Transmitted by the experts from France and Russian Federation

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(France)

(Russian Federation)

Method of Deceleration Measuring and Data Processing for Tyre Rolling Resistance Determination. Testing and Evaluation of the Variant Method Using the dω/dt Form

The report of the ad-hoc working group organized in accordance with the recommendation of the 58th GRB session (ECE/TRANS/WP.29/GRB/56, para. 15)

19-21 November 2013

Contents

Introduction

The ad-hoc working group consisting of the experts from UTAC (France) and NAMI (the Russian Federation) in presence of the experts from ETRTO considered and experimented the Russian experts' proposal presented in the documents ECE/TRANS/WP.29/GRB/2013/10 and GRB-58-12 concerning introduction of the method of deceleration measuring and data processing for tyre rolling resistance determination using the dω/dt form ("Deceleration Calculator" tool). The said documents further specify the new principle of measurement variant method using the dω/dt form and data processing of tyre rolling resistance, already approved by WP.29 and which is included in UN Regulation No. 117, Annex 6.

The ad-hoc meeting of experts in UTAC was proposed by the representative from France and endorsed by the 58th GRB session (Annex 1). The meeting participants are listed in the Annex 2.

The work of the ad-hoc group included the following:

1. Evaluation of the theoretical justification of the method used in the variant method using the dω/dt form , its algorithm of data processing and particularly method of solving equation system, as well as statistical assessment of the method;

2. Experimental assessment of the method on one example of rolling resistance determination of the class C1 tyre on specialized test machine MTS and on test machine not specially designated for these measurements;

3. Consideration experimental data, obtained on tyres by NAMI prior to this measuring campaign on class C2 and C3 tyres in 2013 by this method.

I. Analysis and refinement in the view of modifying the proposed document ECE/TRANS/WP.29/GRB/2013/10

This section of the report contains theoretical justification of the modifying the recent proposal by the Russian Federation presented in document ECE/TRANS/WP.29/GRB/2013/10.

The following modifications had been made:

(a) Test speed range such as: 82-78 (62-58) km/h;

(b) Introduction of note 1 in paragraph 1 with its explanation in the justification part;

(c) Detailed presentation and description of data processing algorithm;

(d) Improved finding of the constants A, B, T_{Σ} ;

(e) Refined formula of deceleration;

(f) Input fields of initial data added to the main window of the “Deceleration Calculator tool”.

1. The proposed principle and its application in the computer program “Deceleration Calculator” is based on the exact relationship:

$$j = \frac{d\omega}{dt} = \frac{d^2z}{dt^2},$$

where:

ω is angular speed in revolutions per second (s^{-1});

t is time in seconds;

z is a number of body revolution during deceleration.

2. Numerous experiments show that the formula in paragraph 2.3 of proposed UN Regulation No. 117 Annex 6 - Appendix 4 is very effective for experimental data approximating:

$$z(t)=A\ln\frac{\cos B(T_{\Sigma}-t)}{\cos BT_{\Sigma}}$$

This formula of constrain between current time t and current angular distance z is the result of transformation of the dependence between residual distance S and time [1], [2] (in common case T = T_{Σ} - t):

$$S = A_m\ln\frac{1}{\cos BT}$$

Residual time T relates to the total deceleration time T_Σ by formula

$$T = T_\Sigma - t \text{ (in local case } T = T_\Sigma \text{ , } S = S_\Sigma \text{).}$$

The second derivative of the function described by formula from paragraph 2.3 of Annex 6 - Appendix 4 is deceleration j in revolution per second squared or s^{-2}:

$$j = \frac{d^2z}{dt^2} = \frac{AB^2}{\cos^2 B(T_\Sigma - t)}$$

3. There is no simplification or assumption between those formulae and the formula of z in paragraph 2. because correspondent transformation is performed according to the rules of differential calculus of. Thus with this method there is no need to measure and calculate speed.

4. An algorithm of determining of parameters A, B, T_Σ includes the following steps:

4.1. The measuring time of each revolution of rotating body which gives experimental dependency shown on figure 1:

$$z = f(t_z)$$

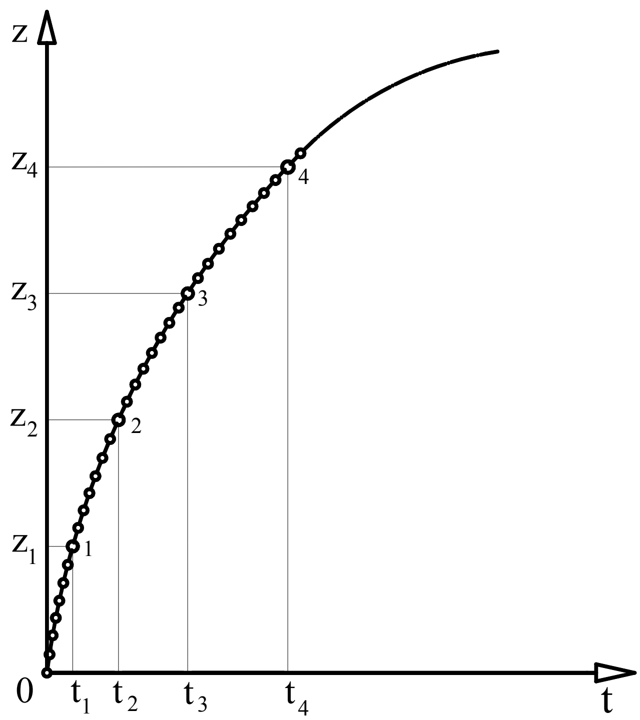


Figure 1

4.2. Finding the value nearest to the maximum z equals n, dividable by 4, dividing it on 4 equal parts and recording the coordinates of 4 points on the experimental curve (see figure 1).

