Informal document No. **GRB-51-12**
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Agenda item 7)

Informal Joint Working Group of GRB and GRRF – 16/17 Nov 2009

Comments of ISO/TC31/WG6 on informal document GRB-50-7.

Scope

- This presentation deals with part D of informal document GRB-50-7.
- Part D is related to draft amendment to R117 Annex 6, test procedure for measuring rolling resistance. It proposes the addition of the following sentence to Paragraph 1, Note 2: *"The measurement of distance-time function and using in data processing second derivation of this function is preferable".*
- A justification is proposed with two main arguments, one on the existing measurement methods and one on the proposed new measurement method.
- This presentation proposes answers to both these arguments.

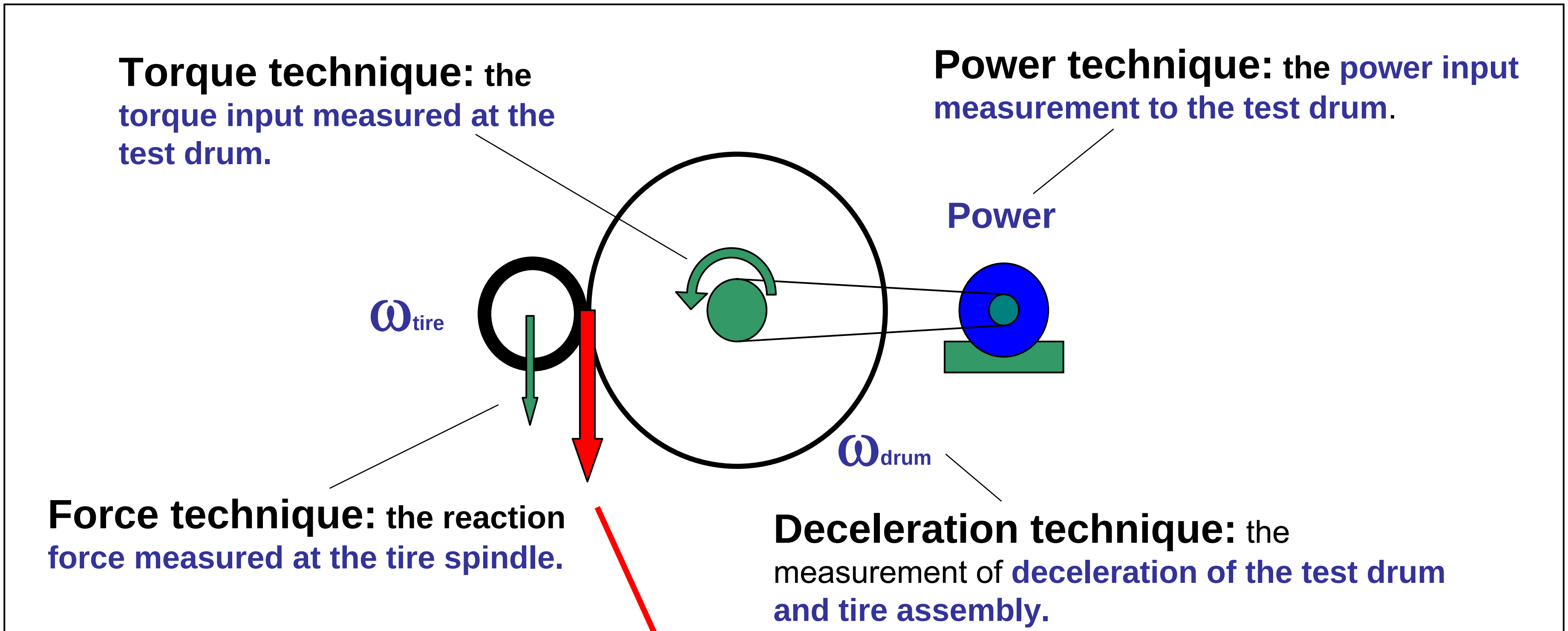
First argument.

"It is clear that the methods set in Regulation No.117 are not equivalent, so it is not indifferent, which method reference machine uses."

- The method set in Regulation 117 was directly derived from the standard ISO 28580.
- The aim of this standard is to measure the force acting at the tyre/drum interface.
- As this force cannot be measured directly, four measurement techniques are allowed to determine it in ISO 28580:
  1. Measurement of the reaction force at the tyre spindle.
  2. Measurement of the torque input at the test drum.
  3. Measurement of deceleration of the test drum and tyre assembly.
  4. Measurement of the power input to the test drum.

First argument - Rolling Resistance measurement techniques

<u>**The same phenomenon is measured, at different points of the testing machine.**</u>



For each technique, the test results are converted to <u>the force acting at the tire/drum interface</u>, which is the tyre rolling resistance.

First argument.

