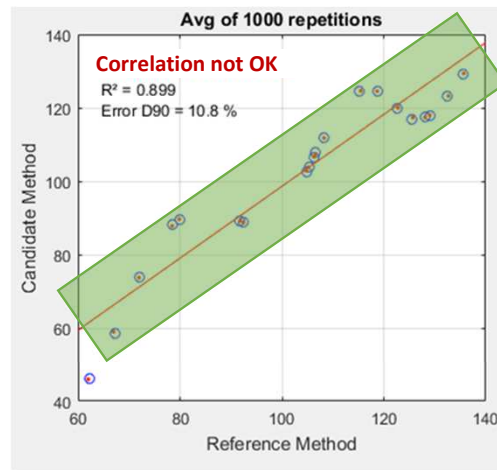
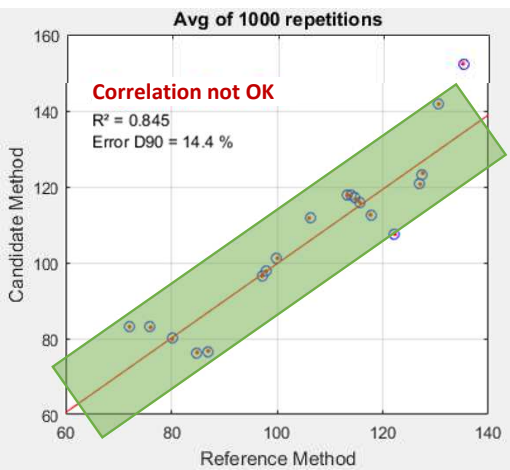
With poorly correlated methods, 26.2% of inversions



What means “Correlate” a method ?

How to decide if a candidate method is correlated with the reference ?

- Example of limit cases



What means “Correlated” a method ?

Proposed criteria to say of a candidate method is correlated :

- *Dispersion of the candidate method : $\sigma_{Cand} \leq 1.5 \times \sigma_{Ref}$ (like in RR)*
- *Threshold on the R^2 of a linear regression : $R^2 \geq 0.90$ (like in Noise & RR)*
- *Last decile (D90) of absolute value of residue : $Err D90 \leq 12.5\%$*
- *Slope of the linear regression in the range $[0.5 ; 2]$, to avoid a method having much less dynamic than the other*

These threshold are for the “True values” (average of many measurements)

How to proceed in real life, with dispersion ?

→ Need to do a DOE (Design Of Experiment)

- ❖ *With a trade-off between cost & good decision rate*



The tested DOE

Small to big DOE, 1 to 5 repetitions :

- 5 tires = one convoy of 5 vehicles : Ref, A, B, C, D
- 7 tires = 2 convoys of 4 vehicles : Ref, A, B, C + Ref, D, E, F
- 9 tires = 2 convoys of 5 vehicles : Ref, A, B, C, D + Ref, E, F, G, H
- 15 tires
 - 4 convoys of 4 vehicles + 1 of 3 veh
 - Or 3 convoys of 5 vehicles + 1 of 3 veh

Cost to run on the convoy method

	5 tires	7 tires	9 tires	15 tires
1 repetition	48 k€	77 k€	96 k€	173 k€
3 repetitions	144 k€	230 k€	288 k€	518 k€
5 repetitions	240 k€	384 k€	480 k€	864 k€

ETRTO recommendation

To be run on the candidate method as well

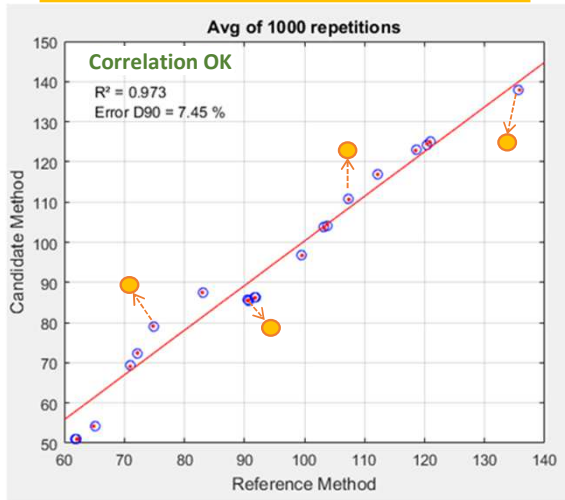


How to evaluate the “efficiency” of the DOE ?

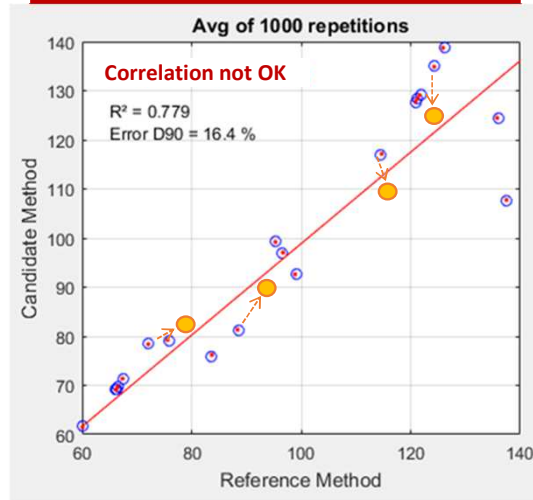
Evaluation made by simulation

- Compare the “theoretical” decision with the “real life” one
 - 2 criteria :
 - % of right decision for correlated methods
 - % of right decision for not correlated methods

Correlated in theory,
not correlated in real life



Not correlated in theory,
correlated in real life



	Correlated in theory	Not corr in theory
Correlated in real life	✓	✗
Not correlated in real life	✗	✓

to refuse a candidate method
although it is relevant
→ industrial efficiency risk

Use of a method which
is not representative
→ Public image risk for
all stakeholders

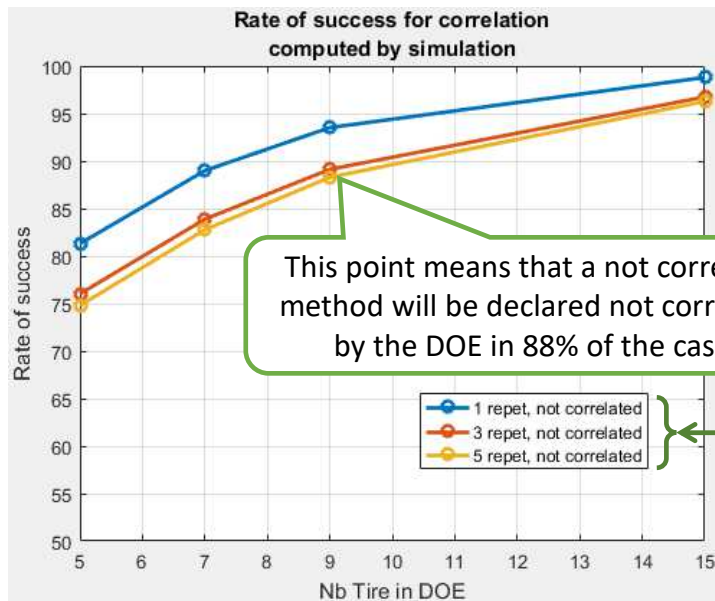


Is the Correlation approach efficient ?