4.3. Working out the equation system on the base of formula from paragraph 2. with substitution of 4 point coordinates as shown on figure 1:

$$\left.\begin{array}{l} z_1 = A\ln\dfrac{\cos B(T_\Sigma - t_1)}{\cos BT_\Sigma} \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ z_4 = A\ln\dfrac{\cos B(T_\Sigma - t_4)}{\cos BT_\Sigma} \end{array}\right\}$$

4.4. Pairwise transformations of the set of equations from paragraph 4.3 above give a set of two equations:

$$\left.\begin{array}{l} \cos^2 B(T_\Sigma - t_1) = \cos BT_\Sigma \cos B(T_\Sigma - t_2) \\ \cos^2 B(T_\Sigma - t_3) = \cos B(T_\Sigma - t_2)\cos B(T_\Sigma - t_4) \end{array}\right\}$$

Parameters B and T_Σ are received from this set by iteration process. Then parameter A may be obtained from the fourth equation from set of 4 equations above, multiplied by 2π:

$$A = \frac{2\pi z_4}{\ln\dfrac{\cos B(T_\Sigma - t_4)}{\cos BT_\Sigma}}$$

Thus the formulae $z = f(t_z)$ and $j = d^2z/dt^2$ become with determined parameters and become ready for subsequent application. The first derivative of the function $z = f(t)$ from paragraph 2. above is the angular speed ω in revolutions per second (s^{-1}):

$$\omega = \frac{dz(t)}{dt} = AB\,\mathrm{tg}B(T_\Sigma - t)$$

One can see from this that:

$$\mathrm{tg}B(T_\Sigma - t) = \frac{\omega}{AB}$$

The next formula follows from geometry and previous relation:

$$\cos^2 B(T_\Sigma - t) = \frac{1}{1 + tg^2 B(T_\Sigma - t)} = \frac{1}{1 + (\omega/AB)^2}$$

Substitution of this equality into formula j in clause 2

yields: $$j = AB^2 + \frac{\omega^2}{A}$$

This relationship is the main formula for the "Deceleration Calculator".

5. Estimation of approximation quality of measured data and its accuracy is executed by the following parameters:

5.1. The standard deviation in percent:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{1}^{n}[1-\frac{z(t)}{z}]^2} \times 100\%$$

5.2. The coefficient of determination:

$$R^2 = 1 - \frac{\sum_{1}^{n}[z - z(t)]^2}{\sum_{1}^{n}[z - \overline{z}]^2},$$

where

$$\overline{z} = \frac{1}{n}\sum_{z=1}^{n} z \frac{1}{n}\left(1+2+...+n\right) = \frac{1+n}{2}$$

The proposed derivative mathematical method approach associated to the used deceleration calculator provides for the approximation an evaluated estimate R^2 close to 1 and a standard deviation $\sigma < 0.03\%$.

II. Theoretical analysis and statistical assessment of the method (UTAC)

Starting with the following equation: $z_m = \frac{A}{2\pi}\ln\frac{\cos B(T_\Sigma - t_m)}{\cos BT_\Sigma}$, corresponding to the chosen function to approximate the measurement results we fit the function $Zm = \frac{A}{2\pi}\ln\frac{\cos B(T_\Sigma - t_m)}{\cos BT_\Sigma} = f(A, B, T_\Sigma, t_m)$.

The experimental data are $(t_{m,} z_m)$ and A, B, T_Σ are the parameters that have to be estimated.

1. Notation:

$\beta = (A, B, T_\Sigma)$ is the unknown parameter vector and belongs to R^3;

$\widehat{\beta} = (\hat{A}, \hat{B}, \hat{T}_\Sigma)$ is the least-squares estimate;

n=: number of data; so $1 \le m \le n$;

$r(\beta) = \begin{pmatrix} z_1 - f(\beta, t_1) \\ z_m - f(\beta, t_m) \\ z_n - f(\beta, t_n) \end{pmatrix}$ is the (n,1) residual vector , evaluated at the current values β

$r(\beta)' = \left(z_1 - f(\beta, t_1) \quad z_m - f(\beta, t_m) \quad z_n - f(\beta, t_n)\right)$ is the (1,n) transpose residual vector;

$X = \frac{\partial f(\beta, t)}{\partial \beta}$: (n,3) matrix of the first partial derivative of the function f;

X' transpose matrix of the matrix X ;

X^- generalized inverse of the X matrix.

2. Nonlinear regression model

The general nonlinear regression model fit with the procedure is represented by the equation:

$z_m = f(A, B, T_\Sigma, t_m) + \varepsilon_m$,

when the model is written for the m -th observation.

For any given value β we can compute the residual sum of square

$$SSE(\beta)=\sum_{m=1}^{n}(z_m-f(\beta,t_m))^2=\sum_{m=1}^{n}(z_m-f(A,B,T_\Sigma,t_m))^2=r(\beta)^{'}r(\beta)$$

3. Nonlinear least squares method

The aim of nonlinear least-squares is to find the value $\hat{\beta}=\left(\hat{A},\hat{B},\hat{T}_\Sigma\right)$ that minimizes $SSE(\beta)$. Because f is a nonlinear function of β, a closed-form solution does not exist for this minimization problem. An iterative process is used instead.

If $\hat{\beta}^{(u)}$ denotes the value of the parameter estimates at the u -th iteration, and $\hat{\beta}^{(0)}$ denotes the starting value the iterative process attempts to find at the u+1 –th iteration a new value $\hat{\beta}^{(u+1)}$ such:

$$SSE(\hat{\beta}^{(u+1)})<SSE(\hat{\beta}^{(u)})$$

4. Looking for the minimum with the Gauss Newton method

To numerically find the minimum of $SSE(\beta)=r(\beta)^{'}r(\beta)$ we have to approximate the model and to substitute the approximation into $SSE(\beta)$.

The first order Taylor series of the residual $r(\beta)$ at the point $\hat{\beta}$ is

$$r(\beta)\approx r(\hat{\beta})-\hat{X}(\beta-\hat{\beta})$$

And by substitution we get

$$SSE(\beta)\approx S_{GN}(\beta)=(r(\hat{\beta})-\hat{X}(\beta-\hat{\beta}))^{'}(r(\hat{\beta})-\hat{X}(\beta-\hat{\beta}))$$

$$=(r(\hat{\beta})^{'}-(\beta-\hat{\beta})^{'}\hat{X}^{'})(r(\hat{\beta})-\hat{X}(\beta-\hat{\beta}))$$

$$=r(\hat{\beta})^{'}r(\hat{\beta})-2r(\hat{\beta})'\hat{X}(\beta-\hat{\beta})+(\beta-\hat{\beta})^{'}\hat{X}^{'}\hat{X}(\beta-\hat{\beta})$$

$S_{GN}(\beta)$ is a quadratic function in β and is easily minimized. The minimum occurs when:

$$\beta-\hat{\beta}=\left(\hat{X}'\hat{X}\right)^{-}\hat{X}'r(\hat{\beta})$$

5. Quality of the adjustment

In nonlinear regression, such a measure like R^2 coefficient of determination is not easily defined. A measure, relatively closely corresponding to R^2 in this case is Pseudo $R^2=1-\dfrac{SSE(\beta)}{\sum_{m=1}^{m=n}z_m^2}$

Closer is R^2 to the value 1 better is the fitting of the model.

