Presented by the experts
from the Russian Federation

Informal document **GRB-58-12**
(58th GRB, 2-4 September 2013,
agenda item 6)

DECELERATION CALCULATOR

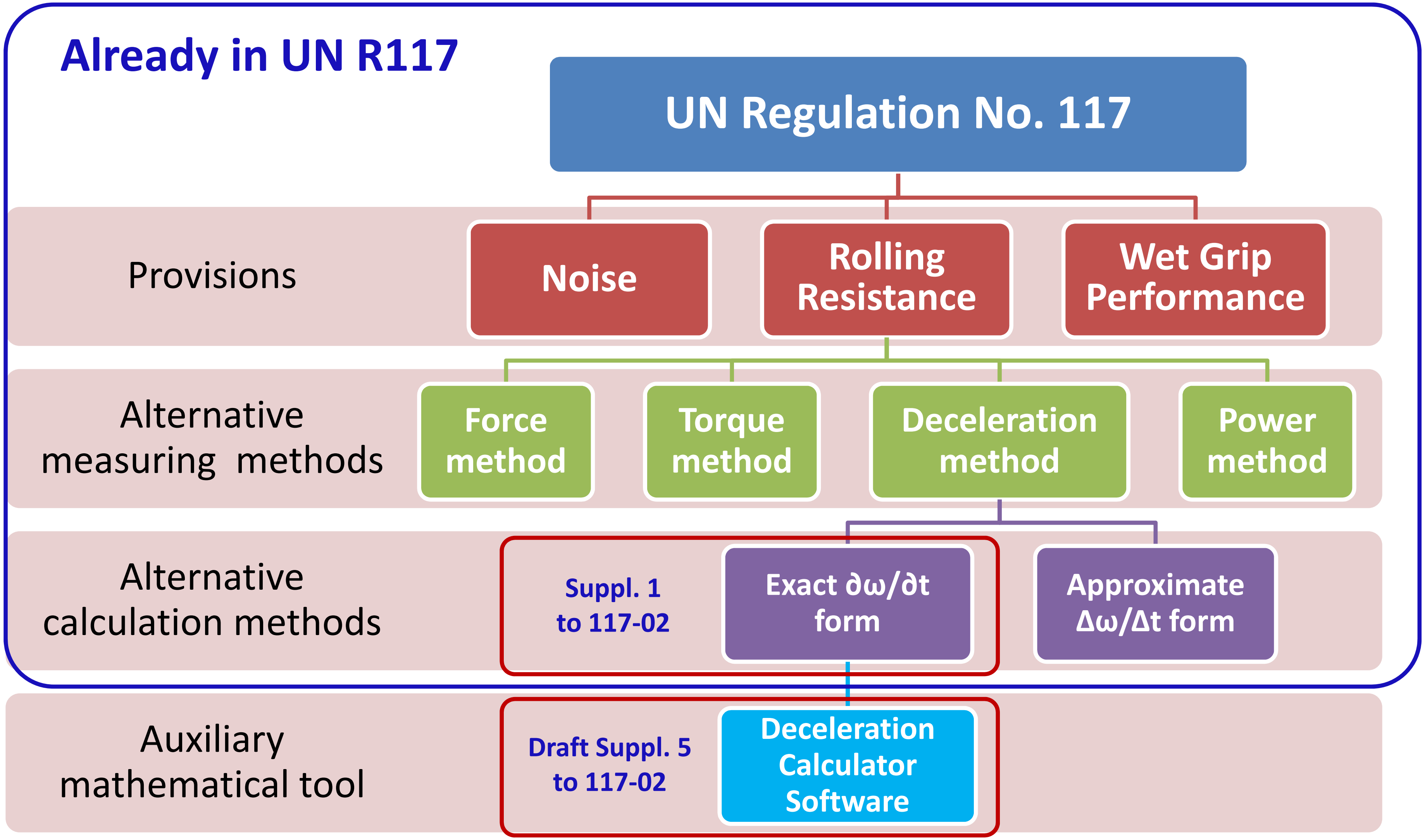
(Explanation)