- The results of these measurements are then interpreted to determine the force acting at the tyre/drum interface.
- The measurements and interpretations are all based on valid physical principles.
- From ISO/TC31/WG6 experts' experience and comparisons, these four ways of determining tyre rolling resistance are equally valid.
- Finally, no public document known to the experts of ISO/TC31/WG6 demonstrates the contrary.
- **Conclusion: The experts of ISO/TC31/WG6 on tyre rolling resistance do not share the opinion that the methods set in Regulation No.117 are not equivalent.**

First argument.

Remark: From ISO/TC31/WG6 experts' experience and measurements, what is important to get a good measurement accuracy is not the choice of the measurement technique, but:

- A good machine monitoring and maintenance.
- A good way of operating it and a good quality system.
- An alignment procedure between measurement machines if direct comparisons of absolute values are needed.

Second argument. Description of the proposed method.

"This new method **(proposed in the document)** *may expand the ability to choose a standard effective method for tyre rolling resistance determination."*

- This method, as described in ISO DIS 18164 Amdt 1 uses a deceleration measurement technique.
- Its specificities lie in:
  - A very low sampling rate (1 time measurement per drum or tyre revolution, versus several thousands in usual deceleration technique).
  - Very large evolution of speeds to compensate the low sampling rate and corresponding acquisition duration (90 to 70 km/h deceleration).
  - A specific semi-analytic data interpretation method.
  - The fact it may be applied to tyre testing drum machines not specifically designed to measure rolling resistance.

Second argument. Description of the proposed method.

- The specific data interpretation method is not based on classic numerical second derivation of distance-time measurement results but on the assumption of a force-speed relation model:

$$\boxed{F = P + QU^2}$$

P, Q are coefficients

U is the circumferential velocity of rotating body

Second argument. Description of the proposed method.

- Combined with the application of the law of mechanics, this model leads to an implicit system of two equations to be solved:

$$\begin{cases} \cos^2 B(t_\Sigma - t_1) = \cos Bt_\Sigma \cos B(t_\Sigma - t_2) \\ \cos^2 B(t_\Sigma - t_3) = \cos B(t_\Sigma - t_2)\cos B(t_\Sigma - t_4) \end{cases}$$

t_Σ is the total deceleration time (the time from the beginning of first revolution to the zero speed);
B is the parameter determined by: $B = \frac{r^2}{I}\sqrt{PQ}$

$t_1 - t_4$ are time values corresponding to 4 segments of records.

Second argument. Description of the proposed method.

- Finally, P and Q are computed from the following equations:

$$\boxed{P = \frac{2p\, z_4 I\, B^2 \cos B t_S}{r \cos B (t_S - t_4)}} \qquad \boxed{Q = \frac{I^2\, B^2}{r^4 P}}$$

I is the inertia of rotating mass

r is the radius of the rotating body

z_4 is the number of revolutions at the end of record

t_S and p are not defined; we assumed they stand respectively for t_Σ and Π.

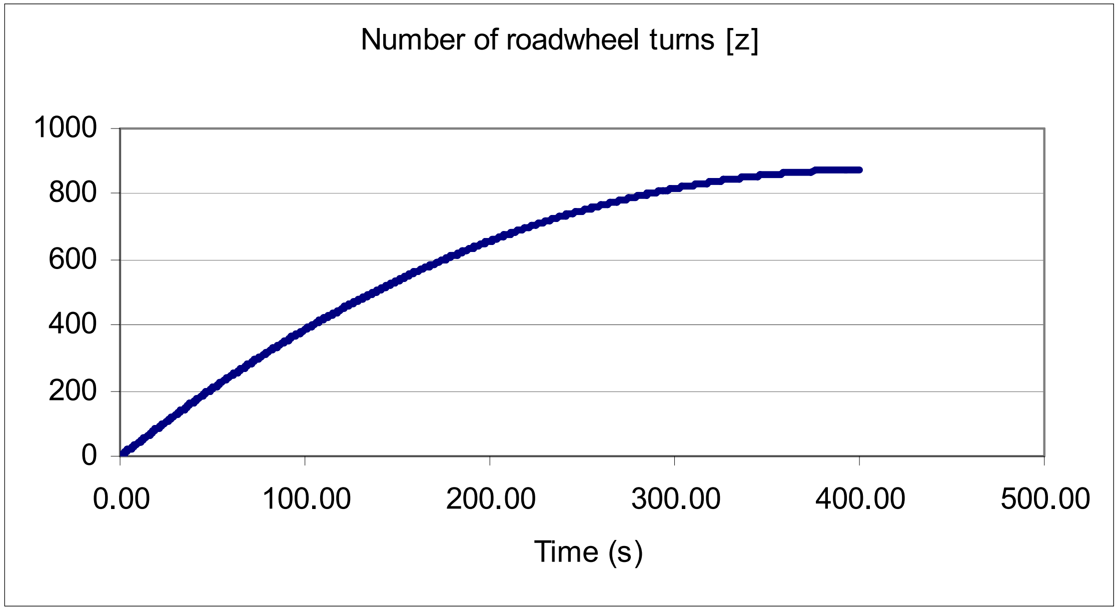
Second argument. Experimental evaluation of the proposed method.