6. Examples

Data set obtained with the UTAC machine	j using the NAMI calculator, first release	j using the NAMI calculator second release	j using the non linear regression model (UTAC)
14-34-13Tyre 205-55-R16, drum R=1,0000m, V=80 km/h, p=0,21MPa, Lm=482,6daN on Machine UTAC-MTS, Vst=82	**0,046627**	**0,046002**	**0,046639**
15-02-29Tyre 205-55-R16, drum R=1,0000m, V=80 km/h, p=0,21MPa, Lm=482,6daN on Machine UTAC-MTS, Vst=82, j=0,046932±0,000131	**0,047516**	**0,046932**	**0,047513**
15-28-33Tyre 205-55-R16, drum R=1,0000m, V=80 km/h, p=0,21MPa, Lm=482,6daN on Machine UTAC-MTS, Vst=82	**0,047589**	**0,046961**	**0,047575**
15-55-14Tyre 205-55-R16, drum R=1,0000m, V=80 km/h, p=0,21MPa, Lm=482,6daN on Machine UTAC-MTS, Vst=82	**0,047552**	**0,046940**	**0,047536**

Calculations for fitting the nonlinear model have been performed by UTAC with the software SAS. However it is possible to do that with any software which allows performing nonlinear regression.

III. Experimental assessment of the method. Consideration of the presented experimental data

NAMI had placed to the ad-hoc working group disposal the measurement kit for determination of deceleration by using exact dω/dt form comprehending:

1. The data logger NAMI-357 (figure 2) with embedded program and the following parameters:

(1) Voltage supply: 8-16 V DC;

(2) Current consumption: not more 300 mA;

(3) The number of measuring channels:

a. Temperature: 3;
b. Impulse sensors: 2;

(4) The measurement range:

a. Temperature: -10 – 80 ºC;
b. Time: 0,01 – 4000 s;

(5) Precision

a. Temperature: ± 0,1ºC;
b. Time: ± 0,01%;

(6) Calibration regime: yes;

(7) Volume of memory for one test: not less 20000 records;

(8) Normal temperature operating condition: 0 - 85ºC;

(9) Transmission range:

a. Indoors: up to 300 m;
b. Outdoors at sight-of-light: up to 1000 m;

2. Two contactless sensors of revolutions (figures 3 and 4) with the following parameters:

Actual distance: 0,01~4,4 m;

Light Source: Red LED;

Spot size: Ø220 mm at 4.4 m;

Supply voltage: DC10~30 V including ripple (P-P) 10%,

Response time: 500 µs max;

Ambient temperature / humidity : -25~+50 ^{0}C / 35~85% RH;

3. Data processing computer program "Deceleration calculator";

4. Additionally, NAMI experts used computer program for tyre rolling resistance determination workable with the equipment described in items 1 and 2 above.

UTAC had placed to the ad-hoc working group disposal two tyre test machines for measurements:

1. UTAC MTS test bench with drum diameter 2.0 m specially designed for rolling resistance measurements (see figures 2 and 3);

2. UTAC HAWITEC test bench with drum diameter 1.7 m designed for the "load-speed tyre".

The installation of the NAMI measurement equipment on UTAC tyre test machines is shown on figures 2, 3, 4 and 5.

Testing of the variant deceleration method using the dω/dt form ("Deceleration Calculator") was executed in parallel measurements of decelerations by the use of the logger NAMI-357 and by regular equipment of UTAC test machines.

The test object on test machines UTAC was one tyre of class C1 205/55R16.

The testing program was in compliance with UN Regulation No. 117 - Annex 6, except for the interval period between the tests performed (number 2, 3, 4). The interval period was 5 minutes with control of pressure between each test at 210 kPa and in addition a skim test was performed for the measurement of tyre spindle parasitic losses on the HAWITEC machine. This force was approximately 500 N.

The test results are presented below.

Table 1 contains the test results of starting series deceleration j measurements obtained by the use of NAMI system installed on UTAC MTS machine.

Table 2 contains comparison of that data with the similar obtained using UTAC MTS system.

Table 3 presents the results of UTAC testing the same tyre in the form of the rolling resistance coefficient C_r. In this connection the special NAMI program, which gives C_r data has been included and data comparison was performed.

The listings of UTAC results which illustrate its technology of decelerations and C_r data obtained are presented in Tables 4-7.

Table 8-a and b illustrate the test results of the tyre 205/55R16 obtained with the help of the UTAC HAWITEC machine installed with NAMI system. That machine is not equipped with the device for rolling resistance measurements. Therefore only NAMI data is presented in the Table 8-a and b. For this machine, the skim-load test was performed at the force application of 500 N.

The measurements of tyre parasitic losses in accordance with UN Regulation No.117- Annex 6 (by removing of tyre from drum) were not possible on this machine. The parasitic losses measurements of the drum with tyre removed show that NAMI system gave data scatter within only 1%.

The parasitic losses measurements by skim test show that the scatter was arisen up to 4.25%. This was caused by the influence not only of NAMI system, but also due to UTAC machine spindle. We need to recall here again that this machine is not dedicated to rolling resistance measurements.

Table 9 shows the results obtained by using the test machine UTAC-HAWITEC with the NAMI measurement system in the form of coefficient C_r. That data are compared with the test results obtained by test machine UTAC-MTS.