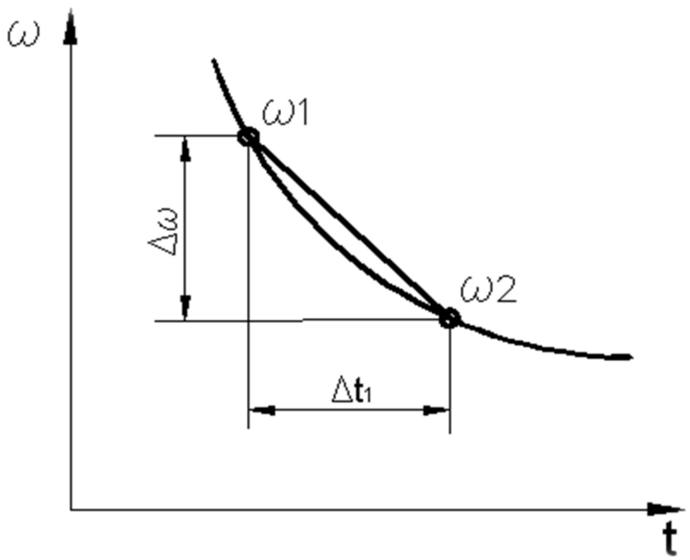
This presentation was prepared by the experts from the Russian Federation following the decision of the 57th GRB session (ECE/TRANS/WP.29/GRB/55, para. 19).

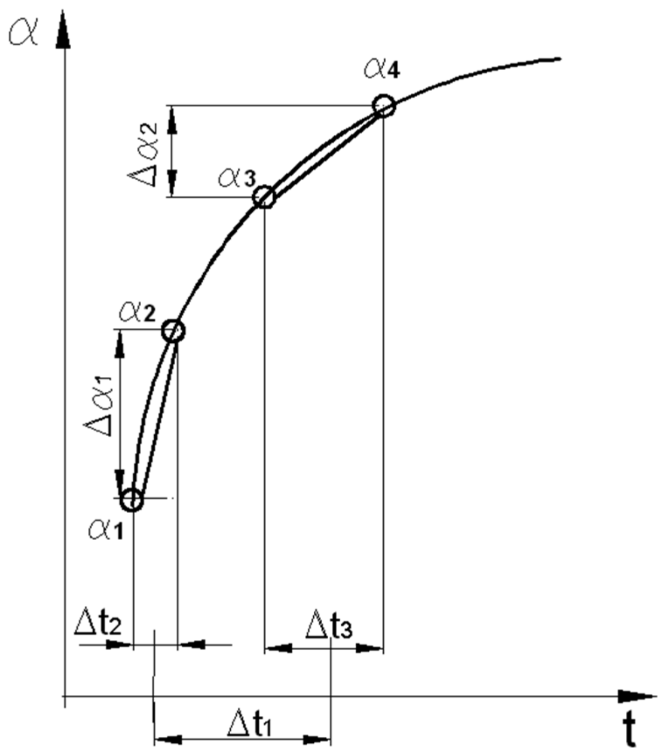
GRB, 58th session

2-4 September 2013

WHAT WILL BE MODIFIED IN UN REGULATION No. 117







DETERMINATION OF DECELERATION BY USING APPROXIMATE Δω/Δt FORM

Deceleration j is a main factor of tyre RR determination. Being multiplied by moment of inertia it yields resistance force. Traditional way to calculate this factor is:

$$j = \frac{\Delta\omega}{\Delta t_1} = \frac{\omega_1 - \omega_2}{\Delta t_1}$$

where Δω- is the speed interval
Δt_1 - is the time interval
ω_1- is the speed value at the beginning of time interval Δt_1
ω_2- is the speed value at the end if time interval Δt_1

To determine the speed values ω_1 and ω_2 it is necessary to measure the distance intervals $\Delta\alpha_1$ and $\Delta\alpha_2$ during any time intervals Δt_2 and Δt_3 :

$$\omega_1 = \frac{\Delta\alpha_1}{\Delta t_2} \quad , \quad \omega_2 = \frac{\Delta\alpha_2}{\Delta t_3}$$

As a result: $$j = \frac{\frac{\Delta\alpha_1}{\Delta t_2} - \frac{\Delta\alpha_2}{\Delta t_3}}{\Delta t_1}$$