Same error on Ref method & Candidate method : $\sigma_{Ref} = 5\%$; $\sigma_{Cand} = 5\%$ (*)

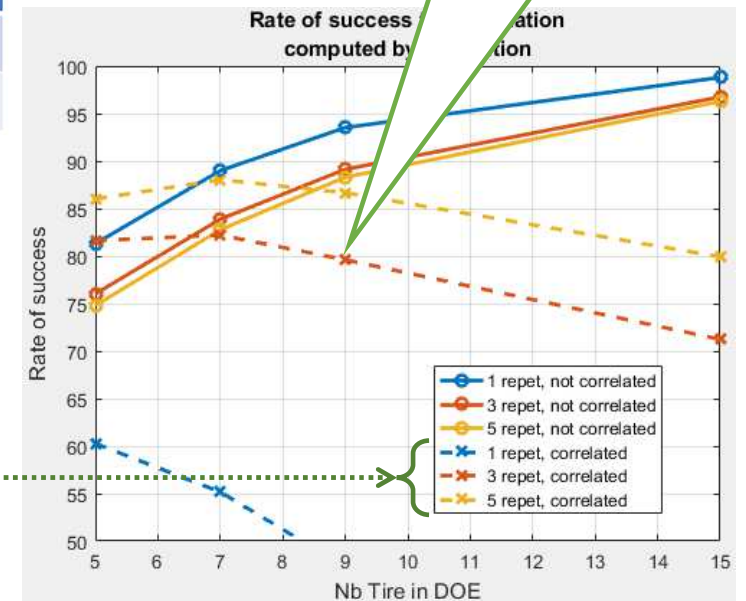
Could simulate correlation of 2 convoy method

(*) Hypothesis, to be confirmed by dispersion assessment tests



This point means that a not correlated method will be declared not correlated by the DOE in 88% of the cases

	Correlated in theory	Not corr in theory
Correlated in real life	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Not correlated in real life	<input type="checkbox"/>	<input checked="" type="checkbox"/>

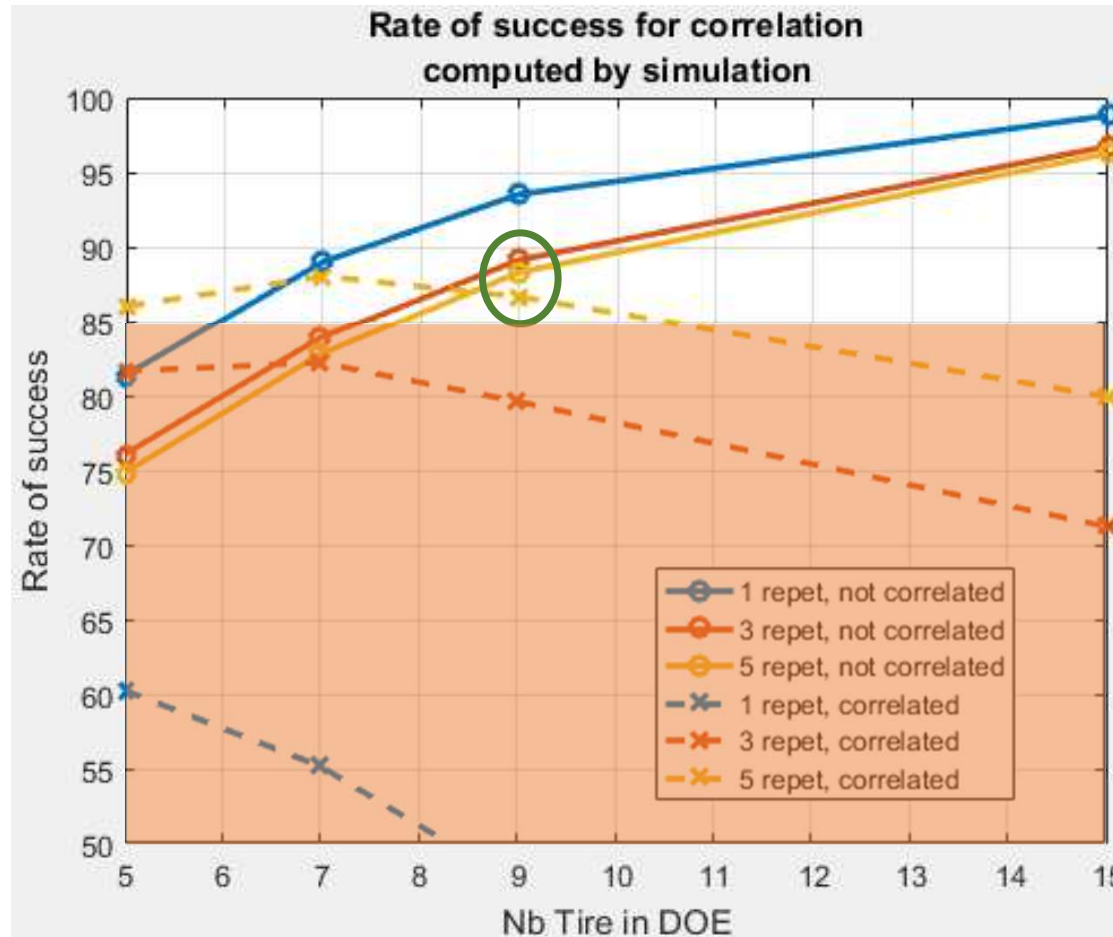


This point means that a correlated method will be seen as correlated by the DOE in 80% of the cases



Is the Correlation approach efficient ?

Discussion



	Correlated in theory	Not corr in theory
Correlated in real life		
Not correlated in real life		

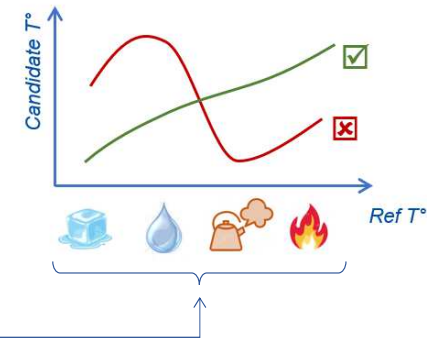
80% success means wrong decision 1 time over 5

90% success means wrong decision 1 time over 10



Requirements on the Correlation DOE

- *Tires of the DOE have to be well distributed in abrasion performance*
 - *At least 1 tire in [60%-80%], 1 tire in [80%-100%], 1 tire in [100%-120%], 1 tire in [120%-140%] : to correlate on the full measurement domain*
 - *Low and high RR values*
 - *Low and high wet grip values*
 - *3PMSF & summer tires*
 - *Different sizes*
- *“Blind” execution of the DOE : the candidate method do not know the results of the DOE on the Ref method, and reciprocally*



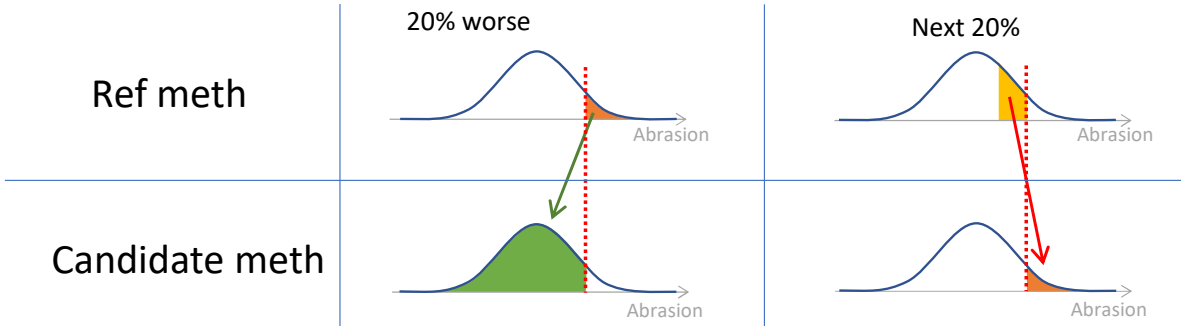


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Appendix

Rate of threshold “inversion”