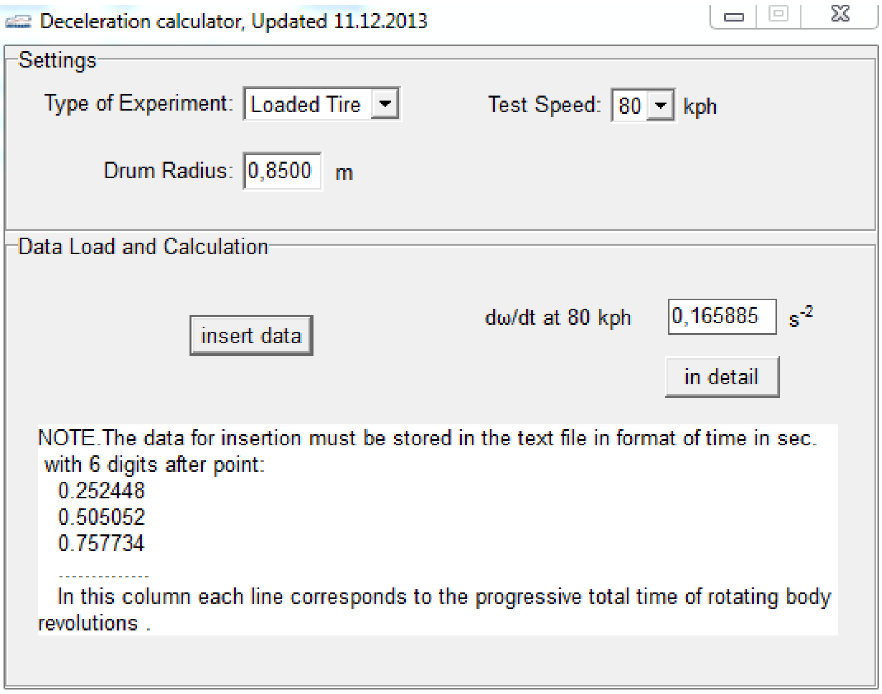
From these results one can see not stable character of C_r value. The cause of this instability needs special investigation. Discrepancy between NAMI-HAWITEC and UTAC MTS average values of C_r does not exceed 1%. However, it can be also that the variability of the results is important with HAWITEC-machine. Calculation of the standard deviation on the 3 measurements, gives approximately 0.5 N/kN. It would be interesting to repeat in future analogous mutual testing on the machine with more control.

Figure 2. Installation of NAMI-357 data logger on MTS test machine in UTAC.

Figure 3. NAMI-357 data logger and drum sensors "S" view on MTS test machine in UTAC.

Figure 4. Tyre sensor of NAMI-357 data logger.

Figure 5. View on HAWITEC test machine in UTAC
on which NAMI-357 data logger and drum sensors “S” were used


Deceleration calculator, Updated 11.12.2013
Settings
Type of Experiment: Loaded Tire
Test Speed: 80 kph
Drum Radius: 0,8500 m
Data Load and Calculation
insert data
dω/dt at 80 kph 0,165885 s-2
in detail
NOTE.The data for insertion must be stored in the text file in format of time in sec. with 6 digits after point:
0.252448
0.505052
0.757734
....
In this column each line corresponds to the progressive total time of rotating body revolutions .

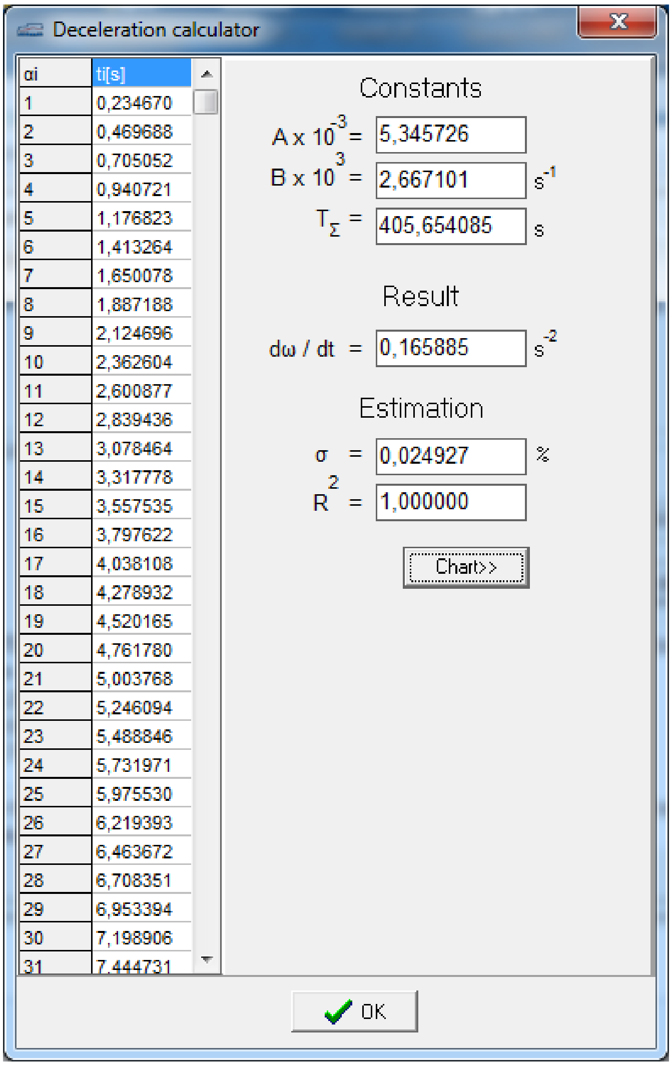
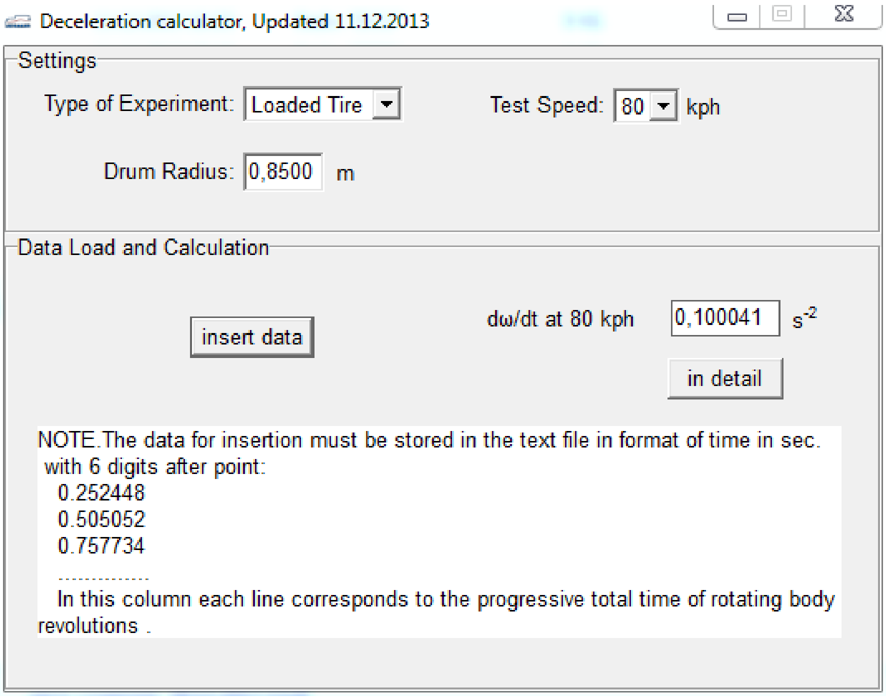