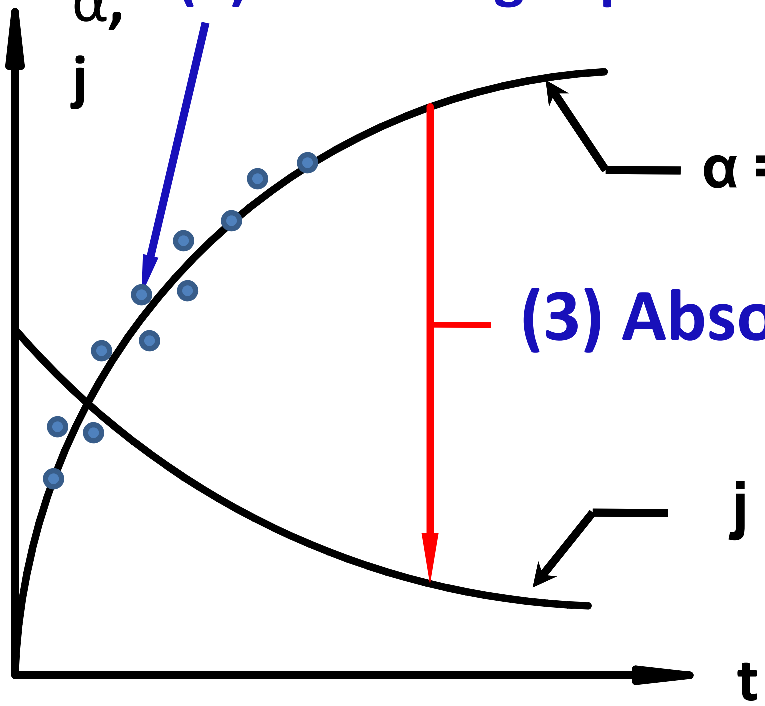
So there are 5 measured sources of j inaccuracy.

Additionally 3 sources of inaccuracy are the linearization of curves $\omega_1 - \omega_2$; $\alpha_1 - \alpha_2$ and $\alpha_3 - \alpha_4$.

DETERMINATION OF DECELERATION BY USING EXACT ∂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:

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

(3) Absolutely accurate transformation:

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

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.

WHAT DOES THE "DECELERATION CALCULATOR" DO?

The "Deceleration Calculator": (1) approximates the experimental data by using formula (A), then it finds the parameters A, B, T_Σ and (2) calculates output $j = d\omega/dt$ by using formula (B).
The parameters A, B and T are determined by using the "4-point" method by the following formulae and algorithm:

$$\alpha_0 = A\ln\frac{1}{\cos BT_\Sigma}$$

$$\alpha_1 = A\ln\frac{1}{\cos B(T_\Sigma - t_1)}$$

$$\cos^{\frac{\alpha_1}{\alpha_0}} BT_\Sigma = \cos B(T_\Sigma - t_1)$$

$$\alpha_2 = A\ln\frac{1}{\cos B(T_\Sigma - t_2)}$$

$$\alpha_3 = A\ln\frac{1}{\cos B(T_\Sigma - t_3)}$$

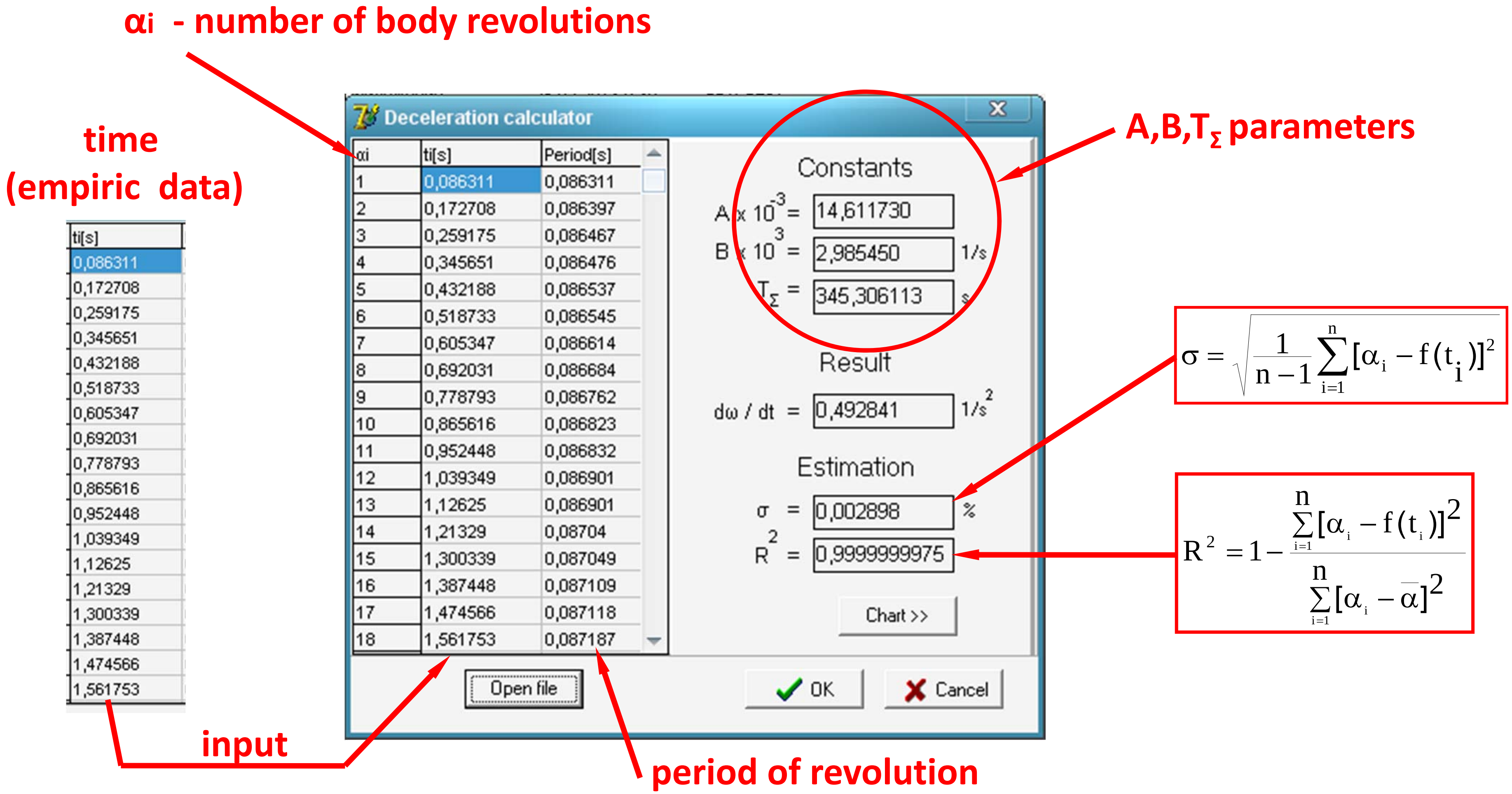
$$\cos^{\frac{\alpha_3}{\alpha_2}} B(T_\Sigma - t_2) = \cos B(T_\Sigma - t_3)$$