R ² threshold	Err D90 threshold	% of tires (Among the 20% lowest)	% of tires (Among the next 20%)
0.90	12.5	15.2%	16.6%
0.85	15	22.3%	24.4%
0.80	17.5	23.9%	26.4%
0.75	20	25.8%	29.2%
0.70	25	26.2%	32.5%

« True value »,
no measurement noise added

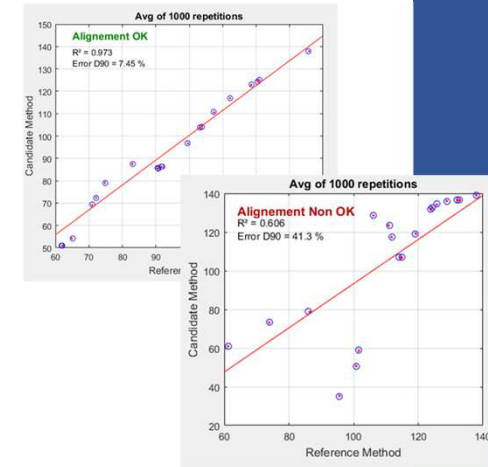
Made with 20 000 random simulations



How to evaluate the “efficiency” of the DOE ?

Run Monte-Carlo simulation

- Generate a candidate method which is correlated or not, based on the “True values”
 - With the aforementioned criteria
 - Gives the “theoretical” decision : the method is correlated or not in the theory
- Simulate the DOE (nb of tires, avg of N repet, ...)
 - Decide if method is correlated in “real life” (including measurement dispersion)
 - Each DOE proposal is evaluated through an average of 500 000 simulations
- Compare the “theoretical” decision with the “real life” one
 - 2 criteria :
 - % of right decision for correlated methods
 - % of right decision for non correlated methods

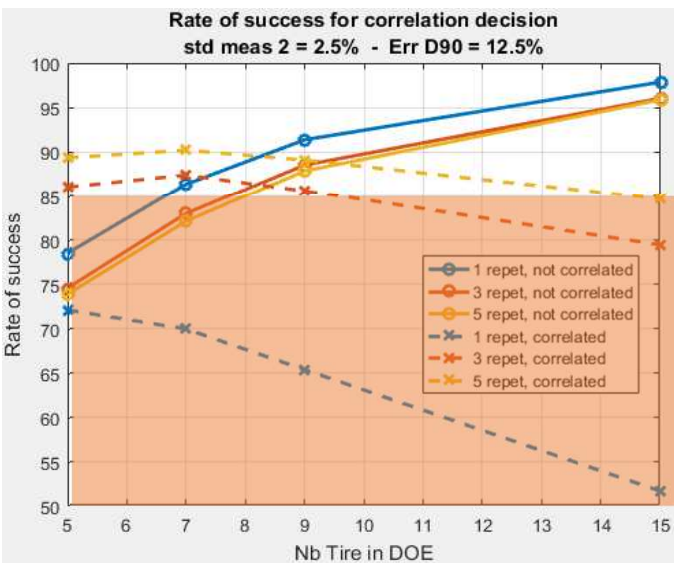


	Correlated in theory	Not corr in theory
Correlated in real life	✓	✗
Not correlated in real life	✗	✓

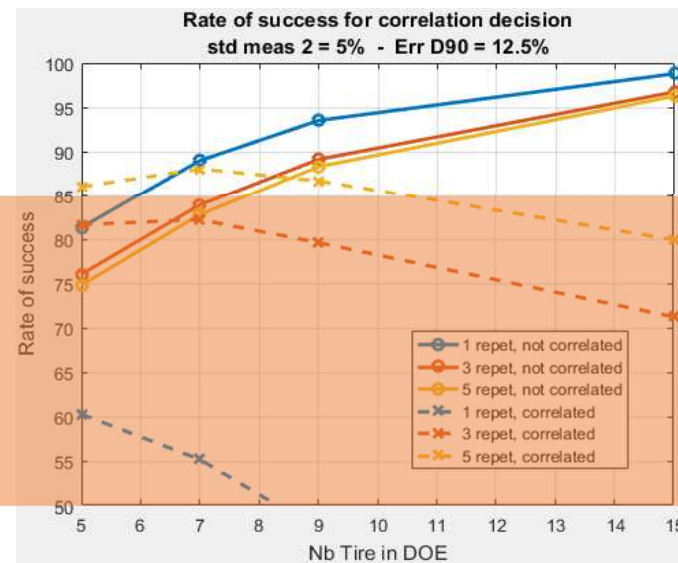
Is the correlation approach efficient ?

What if the candidate method is more or less precise ?

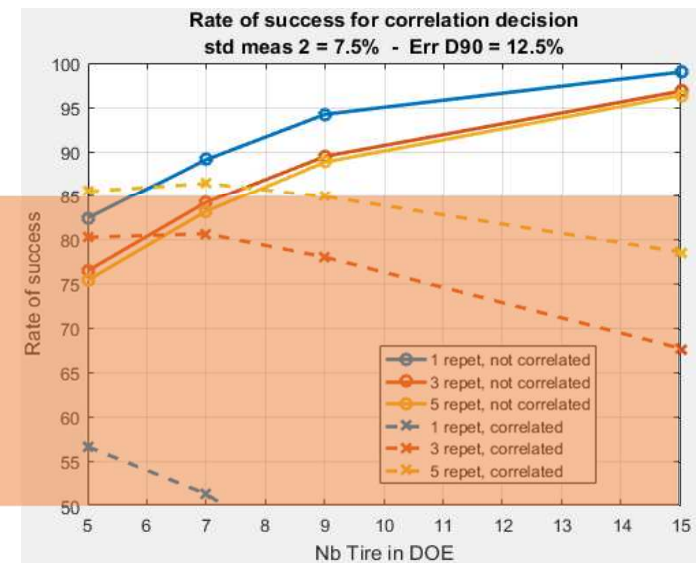
$$\sigma_{Ref}=5\% ; \sigma_{Cand}=2.5\%$$



