Informal document **GRB-59-08**
(59th GRB, 27-29 January 2014,
agenda item 6)

(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)

GRB, 59th session

27-29 January, 2014

The fragment of the report of the Working Party on Noise on its 58th session (ECE/TRANS/WP.29/GRB/56)

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

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 analyzed. 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. **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.

The ad-hoc working group participants:

France (UTAC):
Serge Ficheux,
Thierry Ageron,
Celine Berthou,
Marc-Antoine Scorianz.

The Russian Federation (NAMI):
Vladimir Petrushov,
Evgeny Redkin.

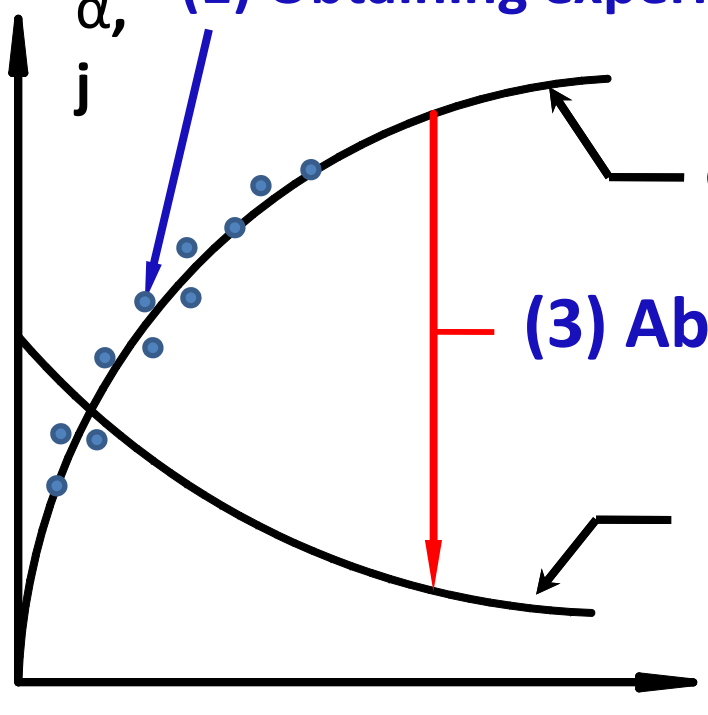
ETRTO:
Jean-Claude Noirhomme,
Georges Dimitri.

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.

DETERMINATION OF DECELERATION BY USING DIFFERENTIAL ∂ω/∂t FORM

In the alternative calculation method a function "distance-time" α=f(t) is used. Deceleration is the second derivative of that function. There is no need to measure/calculate speed. This increases accuracy of the method.



(1) Obtaining experimental data

(2) Approximation:

$$\alpha = A\ln\frac{1}{\cos B(T_\Sigma - t)} \qquad (A)$$

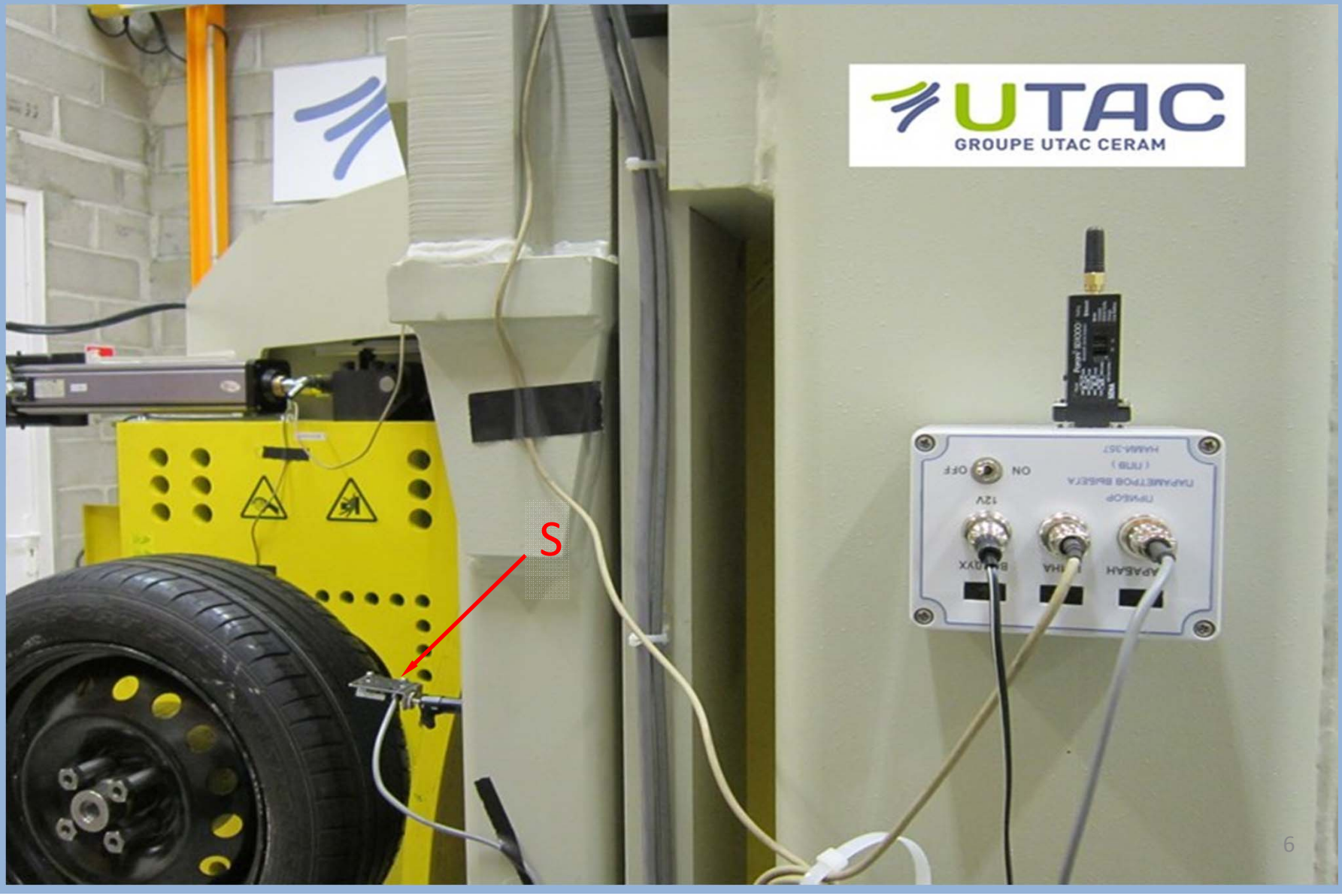
(3) Absolutely accurate transformation:

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

So it is enough to record in discrete form function α_i=f(t) then approximate it by formula (A) and take a result in form of (B).

This is simple. This is accurate. σ<0.03% , R^2 >0.999.

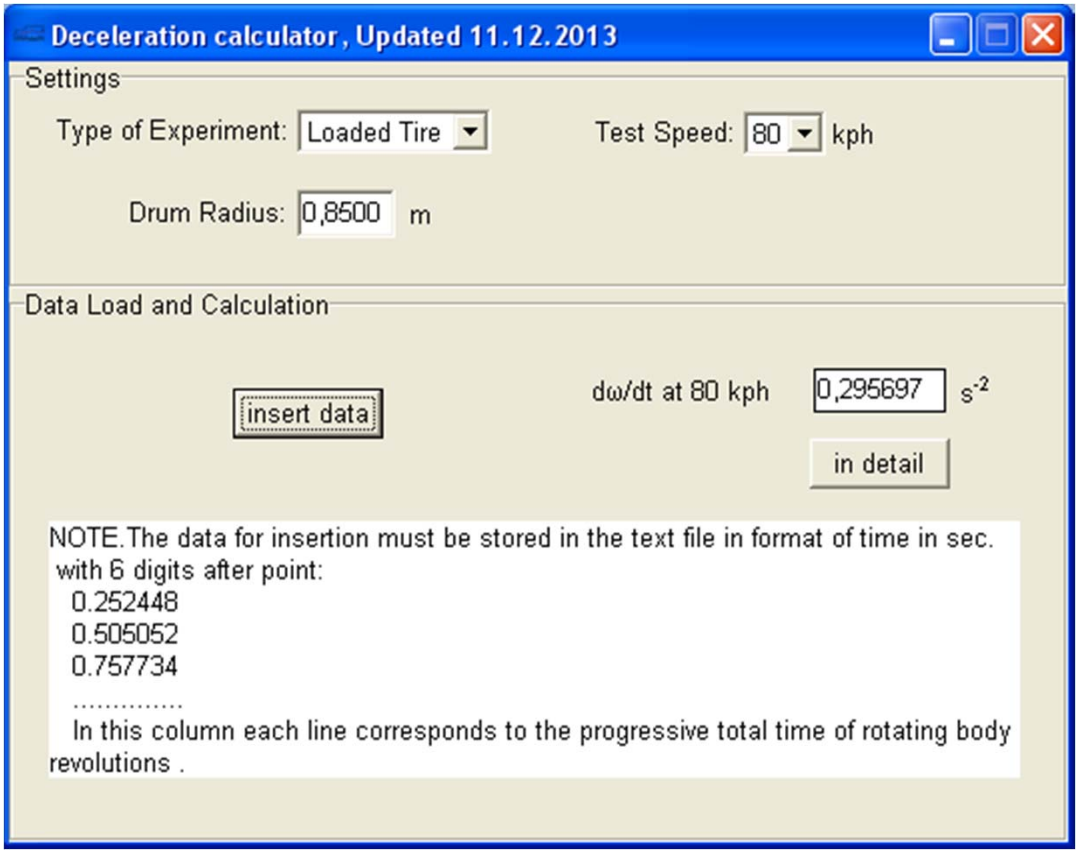
Installation of NAMI-357 data logger on MTS test machine in UTAC ("S" – drum sensor).

