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Road vehicles — Calibration procedure for displacement devices

Véhicules routiers — Procédés de calibration pour les dispositifs de déplacement

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Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 36, *Safety and impact testing*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document was written to address the need of the automotive crash testing community for a well-defined calibration method of displacement sensors.

Road vehicles — Calibration procedure for displacement devices

1 Scope

This document establishes a procedure to calibrate 1D displacement transducers with nearly linear transfer functions. This procedure is tailored to the needs of sensors used in crash tests. The calibration is carried out with the sensor disassembled from the dummy or test system. The procedure is valid for sensors with analogue as well as digital output.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
displacement calibration
point to point calibration against a traceable reference

4 Displacement calibration procedure

4.1 General

The calibration is running according the classic calibration method for standard displacement devices like dial gauges. The procedure is performed on a linear calibration fixture and measurement system.

During displacement calibration components are used to fix the transducer to a calibration fixture. These components do not necessarily belong to the final assembly of the sensor as used in the dummy.

The calibration data are entered into a data-processing software. The software calculates the maximum interpolation error and the maximum hysteresis per calibration range. In addition, the software calculates the repetition error at a measuring point that is approached from one direction.

4.2 Preparations

Check the sensor and the calibration fixture for any mechanical play, like loose screws, mechanical components, interfaces, etc., and fix as necessary.

4.3 Test equipment set up

— Conduct the calibration in a temperature-controlled environment between 20 °C - 25 °C.

— The transducer, cabling, and any associated circuitry has to be connected to the measurement system in the same fashion as during normal operation.

— The measuring system shall warm up according to the manufacturer's specifications and the sensor signal has to be stable before taking calibration data.

4.4 Establish starting point

— Secure the sensor to the fixture. Fasten until secure.

— Install the zero displacement point ds of the sensor similar to the initial point in the application.

— If the application is not known set the zero displacement point (DS) of the sensor smaller than 2 % of full scale.

— The calibration range can be defined close to the application range and does not necessarily need to be the channel amplitude class (CAC) defined in ISO 6487.

4.5 Displacement calibration data collection

— At least 10 points distributed over the calibration range.

— At least in addition 5 repetitions between the zero-displacement point and a second point at an application related value from the same direction.

Table 1 shows the measuring points for determining hysteresis, interpolation error and repetition.

Table 1 — Measuring points

Hysteresis		**Repetition**
Interpolation error		
At least 10 points increasing	Same points decreasing	At least in addition 5 repetitions between the zero-displacement point and a second point at an application related value from the same direction

Annex A shows an example of the evaluation.

5 Calibration data processing

5.1 General

During evaluation, random deviations of the measured values should be minimised, e.g. by averaging at the individual stages or using a higher-order polynomial over all measured values. The following example shows the evaluation for a 1st order polynomial under the assumption that the output signal of the transducer is represented precisely enough by a 3rd order polynomial.

5.2 ISO 6487 definition

— Calculate the interpolation function 1st order (e.g. Excel function { = RGP(y;x;0;1)}) determined by the method of least squares.

— Calculate the interpolation error of the increasing signal as the maximum of the absolute value of the difference of the increasing signal and the interpolation function 1st order.

— Calculate the hysteresis as the maximum of the absolute value of the difference of the increasing and decreasing signal at the same point.

— The sensitivity of the sensor is given by the linear term of the interpolation function 1st order.

— The following is an option for the mathematical calculation:

calculate in addition the interpolation function 3rd order of the increasing signal and decreasing signal separately (e.g. Excel function { = RGP(y;x^column(A:C);0;1)}):

— calculate the interpolation error of the increasing signal as the maximum of the absolute value of the difference of interpolation function 3rd order and the interpolation function 1st order of the increasing signal,

— calculate the hysteresis as the maximum of the absolute value of the difference of the increasing interpolation function 3rd order and decreasing interpolation function 3rd order at the same point,

calculate the repetition as standard deviation at the repetition point;

the transfer function of the sensor is given by the terms of the interpolation function 3rd order of the increasing signal.

5.3 SAE 2570 definition

The data processing follows the steps of 5.1 with the terminal line as defined in SAE 2570 as interpolation function 1st order.

Annex A
(informative)

Example: Knee-slider (FS: 35 mm)

A.1 General

Tables A.1, A.2 and Figure A.2 show examples of the results of a calibration and the corresponding evaluation.