$$B, T_\Sigma;$$

$$A = \frac{\alpha_0}{\ln\frac{1}{\cos BT_\Sigma}}$$

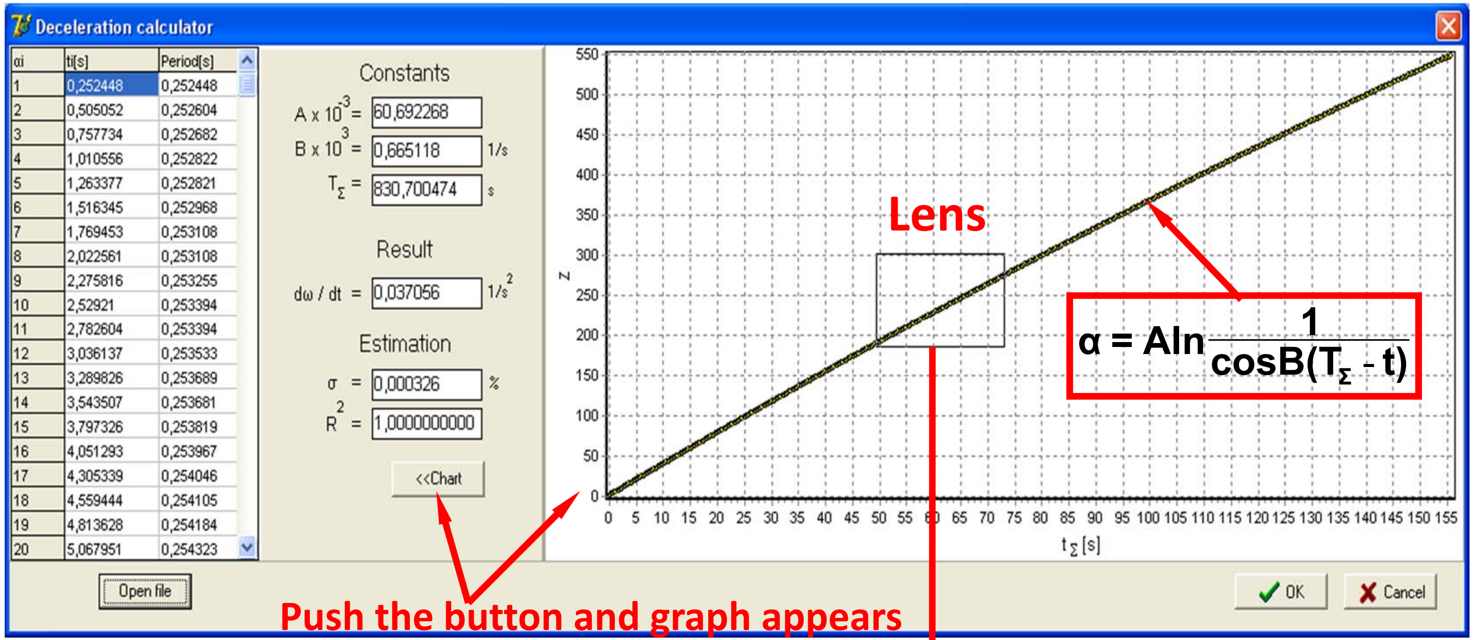
So an operator becomes free from calculus but reserves under his control a quality of approximation in the forms of standard deviation σ and quadrature of correlation coefficient R^2 .

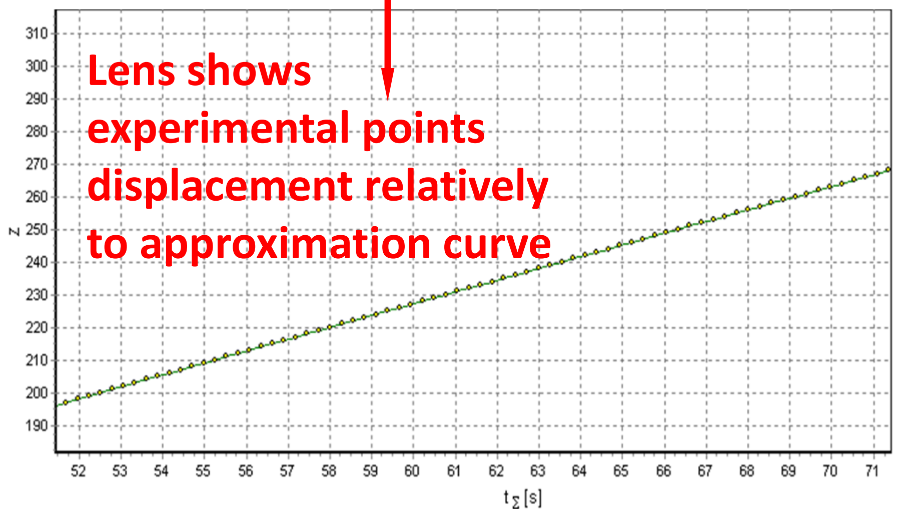
THE “DECELERATION CALCULATOR” MAIN WINDOW



It is enough to measure period of each revolution of the rotating body by cumulative sum, and calculator will provide the results.

THE "DECELERATION CALCULATOR" DATA PROCESSING VISUALIZATION





The lens area in this slide is a visual proof that no additional experimental points between indicated may give additional increase of the approximation accuracy.