Deceleration calculator
αi ti[s]
1 0,234670
2 0,469688
3 0,705052
4 0,940721
5 1,176823
6 1,413264
7 1,650078
8 1,887188
9 2,124696
10 2,362604
11 2,600877
12 2,839436
13 3,078464
14 3,317778
15 3,557535
16 3,797622
17 4,038108
18 4,278932
19 4,520165
20 4,761780
21 5,003768
22 5,246094
23 5,488846
24 5,731971
25 5,975530
26 6,219393
27 6,463672
28 6,708351
29 6,953394
30 7,198906
31 7,444731
Constants
A x 10-3 = 5,345726
B x 103 = 2,667101 s-1
TΣ = 405,654085 s
Result
dω / dt = 0,165885 s-2
Estimation
σ = 0,024927 %
R2 = 1,000000
Chart>>
OK

Figure 6. Main windows of the “Deceleration Calculator” (see Table 8, line 1).



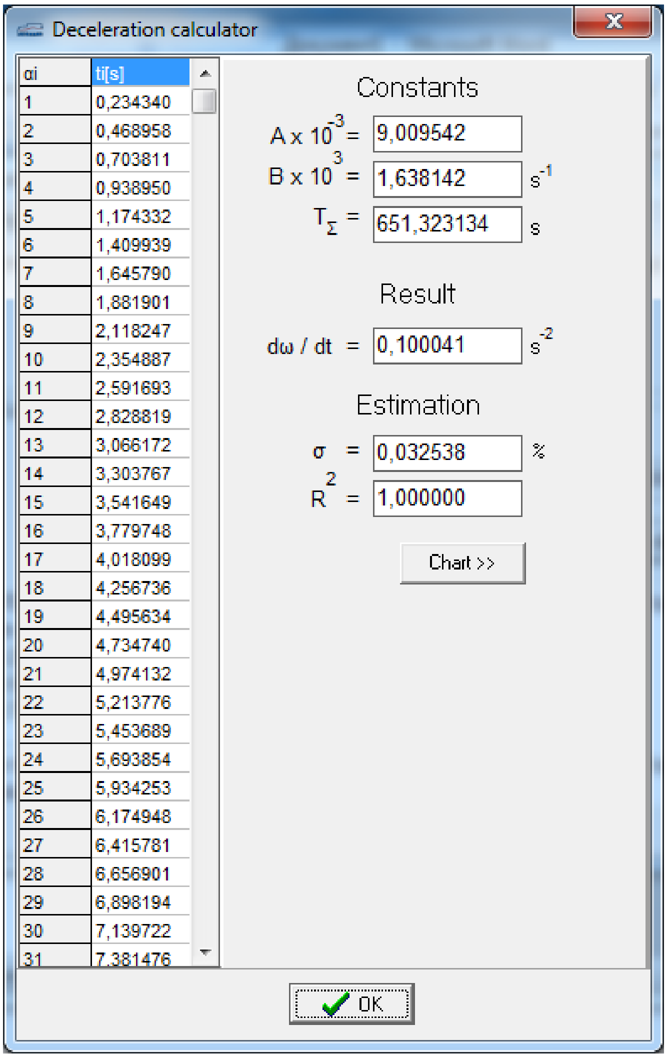


Figure 7. Main windows of the “Deceleration calculator” (see Table 8, line 2).

Table 1. Deceleration j at 80 km/h and different speed range

Test machine UTAC1, Tyre 205/55R16, p = 0,21 MPa, Lm = 482,6daN, R_T = 0,3045 m, I_T = 0,97kgm^2, Measuring device NAMI-357. Data processing by the “Deceleration Calculator”.

Test №	**V, km/h**	**82-74**	**82-78**
1	j, s^{-2}	0,046932	0,046995
	δ, %	0	0,13
2	j, s^{-2}	0,046961	0,046994
	δ, %	0	0,07
3	j, s^{-2}	0,04694	0,046852
	δ, %	0	-0,19

Note: 1. δ - deviation relatively basic range 82-74 km/h.

Table 2. NAMI-357 – UTAC-MTS j data comparison at 80 km/h

Test №	**j, s^{-2}**		**Δ, %**
	NAMI	**UTAC**	
1	0.0470	0.0462	-1,70
2	0.0470	0.0462	-1,70
3	0.0469	0.0461	-1,71
Average	0.0469 (±0.00%)	0.0462 (±0.00%)	-1,70
Speed range	82-78 km/h	82-79 km/h	-

Note: the comparison of parasitic losses as cause of Δ value was not executed.

Table 3. NAMI-357 – UTAC-MTS Cr data comparison- results obtained on the same machine (UTAC-MTS)

Test №	**Cr, N/kN**		**Δ, %**
	NAMI	**UTAC**	
1	7.293	7.510	2,98
2	7.300	7.513	2,92
3	7.295	7.517	3,04
Average	7.296 (±0.06%)	7.513 (±0.05%)	2,97
Std DEV	0,0036	0,0035	

Note: in NAMI calculation moments of inertia determined by UTAC system were used. Average values are given with limit of their confidence intervals at the confidence level of 95 %, expressed in percent of the average.