$$\sigma_{Ref}=5\% ; \sigma_{Cand}=5\%$$



$$\sigma_{Ref}=5\% ; \sigma_{Cand}=7.5\%$$





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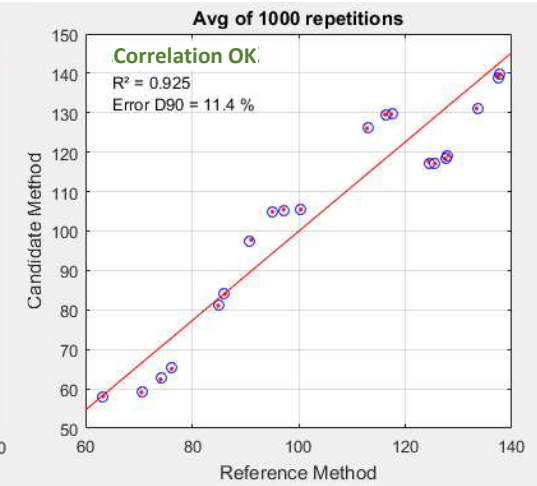
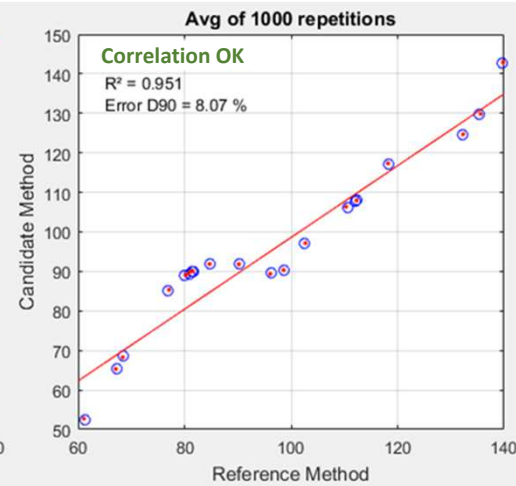
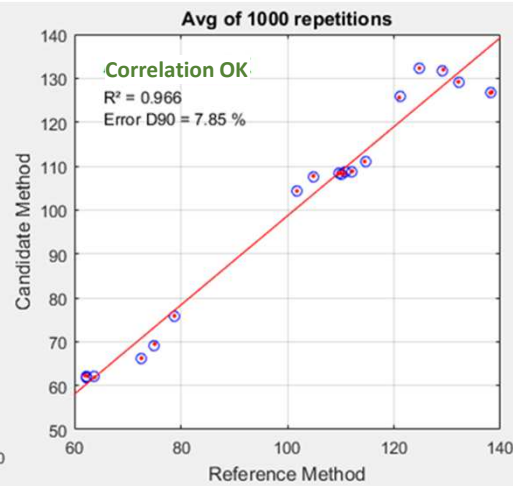
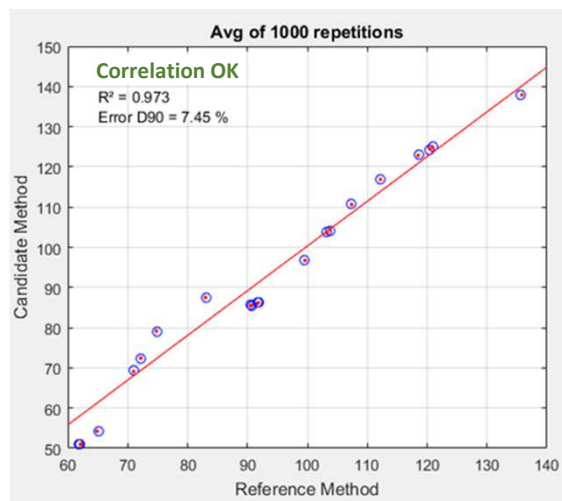
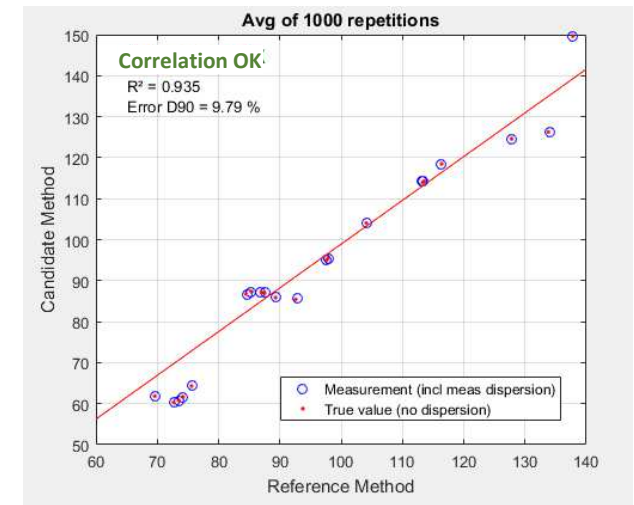
Example of correlation

$$R^2 \geq 0.9$$

$$\text{Err } D90 \leq 12.5\%$$

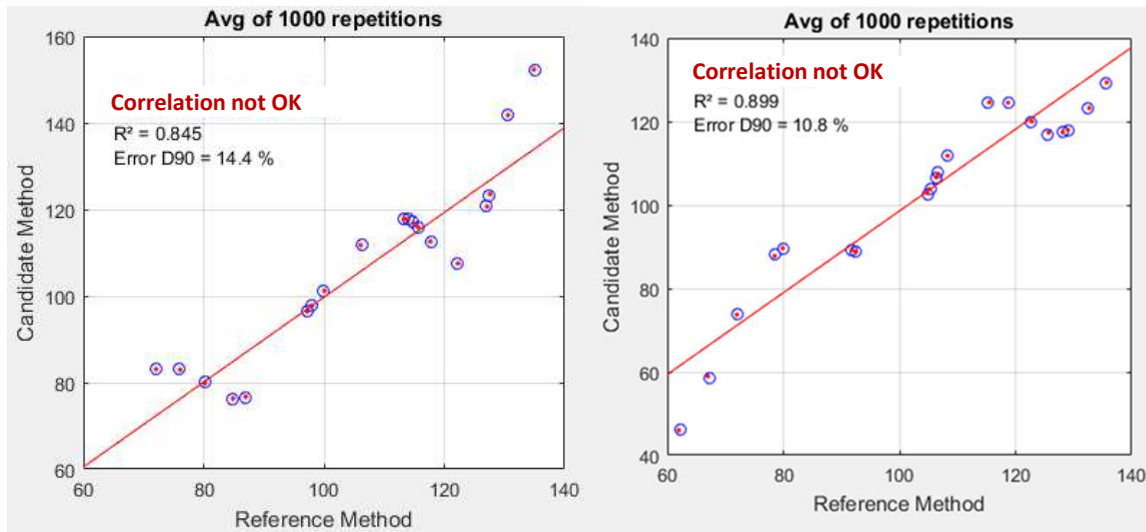
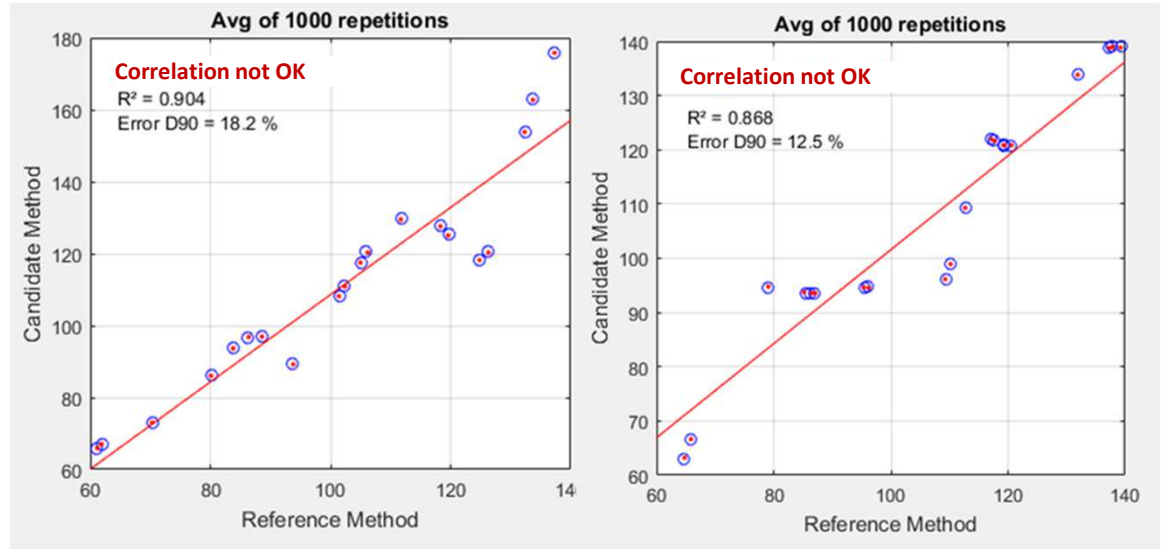
$$R^2 \geq 0.9 - \text{Err D90} \leq 12.5\%$$