The approximation accuracy reached by the "Deceleration Calculator" is placed on the upper level (typically $\sigma<0{,}03\%$, $R^2>0{,}9999$).

Therefore the usage of encoders as moving sensors and especially of deceleration sensors brings no advantage when the "Deceleration Calculator" is used.

ABOUT MEASURING ENCODERS

Modern measuring encoders are capable for speed and acceleration measurements. Their main feature is several thousand pulses for one turn. But decreasing the segment size increases requirements to accuracy.

Application of such encoders with the calculation method by using approximate $\Delta\omega/\Delta t$ form allows to improve the accuracy as those encoders remove the task from the field of seconds to the field of micro- and nanoseconds.

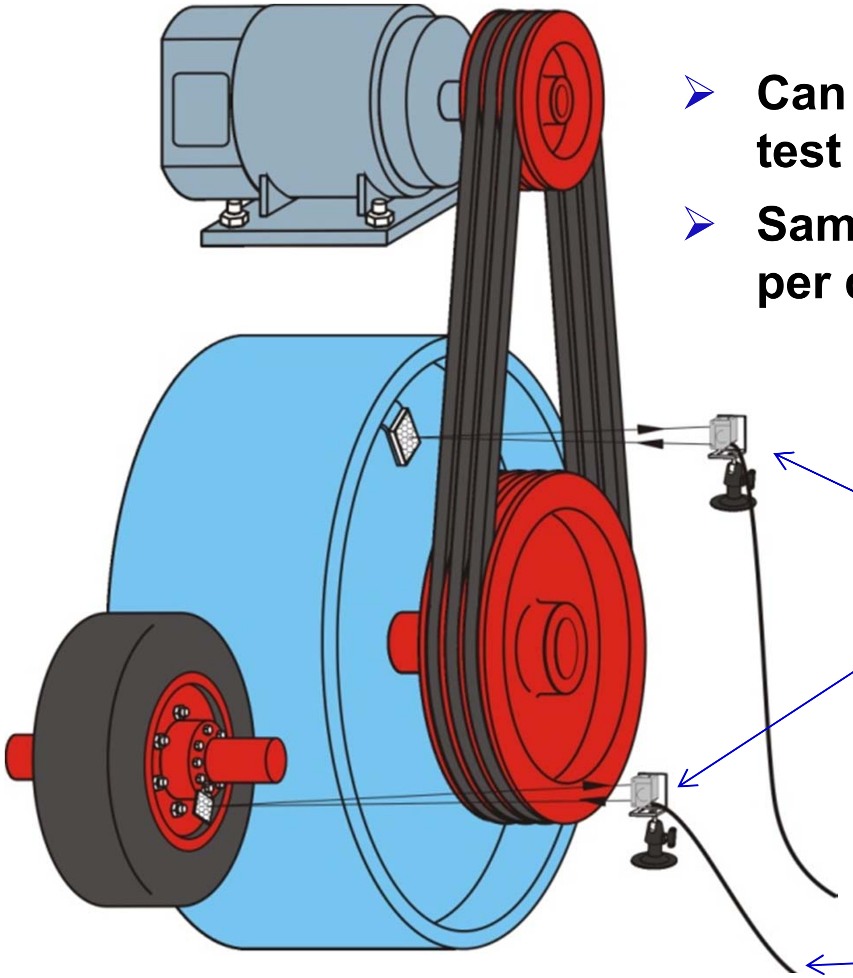
But 5 sources of inaccuracy as explained above take place anyway in this field due to formula:

$$\mathbf{j} = \frac{\frac{\Delta\alpha_1}{\Delta t_2} - \frac{\Delta\alpha_2}{\Delta t_3}}{\Delta t_1}$$

It is not a bad idea to apply encoder for time-distance measurements, but in this case its extreme capabilities will not exceed the existing accuracy of the “Deceleration Calculator”.