Table 4

Station #1 ISO 28580 Rolling Resistance Report
Deceleration Method

Test Request :	ISO Decel80 PC F Ru short	**Test Date:**	11/20/13
Test Procedure:	ISO Decel80 PC C1 600s	**Test Time:**	11:37 AM
Tire Class:	Passenger	**Tire Construction Code:**	Radial
Tire Manufacturer:	DUNLOP	**Tire DOT Code:**	N50FJCUR
Tire Brand:	SP Sport fast response	**Tire Type:**	Routier
Tire Size:	205/55R16		
		Wheel Diameter:	16 in
Reference Load:	6031	**Rim Width:**	6,5 in
Reference Inflation:	210	**Wheel Plane Offset:**	ET43C60/4-100
Maximum Load:	6100	**Adaptor Id:**	ET43C60/4-100
Maximum Inflation:	300		
		Tire Info 1	91,00
Initial Inflation:	210,00	**Tire Info 2**	V
Design Tire Diameter:	630,3 mm	**Tire Info 3**	
Tire Identifier:	RU03	**Tire Info 4**	3912,00

Drum and tire Inertia:	**1114,76**	kg m^2
Drum Inertia:	**1106,3**	kg m^2
Spindle Inertia:	**0,84**	kg m^2
Motor Inertia:	**2,121**	kg m^2
Total Inertia:	**1116,89**	kg m^2

Coast at Load	Decel:	**-0,0462**	rad/sec^2
Coast at Skim	Decel:	**-0,0138**	rad/sec^2

Test Condition Information							Skim Information			Rolling Resistance					
Cnd	Vr		T_a	RL	F_z	F_X	RL	F_{zs}		F_{rc}	F_R	F_{R25}	F_{R02}	F_{Ralign}	C_R
	kph		degC	m	N	N	m	N		N	N	N	N	N	N/kN
2	79,96		25,13	0,290	4824,46	-31,96	0,315	100,02		51,59	36,19	36,23	36,23	36,23	7,510
3															

Table 5

Station #1 ISO 28580 Rolling Resistance Report

Deceleration Method

Test Request :	ISO Decel80 PC F Ru short	**Test Date:**	11/20/13
Test Procedure:	ISO Decel80 PC C1 600s	**Test Time:**	12:03 PM
Tire Class:	Passenger	**Tire Construction Code:**	Radial
Tire Manufacturer:	DUNLOP	**Tire DOT Code:**	N50FJCUR
Tire Brand:	SP Sport fast response	**Tire Type:**	Routier
Tire Size:	205/55R16		
		Wheel Diameter:	16 in
Reference Load:	6031	**Rim Width:**	6,5 in
Reference Inflation:	210	**Wheel Plane Offset:**	ET43C60/4-100
Maximum Load:	6100	**Adaptor Id:**	ET43C60/4-100
Maximum Inflation:	300		
		Tire Info 1	91,00
Initial Inflation:	210,00	**Tire Info 2**	V
Design Tire Diameter:	630,3 mm	**Tire Info 3**	
Tire Identifier:	RU04	**Tire Info 4**	3912,00

Drum and tire Inertia:	**1114,69**	kg m^2
Drum Inertia:	**1106,3**	kg m^2
Spindle Inertia:	**0,83**	kg m^2
Motor Inertia:	**2,121**	kg m^2
Total Inertia:	**1116,81**	kg m^2

Coast at Load	Decel:	**-0,0462**	rad/sec^2
Coast at Skim	Decel:	**-0,0138**	rad/sec^2

Test Condition Information							Skim Information			Rolling Resistance					
Cnd	**Vr** kph		**T_a** degC	**RL** m	**F_z** N	**F_X** N	**RL** m	**F_{zs}** N		**F_{rc}** N	**F_R** N	**F_{R25}** N	**F_{R02}** N	**F_{Ralign}** N	**C_R** N/kN
2	79,96		25,15	0,290	4824,24	-31,95	0,315	100,13		51,56	36,20	36,24	36,24	36,24	7,513
3															

Table 6

Station #1 ISO 28580 Rolling Resistance Report

Deceleration Method

Test Request :	ISO Decel80 PC F Ru short	**Test Date:**	11/20/13
Test Procedure:	ISO Decel80 PC C1 600s	**Test Time:**	12:30 PM
Tire Class:	Passenger	**Tire Construction Code:**	Radial
Tire Manufacturer:	DUNLOP	**Tire DOT Code:**	N50FJCUR
Tire Brand:	SP Sport fast response	**Tire Type:**	Routier
Tire Size:	205/55R16		
		Wheel Diameter:	16 in
Reference Load:	6031	**Rim Width:**	6,5 in
Reference Inflation:	210	**Wheel Plane Offset:**	ET43C60/4-100
Maximum Load:	6100	**Adaptor Id:**	ET43C60/4-100
Maximum Inflation:	300		
		Tire Info 1	91,00
Initial Inflation:	210,00	**Tire Info 2**	V
Design Tire Diameter:	630,3 mm	**Tire Info 3**	
Tire Identifier:	RU05	**Tire Info 4**	3912,00

Drum and tire Inertia:	**1114,72**	kg m^2
Drum Inertia:	**1106,3**	kg m^2
Spindle Inertia:	**0,83**	kg m^2
Motor Inertia:	**2,121**	kg m^2
Total Inertia:	**1116,84**	kg m^2

Coast at Load	Decel:	**-0,0461**	rad/sec^2
Coast at Skim	Decel:	**-0,0137**	rad/sec^2

Test Condition Information							Skim Information			Rolling Resistance					
Cnd	Vr		T_a	RL	F_z	F_X	RL	F_{zs}		F_{rc}	F_R	F_{R25}	F_{R02}	F_{Ralign}	C_R
	kph		degC	m	N	N	m	N		N	N	N	N	N	N/kN
2	79,96		25,21	0,290	4824,56	-31,90	0,315	99,96		51,54	36,21	36,27	36,27	36,27	7,517
3															

Table 7. UTAC-MTS ISO 28580 Roiling Resistance Deceleration Repeatability

Test Number	Test Date	Test	Cond1 80 km/h Frr N	Cond2 0 km/h Frr N	Average Frr N	Average Cr N/kN
Radial Force		**N**	4824			
Inflation Pressure		**N**	210			
1	Nov-20-2013	a	36.231			7.510
2	Nov-20-2013	b	36.245			7.513
3	Nov-20-2013	c	36.268			7.517
Average		N	**36.248**			**7.513**
Standard Deviation		N	**0.019**			**0.004**
						0.05%
S.D. Spec	0.050	N	Meets Spec			