Example of correlated cases



$R^2 \geq 0.9$ - $Err D90 \leq 12.5\%$

Example of not correlated cases





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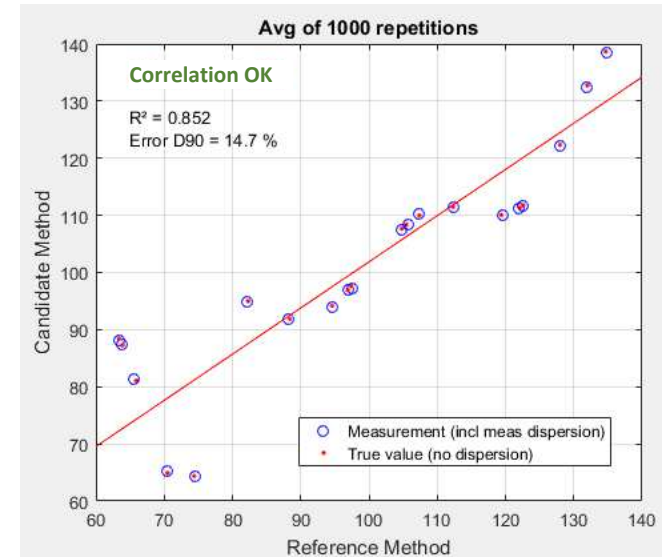
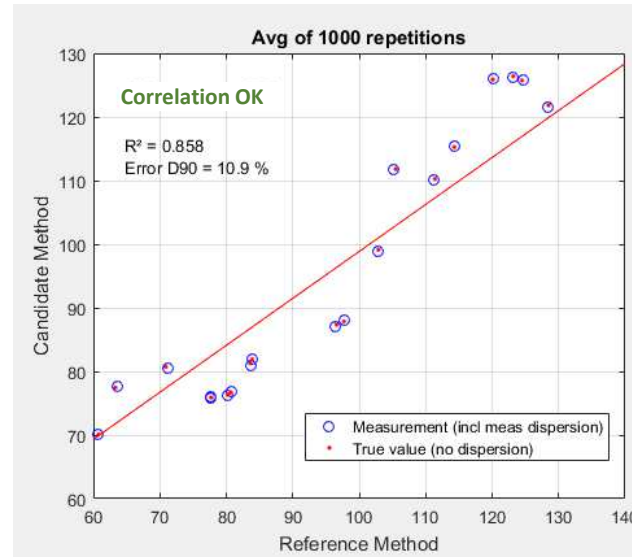
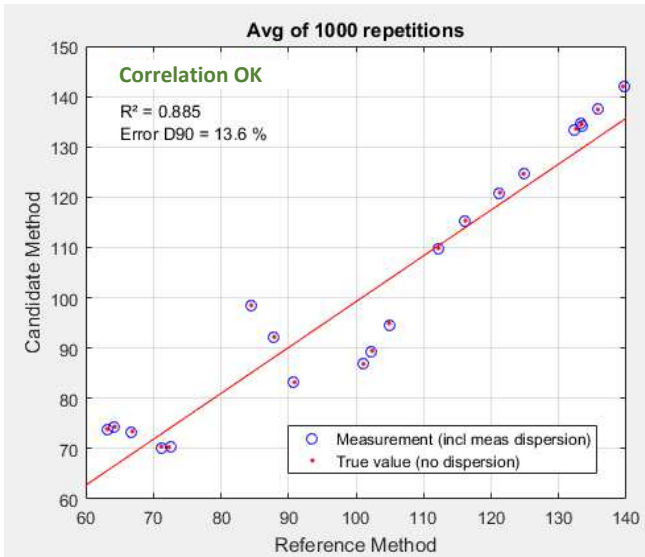
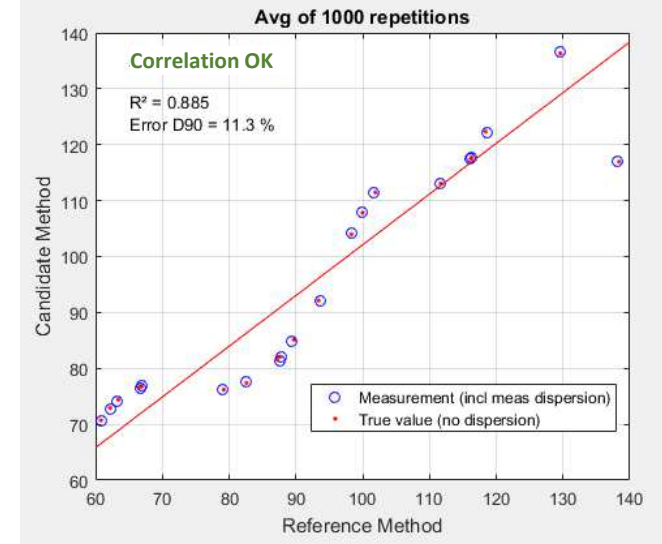
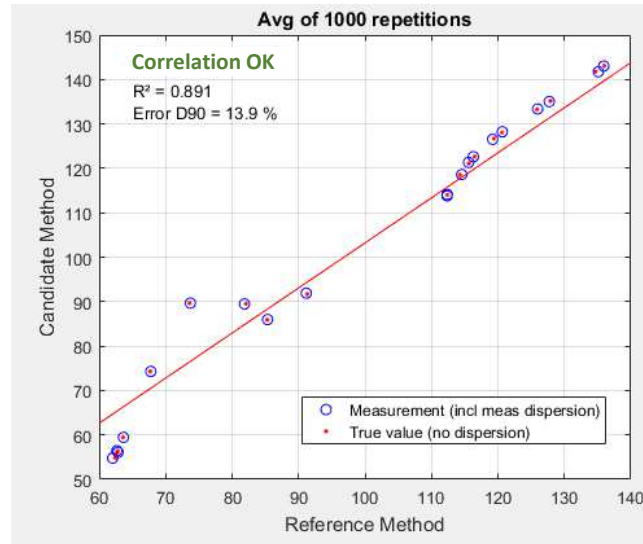
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Example of correlation