A MEASUREMENT KIT FOR DETERMINATION OF DECELERATION BY USING EXACT ∂ω/∂t FORM

- **Can be mounted on any standard test machine**
- **Sampling frequency: one pulse per drum/wheel revolution**



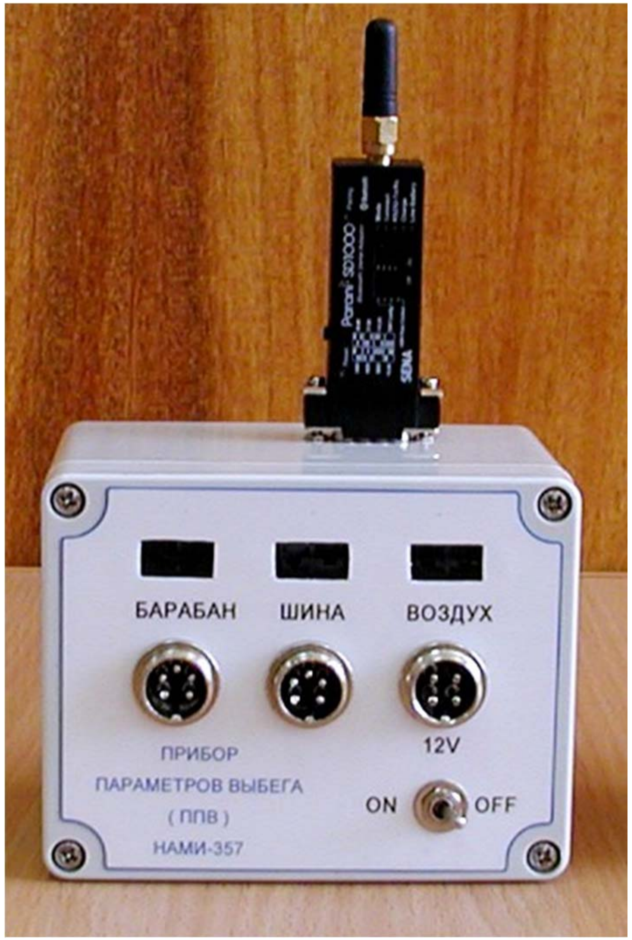
Retroreflecting revolution sensors

To any data logger

αi	ti[s]
1	0,252448
2	0,505052
3	0,757734
4	1,010556
5	1,263377
6	1,516345
7	1,769453
8	2,022561
9	2,275816
10	2,52921
11	2,782604
12	3,036137
13	3,289826
14	3,543507
15	3,797326
16	4,051293
17	4,305339
18	4,559444
19	4,813628
20	5,067951
21	5,322352
22	5,576892
23	5,831432
24	6,086189
25	6,340946
26	6,595842
27	6,850816
28	7,105929
29	7,36112
30	7,61638
31	7,87178
32	8,127257
33	8,382865
34	8,638559
35	8,894314
36	9,150148
37	9,40612
38	9,66217
39	9,918359
40	10,174618
41	10,430955
42	10,687431
43	10,943976
44	11,200668
45	11,457431
46	11,714262
47	11,971241
48	12,22829
49	12,485408
50	12,742674

ACTUAL MEASUREMENT KIT FOR MOUNTING ON ANY TEST MACHINE

Sensors with magnetic supports for revolution measuring



Data Logger

IMPLEMENTATION OF THE “DECELERATION CALCULATOR”

- The mathematical apparatus of the “Deceleration Calculator” was the object of positive assessment by the institutes of Russian Academy of Science: Keldysh Institute of Applied Mathematics and A.Ishlinskiy Institute for Problems in Mechanics.
- The calculation method in exact dω/dt form is successfully used for a long time being standardized in the Russian national standard GOST R 52102.
- Several hundreds calculus are made by using the “Deceleration Calculator”. 14 of them are included in the program pack on the website: http://nami.ru/upload/calculator.zip
- An adaptability of the “Deceleration Calculator” to the untrained personal was tested on the group of 6 students of MAMI Technical University (Moscow). All of them took 10-12 minutes to run the data processing.
- The latest version of the software supports the both types of decimal part (point or comma) set on computers.

CONCLUSIONS

- **The deceleration test method in exact dω/dt form, the "Deceleration Calculator" software and the test device are alternative to the other existing test methods and devices**

- **The "Deceleration Calculator" software has been successfully implemented in Russia, therefore Russian experts do not foresee concerns with application of that mathematical tool**

- **Having enough experience with the proposed method the Russian tyre industry is very interested in its inclusion in UN Regulation No.117, Annex 6**

Thank you for your attention!