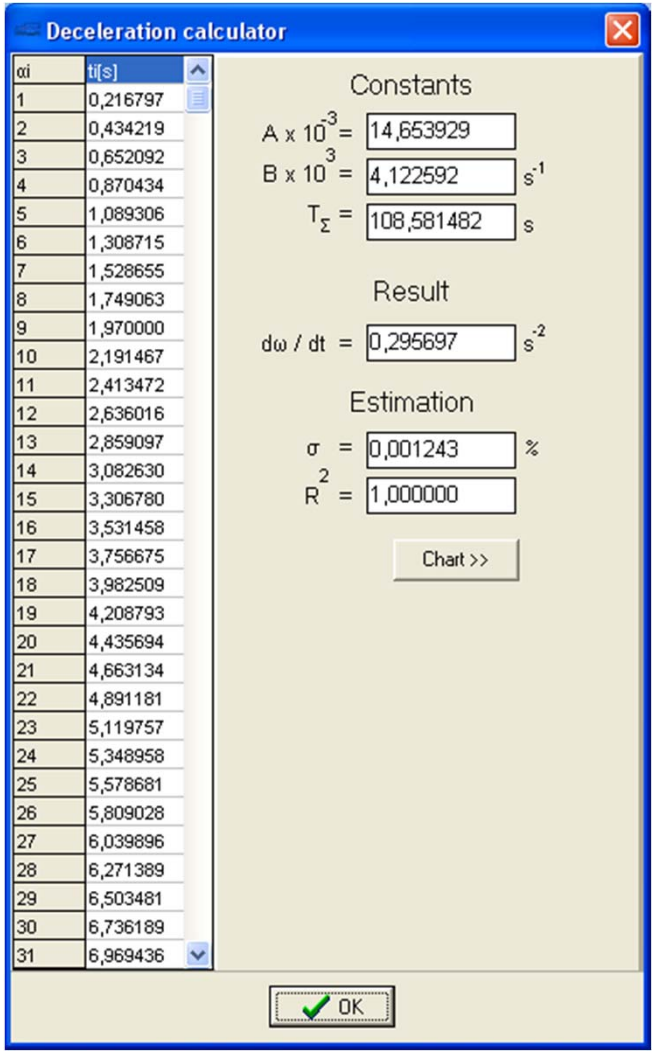


Tyre sensor “S” of NAMI-357 data logger.

HAWITEC test machine in UTAC on which NAMI-357 data logger was used

“Deceleration Calculator” windows





*** Loaded test data file:**

Tyre 225-70R15C p=0,45MPa, Lm=934daN on machine VMI FMTM25, #1,

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.

MTS UTAC

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															

UTAC-MTS ISO 28580 Roiling Resistance Deceleration Repeatability

Radial Force N			4824			
Inflation Pressure N			210			
Test Number	**Test Date**	**Test**	**Cond1** 80 km/h Frr N	**Cond2** 0 km/h Frr N	**Average** Frr N	**Average** Cr N/kN
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			

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=500kgm², №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=500kgm², №2	j, s^{-2}	0,092299	0,092965	0,094648
	δ, %	0	0,72	2,54

Table 8-b. Parasitic losses of the machine HAWITEC - drum R=0.8500 m, I_d = 573kgm² (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

NAMI-354 test machine with device NAMI-357

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

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

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.

Conclusions

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

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

Conclusions (continued)

- 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.
- 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 Nizhnekamsktyre 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.

Conclusions (end)

- **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 the Russian Federation for Annex 6 – Appendix 4 to UN Regulation No. 117 for 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.**

Thank you for your attention!