$$R^2 \geq 0.85$$
$$\text{Err } D90 \leq 15\%$$

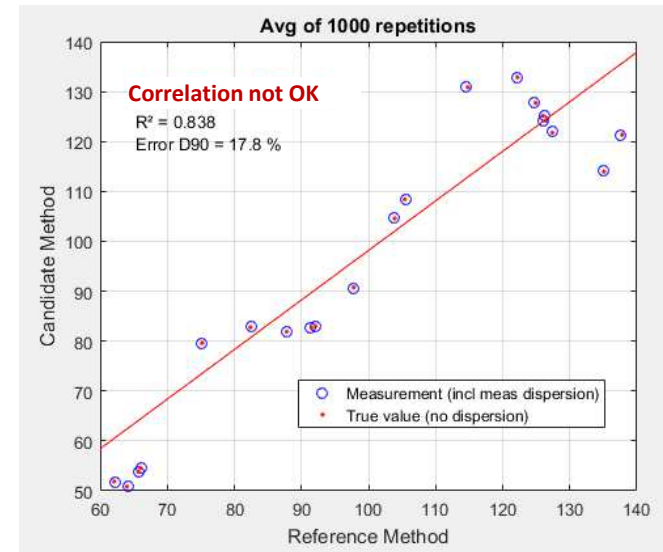
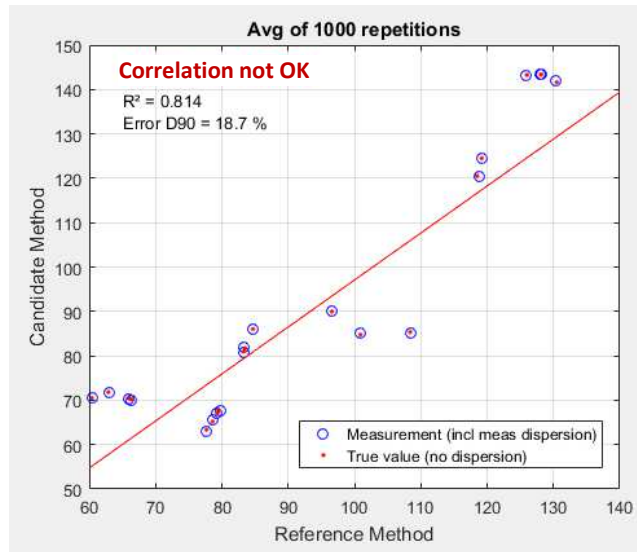
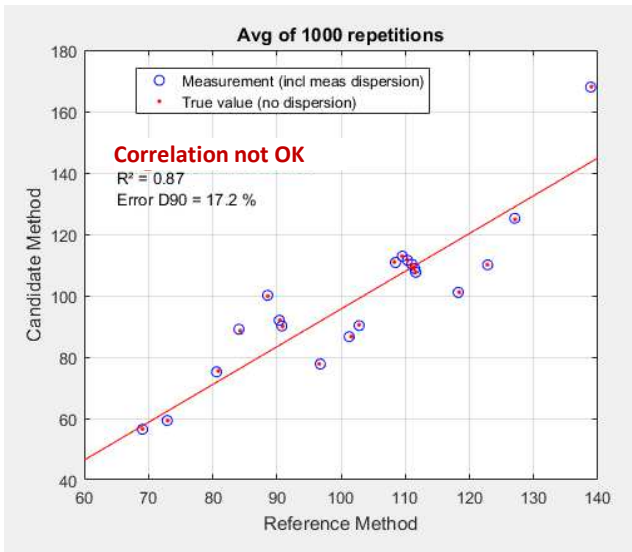
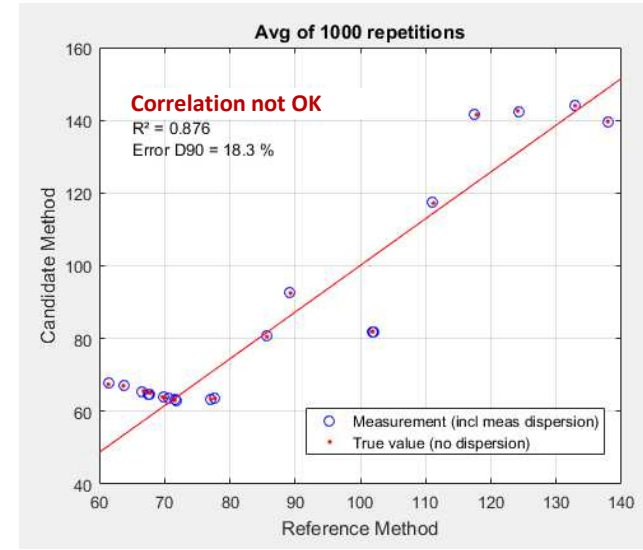
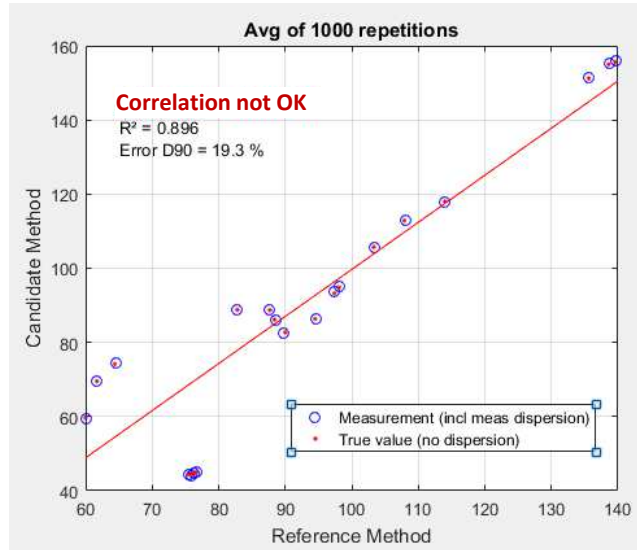
$R^2 \geq 0.85$ - $Err D90 \leq 15\%$