Note: 1. Machine name: UTAC-Rrsi, Station Number: 1

Table 8-a. Deceleration j at 80 kph and different speed range (Test machine UTAC-HAWITEC fitted with NAMI system)

Test object	V, kph	82-60	82-65	82-70
Tyre 205/55R16, p=0,21MPa, Lm=482,6daN №2	j, s^{-2}	0,159718	0,161792	0,165885
	δ, %	0	1,30	3,86
PL of Machine , drum R=0,85m, I_D=500kgm^2, №1	j, s^{-2}	0,096398	0,09757	0,100041
	δ, %	0	1,22	3,78
PL of Machine , drum R=0,85m, I_D=500kgm^2, №2	j, s^{-2}	0,092299	0,092965	0,094648
	δ, %	0	0,72	2,54

Note: δ - deviation relatively basic range 82-60 kph

Table 8-b. Parasitic losses of the machine HAWITEC - drum R=0.8500 m, I_d = 573kgm^2 (deceleration j at 80 km/h and different speed range)

Test №	Speed range, km/h	j, s^{-2}	δ, %
drum with tyre removed			
1	82-78	0,050802	0
2	82-70	0,050373	-0,84
3	82-60	0,050481	-0,63
skim test with tyre 205/55R16			
4	82-60	0,096398	0
5	82-60	0,092299	-4.25

Note: δ - deviation relatively basic range:

- for drum without tyre from Test № 1;
- for skim test from Test № 4.

Table 9. NAMI-357 – fitted on UTAC-HAWITEC C_r data comparison with UTAC results on UTAC-MTS machine and system.

Test №	Cr, N/kN		Δ, %
	NAMI HAWITEC	UTAC MTS	
1	8.056	7.510	-6.78
2	7.053	7.513	6.52
3	7.645	7.517	-1.67
Average	7.585 (±6.65%)	7.513 (±0.05%)	-0.95

Note 1: δ - deviation relatively basic range;
Δ - discrepancy between NAMI HAWITEC and UTAC MTS data.
Note 2: these results are obtained in the supposition that total inertia of test Machine HAWITEC equals to 573 kg-m^2;
Note 3: these results show that finding the cause of large scatter should be continued. The explanations are provided on page 13 of this report.

IV. The results obtained from NAMI experiments prior to the ad-hoc working group measuring campaign

Table 10 gives an example of recorded data, which confirms discovered effect that dependently of adjustment and specificity of a test machine, lower speed of recording range may be reduced down to 60 (40) km/h.

Table 11 shows the results of testing tyres of classes C1, C2, C3 using the test machine NAMI-354 (figure 8).

Table 12 illustrates deceleration j obtained with the test machine IPZ-4 of Nizhnekamsk tyre plant (figure 9).

Besides the main task to compare deceleration values obtained with the help of the measurement systems UTAC and NAMI, the results obtained by NAMI show practical independence of the measured deceleration from the test speed range. This made for explanation of note 1 in paragraph 1 of the modified proposal (see the document amending document ECE/TRANS/WP.29/ GRB/2013/10).

Table 10. Deceleration j at 80 km/h and different speed ranges
(the test machine NAMI-354)

Test object	V, km/h	82-60	82-65	82-70	82-75	82-78
Tyre 245-45R18 , p=0,21MPa, Lm=558daN	j, s^{-2}	0,052948	0,052952	0,052951	0,052962	0,052943
	δ, %	0	0,01	0,01	0,03	-0,01
Tyre 225-65R16, p=0,48MPa, Lm=934daN	j, s^{-2}	0,060282	0,060289	0,060292	0,060296	0,060322
	δ, %	0	0,01	0,02	0,02	0,07
Tyre 385-65R22,5, p=0,9MPa, Lm=3752daN	j, s^{-2}	0,121942	0,121937	0,121937	0,121882	0,121586
	δ, %	0	0,00	0,00	-0,05	-0,29
PL of Tyre 245-45R18 , R_T=0,3251m , I_T=1,62kgm^2	j, s^{-2}	0,944855	0,942777	0,942093	0,942352	0,94089
	δ, %	0	-0,22	-0,29	-0,26	-0,42
PL of Tyre 225-65R16, R_T=0,3386m, I_T=1,91kgm^2	j, s^{-2}	0,730843	0,731234	0,731226	0,730347	0,731308
	δ, %	0	0,05	0,05	-0,07	0,06
PL of Tyre 385-65R22,5 , R_T=0,526m , I_T=20,45kgm^2	j, s^{-2}	0,160768	0,160874	0,160874	0,160832	0,160767
	δ, %	0	0,07	0,07	0,04	0,00
PL of Machine NAMI-354, drum R=1m, I_D=1920 kgm^2	j, s^{-2}	0,016026	0,016024	0,016024	0,016021	0,01602
	δ, %	0	-0,01	-0,01	-0,03	-0,04

Note: δ - deviation relatively basic range 82-60 km/h

Table 11. Deceleration j at 80 km/h and different speed range
Tyre classes C1, C2, C3. (the test machine NAMI-354)

Test object	**V, km/h**	**82-60**	**82-65**	**82-70**	**82-75**	**82-78**
Tyre 245-45R18 , p=0,21MPa, Lm=558daN	j, s^{-2}	0,052959	0,05295	0,052954	0,052959	0,052893
	δ, %	0	-0,02	-0,01	0,00	-0,12
Tyre 225-65R16, p=0,48MPa, Lm=934daN	j, s^{-2}	0,060292	0,060283	0,060289	0,060298	0,060263
	δ, %	0	-0,01	0,00	0,01	-0,05
Tyre 385-65R22,5, p=0,9MPa, Lm=3752daN	j, s^{-2}	0,12191	0,121912	0,121939	0,121884	0,122135
	δ, %	0	0,00	0,02	-0,02	0,18
PL of Tyre 245-45R18 , R_T=0,3251m ,I_T=1,62kgm^2	j, s^{-2}	0,943733	0,943586	0,942249	0,942797	0,941301
	δ, %	0	-0,02	-0,16	-0,10	-0,26
PL of Tyre 225-65R16, R_T=0,3386m, I_T=1,91kgm^2	j, s^{-2}	0,730906	0,730368	0,730385	0,73143	0,727825
	δ, %	0	-0,07	-0,07	0,07	-0,42
PL of Tyre 385-65R22,5 , R_T=0,526m , I_T=20,45kgm^2	j, s^{-2}	0,161085	0,160929	0,160874	0,16077	0,16103
	δ, %	0	-0,10	-0,13	-0,20	-0,03
PL of Machine, drum R=1m, I_D=1920 kgm^2	j, s^{-2}	0,016032	0,016025	0,016023	0,016024	0,016025
	%	0	-0,04	-0,06	-0,05	-0,04