A.2 Measurement data

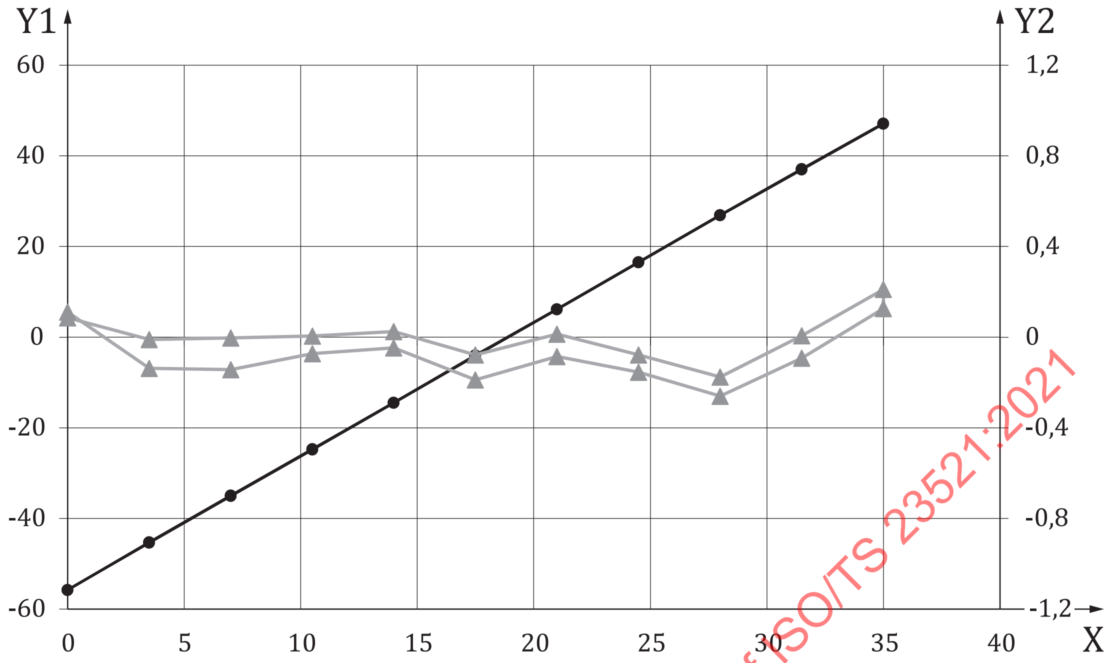
Table A.1 — Measurement data

Position	Output in (mV/V) Measurement points		Linear regression (increasing)	Relative nonlinearity in % FS		Hysteresis in % FS	Measurement uncertainty
DS in mm	increasing	decreasing	(mV/V)	increasing	decreasing		
0,0	−55,7557	−55,7817	−55,6675	0,09	0,11	−0,03	20 µm
7,0	−35,0691	−34,9266	−35,0732	0,00	−0,14	0,14	
10,5	−24,7819	−24,7017	−24,7761	0,01	−0,07	0,08	
14,0	−14,5041	−14,4305	−14,4789	0,02	−0,05	0,07	
17,5	−4,1009	−3,9882	−4,1817	−0,08	−0,19	0,11	
21,0	6,1014	6,2029	6,1154	0,01	−0,09	0,10	
24,5	16,4934	16,5716	16,4126	−0,08	−0,15	0,08	
28,0	26,8904	26,9772	26,7097	−0,18	−0,26	0,08	
31,5	36,9997	37,1012	37,0069	0,01	−0,09	0,10	
35,0	47,0873	47,1740	47,3041	0,21	0,13	−0,08	

A.3 Results

Table A.2 — Results

Full scale (FS)	0 - 25	mm
Output bandwidth	102,8430	(mV/V)
Slope / sensitivity	2,9420	(mV/V)/mm
Constant term	−55,6675	(mV/V)
Interpolation error / FS	0,21	% FS
Hysteresis / FS	0,14	% FS
Repeatability	0,0454	mm
Transfer function	0,3399	mm/(mV/V)
Inverse constant term	18,9214	mm



Key

X displacement in mm

Y1 readings in (mV/V)

Y2 relative interpolation error in % FS

readings

relative interpolation error in % FS

Figure A.2 — Measurement data

A.4 Uncertainty calculation

The measurement uncertainty calculation contains the CMC of the calibration system and the results of the actual calculation. The uncertainty calculation takes the following standard uncertainties into account:

1) CMC of the calibration system:	0,010 mm	or	0,029 % FS
Actual calibration results:			
2) Interpolation error of the sensor: 0,21 % FS (rectangular distribution)	0,045 mm	or	0,126 % FS
3) Hysteresis of the sensor: 0,14 % FS (rectangular distribution)	0,030 mm	or	0,084 % FS
4) Repetition of the sensor:	0,005 mm	or	0,015 % FS
Quadratic addition of 1) – 4):	0,056 mm	or	0,16 % FS
The measurement uncertainty expanded with k = 2:	0,12 mm	or	0,35 % FS