Example of correlated cases



$R^2 \geq 0.85$ - $Err D90 \leq 15\%$

Example of not correlated cases





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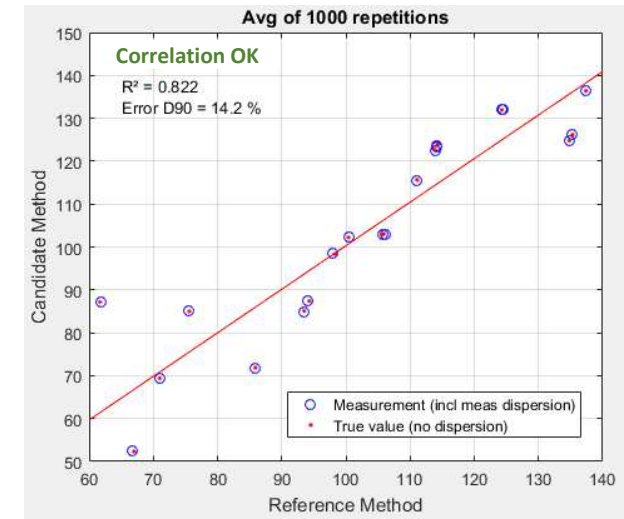
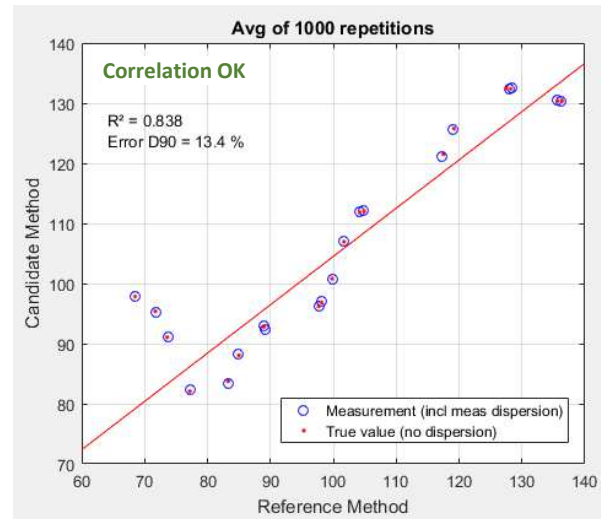
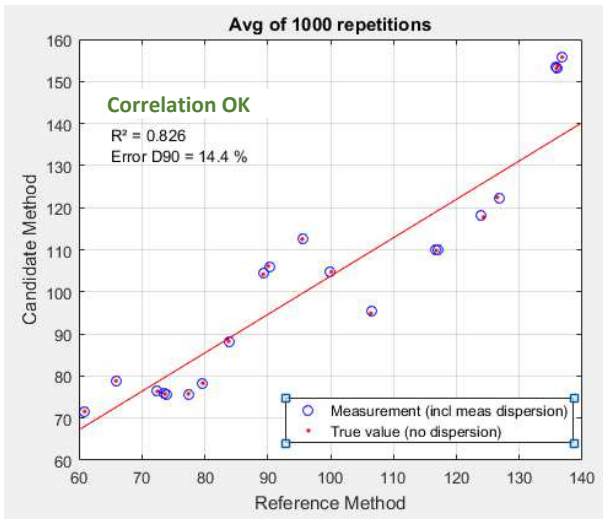
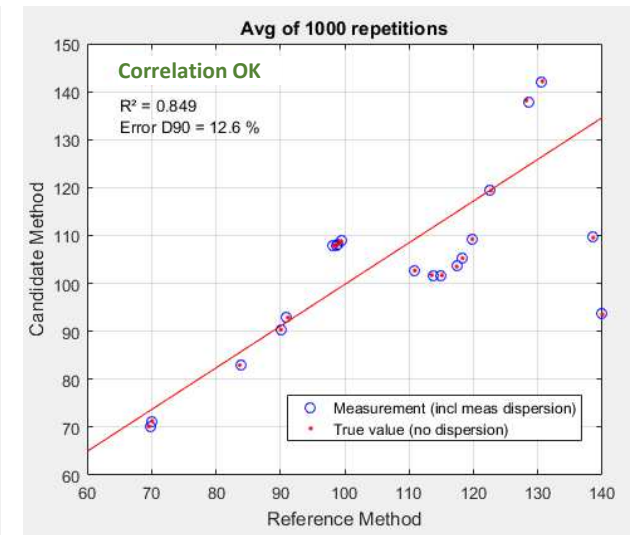
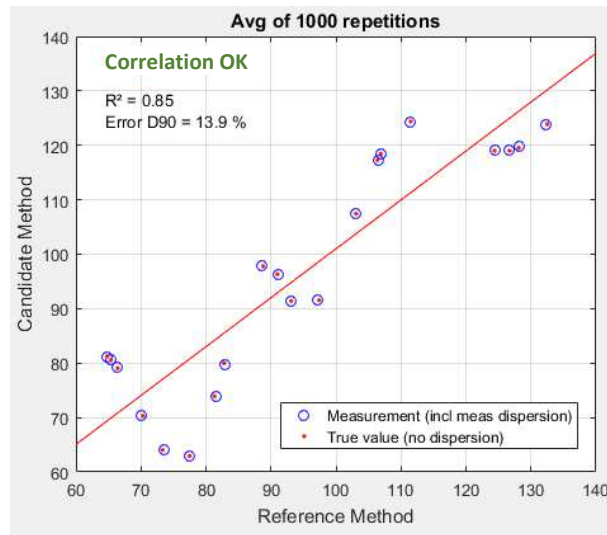
Example of correlation

$$R^2 \geq 0.80$$

$$\text{Err } D90 \leq 17.5\%$$

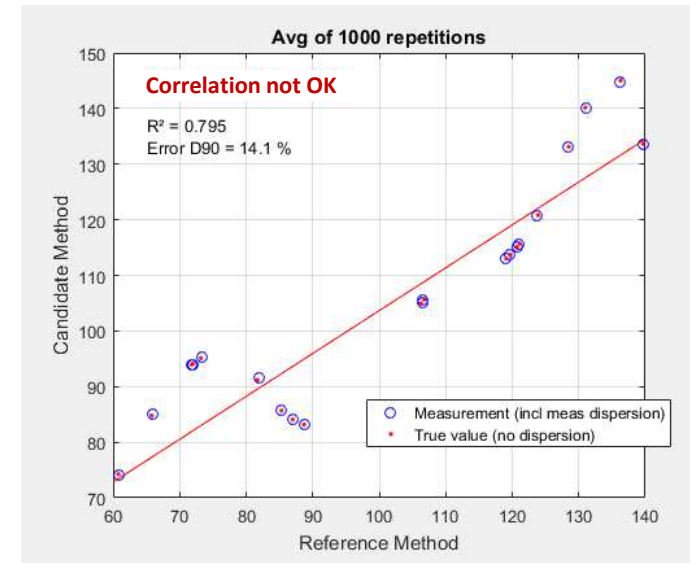
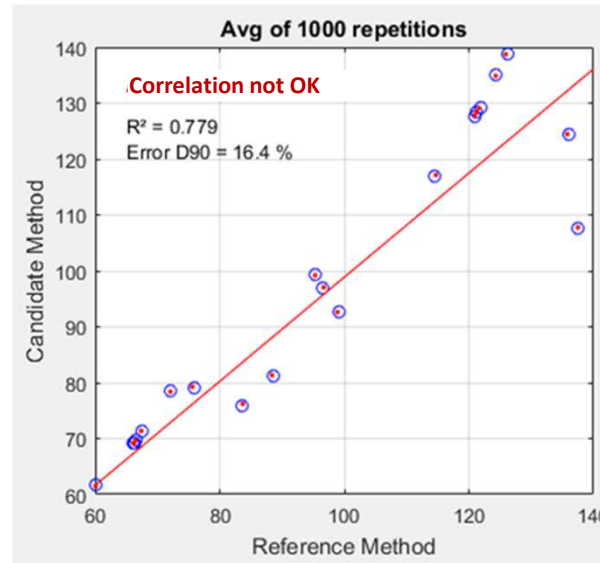
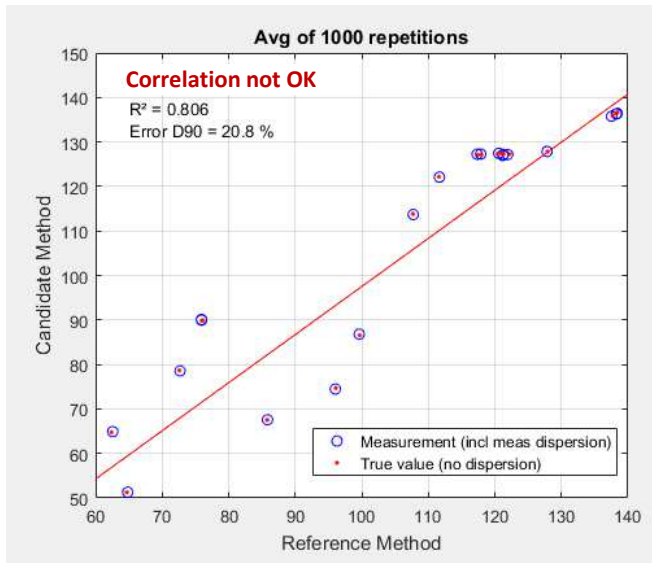
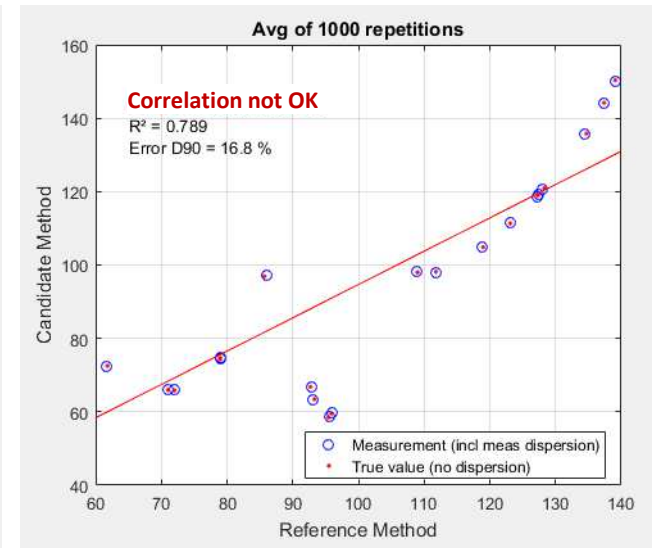
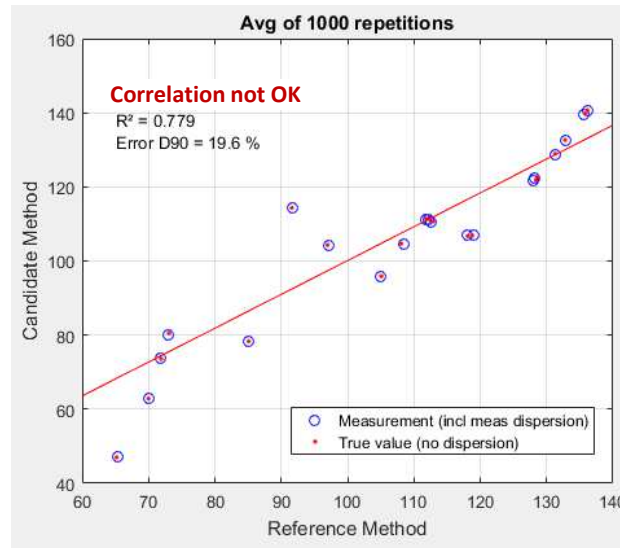
$R^2 > 0.8$ - Err D90 < 17.5%