Notes:

1. δ - deviation relatively basic range 82-60 km/h;
2. For parasitic losses of the test machine highest speed 80 km/h;
3. Some difference between Table 11 and Table 10 are explained by developing of approximation function used for data in Table 10.

Table 12. Deceleration j at 80km/h and different speed range. Tyre class C3. (The test machine IPZ-4)

Test object	V, km/h	80-60	80-65	80-70	80-75	80-76
Tyre 275/70R22,5, p=0,92MPa, Lm=2628daN	j, s^{-2}	0,357413	0,357128	0,356702	0,357485	0,356546
	δ, %	0	-0,08	-0,20	0,02	-0,24
Tyre 12.00R20, p=0,85MPa, Lm=3131daN	j, s^{-2}	0,497461	0,496501	0,497141	0,504332	0,504332
	δ, %	0	-0,19	-0,06	1,38	1,38
PL of Tyre 275/70R22,5, R_T =0,4746m , I_T=16,5466kgm^2	j, s^{-2}	0,174491	0,174556	0,174458	0,174796	0,175329
	δ, %	0	0,04	-0,02	0,17	0,48
PL of Tyre 12.00R20, R_T=0,3251m , I_T=25,6829kgm^2	j, s^{-2}	0,134294	0,133752	0,132932	0,133426	0,133684
	δ, %	0	-0,40	-1,01	-0,65	-0,45
PL of Machine, drum R=0,796m, I_D=516 kgm^2	j, s^{-2}	0,074761	0,074826	0,074872	0,074661	0,074707
	%	0	0,09	0,15	-0,13	-0,07

Note: δ - deviation relatively basic range 80-60 km/h.

Figure 8. NAMI-354 test machine (at the top) with device NAMI-357 (bottom).
“C” – electromagnetic clutch which decouples drum from motor during coastdown.

Figure 9. The equipment NAMI-357 on the test machine IPZ-4
at the Nizhnekamsk Tyre Plant

Conclusions

Testing of the "Deceleration Calculator" executed using two tyre test machines of UTAC had shown:

1. Good adaptability of the mentioned computer program as well as logger NAMI-357 to the tyre test machines.

2. The comparison of test data had shown satisfactory fit of deceleration data obtained by the both systems UTAC and NAMI on MTS machine. Taking into account the difference between the methods of parasitic losses and rolling radius determination obtained discrepancy of deceleration approximately of 1.7% may be estimated as high.

3. The obtained data presented by NAMI had shown that the algorithm of the "Deceleration Calculator" practically provides independence of measured deceleration from test speed range in span from 4 to 20 km/h.

4. UTAC was successful to program the solution of the equation system presented by NAMI, with one of the module of the currently used software "SAS". The statistic assessment of this solution in comparison with the results obtained by the "Deceleration Calculator" had shown good closeness of agreement.

5. Even though only one C1 reference tyre had been tested during this study, for the present time it may be presumed that the test results on C2 and C3 tyres presented by NAMI may be repeated using such test machines as MTS, but this would need to be considered in future on the base of mutual testing. It has to be noted that data characterizing C2 and C3 class tyres had been obtained by NAMI and Nizhnekamsk tyre plant on their machines with satisfactory accuracy using not specialized test machines. Common experiments using a test machine not specialized for rolling resistance, but for load and speed measurements, shown a low reproducibility, which needs to be investigated further, including finalizing spindle mechanical system diagnostics.

6. On the basis on the obtained test results the ad-hoc working group proposes the introduction of those amendments for clarifications and to adopt the proposal by Russian Federation for Annex 6 – Appendix 4 to UN Regulation No. 117for measurements and data processing for deceleration value obtaining in differential form dω/dt as presented in the document amending document ECE/TRANS/WP.29/GRB/2013/10.

References

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Annex 1

The fragment of the report of the Working Party on Noise on its fifty-eighth session (ECE/TRANS/WP.29/GRB/56)

VII. Regulation No. 117 (Tyre rolling noise and wet grip adhesion) (agenda item 6)

Documentation: ECE/TRANS/WP.29/GRB/2013/10, informal documents GRB-58-02, GRB-58-12 and GRB-58-13

15. The expert from the Russian Federation made a presentation (GRB-58-12) to introduce a revised proposal (ECE/TRANS/WP.29/GRB/2013/10) that would introduce a "Deceleration Calculator" software for the deceleration test method in the test procedure for measuring rolling resistance. The expert from France informed GRB that the proposed calculator had been verified for a first cycle of tests by the Technical Union for the Automobile, Motorcycle and Cycle Industries (UTAC). However, he added that the method should be still thoroughly analysed. The expert from ETRTO expressed some doubts on the variability of the method by temperature change and stated that further work was needed to demonstrate equivalence. The expert from the Russian Federation recalled that full cooperation was offered by the Russian experts as well as data sharing and asked GRB to take into consideration the positive experience developed by the industrial sector of his country in this field. The expert from France proposed to host a meeting of experts (date to be defined) in UTAC to further the exchange of views and finalize the proposal. The Chair of GRB suggested that other laboratories would start similar activities to evaluate the proposed method and devise possible alternative calculators to provide wider choice to future users. Finally, GRB endorsed the ad hoc meeting with the experts of ETRTO and the Russian Federation which was proposed by the expert from France to test the proposed "Deceleration Calculator". It was also noted that once that the calculator was accepted by GRB as a valid alternative to the current one, it could be hosted on the WP.29 website, as an example, with an anonymous reference.

Annex 2.

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