- This method was evaluated through real measurements and tentative resolution of the implicit system of equations.
- Several measurement were made on 2 different machines (one designed for rolling resistance measurement and an other one) with the same physical tyre:

Michelin 195/65R15 Energy 3A 91T

Second argument. Experimental evaluation of the proposed method.

- An example of deceleration obtained is shown below (tyre applied on the drum):



This measurement was done until t_{Σ}, total deceleration time, to check the result obtained.

Second argument. Experimental evaluation of the proposed method.

- Deceleration was made from 84.3 km/h to zero speed.
  Data interpretation was made between 80 and 60 km/h.
  Experimental value for t_{Σ} was 377 s (from 80 km/h)
- The segments of record were:

z4	345	t4	94.50
z3	259	t3	67.94
z2	173	t2	43.66
z1	86	t1	20.94

Second argument. Experimental evaluation of the proposed method.

Since no specification is given on the way to solve the implicit system of two equations

$$\begin{cases} \cos^2 B(t_\Sigma - t_1) = \cos Bt_\Sigma \cos B(t_\Sigma - t_2) \\ \cos^2 B(t_\Sigma - t_3) = \cos B(t_\Sigma - t_2)\cos B(t_\Sigma - t_4) \end{cases}$$

it was assumed it has to be done numerically the commonly accessible tool Microsoft Excel solver was used.

As cosine is a periodic function, multiple solutions exist.

For instance these 3 sets for t_Σ and B :

There is no indication in the method for the choice.

T_Σ	374.80
B	2.06
T_Σ	449.87
B	1.00
T_Σ	299.30
B	2.01

Second argument. Experimental evaluation of the proposed method.

Data interpretation was continued to compute the resistance force (in N).
The following values were obtained for the 3 preceding solutions to the system at 70 km/h (19.44 m/s) :

T_{Σ}	B	F
374.80	2.06	4.76E+06
449.87	1.00	8.99E+05
299.30	2.01	5.61E+06

These values are very different and none of them has the correct order of magnitude (about 40 N).

Second argument. Experimental evaluation of the proposed method.

A second attempt was done, using the equations published in SAE report 2009-01-0072, for the same speed of 70 km/h (19.44 m/s) :

T_{Σ}	B	F
374.80	2.06	9.85E+02
449.87	1.00	1.86E+02
299.30	2.01	1.16E+03

These values are not the same as the previous ones. They are still very different and none of them has the correct order of magnitude (about 40 N for F).

Second argument. Experimental evaluation of the proposed method.

- An attempt was carried out to determine tyre rolling resistance from the measured data through a classic numerical resolution method (second derivation of distance-time measurement results), adapted to the very low sampling rate used here.
- The whole deceleration curve was used to get the best possible accuracy and the rolling resistance coefficient was computed for a speed of 80 km/h.
- Machine A is the one specifically designed for rolling resistance measurement and B is the other one.
- 10 measurements were made, 4 on machine A et 6 on machine B.

Second argument. Experimental evaluation of the proposed method.

- The results are as follows (forces expressed in N):

Machine	Test n°	Force tyre+drum	Parasitic loss tyre spindle	Parasitic loss drum	Tyre RR Force	Cr 80 km/h (N/kN)
A	1	48.76	1.32	5.98	41.47	8.58
A	2	49.54	1.32	5.98	42.25	8.75
A	3	50.85	1.32	5.98	43.55	9.02
A	4	45.73	1.34	5.98	38.41	7.95
B	1	94.96	2.96	48.55	43.45	9.00
B	2	93.83	3.01	48.00	42.82	8.87
B	3	92.89	2.88	47.40	42.61	8.82
B	4	92.69	3.02	47.66	42.01	8.70
B	5	92.71	3.01	47.49	42.21	8.74
B	6	92.50	2.88	47.34	42.28	8.75

Second argument. Experimental evaluation of the proposed method.

- These results were statistically analysed (in N/kN):

Mach / Test	Cr	Cr 2m	Average	Std Dev
A 1	8.58	8.41	8.40	0.4429
A 2	8.75	8.57		
A 3	9.02	8.84		
A 4	7.95	7.79		
B 1	9.00	8.73	8.55	0.1054
B 2	8.87	8.60		
B 3	8.82	8.56		
B 4	8.70	8.44		
B 5	8.74	8.48		
B 6	8.75	8.50		

As a reference, the value measured on machine A with the usual deceleration method is 7.88 N/kN and the average standard deviation is 0.05 N/kN.

Second argument. Experimental evaluation of the proposed method.

- Conclusion:
  After having tried to apply the proposed new method, the experts from ISO/TC31/WG6 on tyre rolling resistance measurement found that:
  - Multiple and non realistic values for tyre rolling resistance were obtained with the proposed data interpretation process and commonly accessible resolution tools.
  - The use of the proposed very low sampling rate (1 time measurement per drum or tyre revolution) lead to an important decrease of measurement accuracy (between 2 and 8 times).

They recommend that the proposals made in Informal Document GRB-50-07 part D are not adopted in UN/ECE R117.