Example of correlated cases



$R^2 > 0.8$ - Err D90 < 17.5%

Example of not correlated cases





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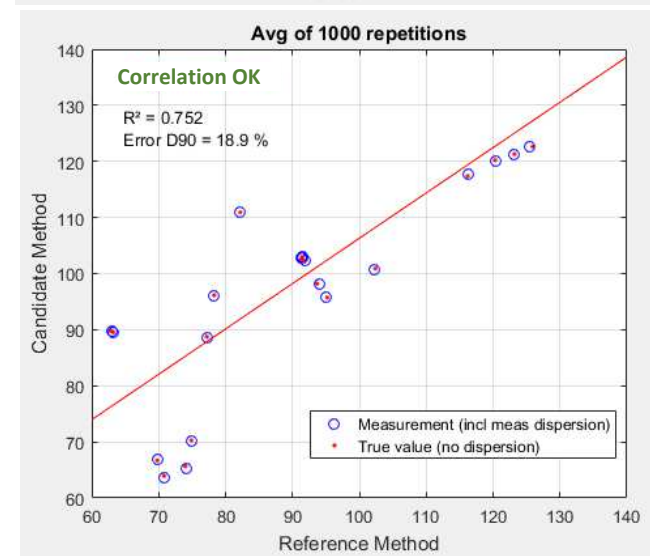
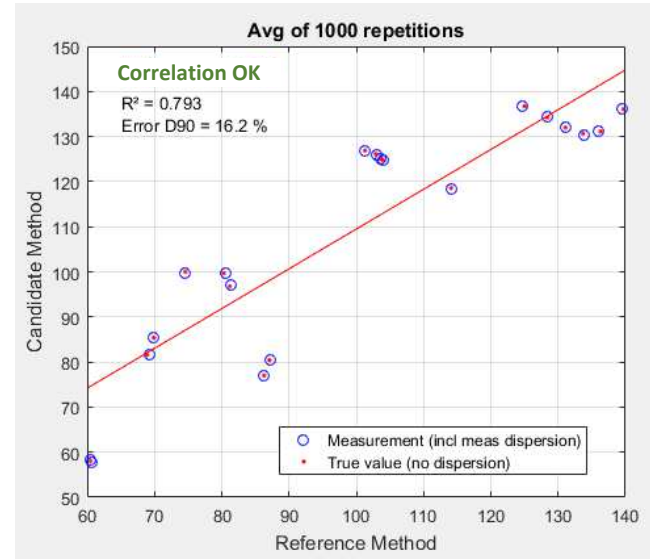
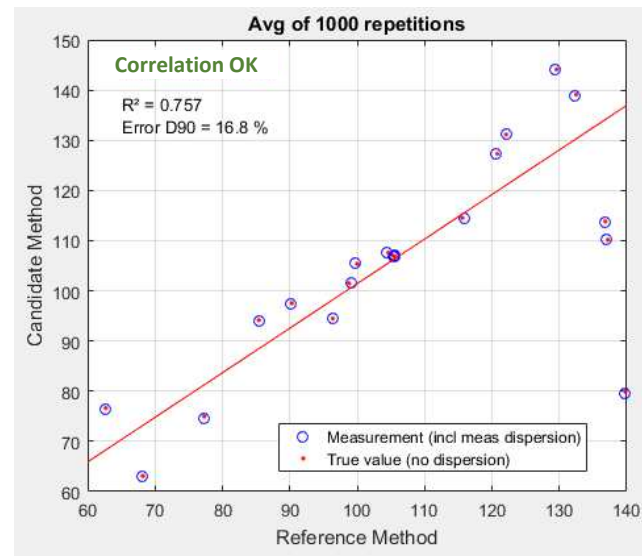
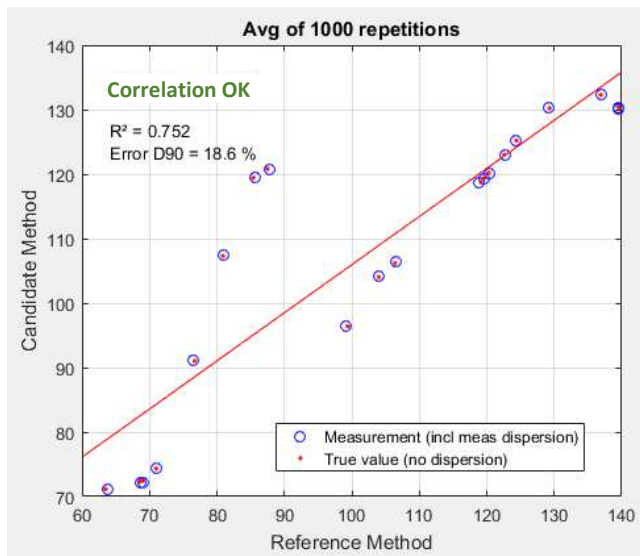
The European Tyre and Rim
Technical Organisation

Example of correlation

$$R^2 \geq 0.75$$
$$\text{Err } D90 \leq 20\%$$

$R^2 > 0.75$ - $Err D90 < 20\%$

Example of correlated cases



$R^2 > 0.75$ - $Err D90 < 20\%$

Example of not correlated cases

