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Road vehicles — Displacement calibration method of IR-TRACC devices

Véhicules routiers — Méthode d'étalonnage de déplacement des dispositifs IR-TRACC

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Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 36, *Anthropomorphic test devices*.

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 non-linear telescopic displacement sensors known as IR-TRACC. This device is commonly used on crash dummies to measure the chest deflection as injury an assessment parameter. Various aspects specific to this type of sensors are addressed in this procedure, among others linearization of the exponential voltage output and the sensitivity to tubes position of the telescopic devices.

Road vehicles — Displacement calibration method of IR-TRACC devices

1 Scope

This document establishes a procedure to calibrate IR-TRACC displacement transducers. Like all other sensors used on dummies, calibration is required. The calibration is carried out with the sensor disassembled from the dummy. The procedure is valid for sensors with analogue as well as digital output.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6487, *Road vehicles — Measurement techniques in impact tests — Instrumentation*

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 http://www.electropedia.org/

3.1
IR-TRACC
Infra-Red Telescoping Rod for the Assessment of Chest Compression
non-ratiometric displacement transducer used to measure chest deflection in crash dummies

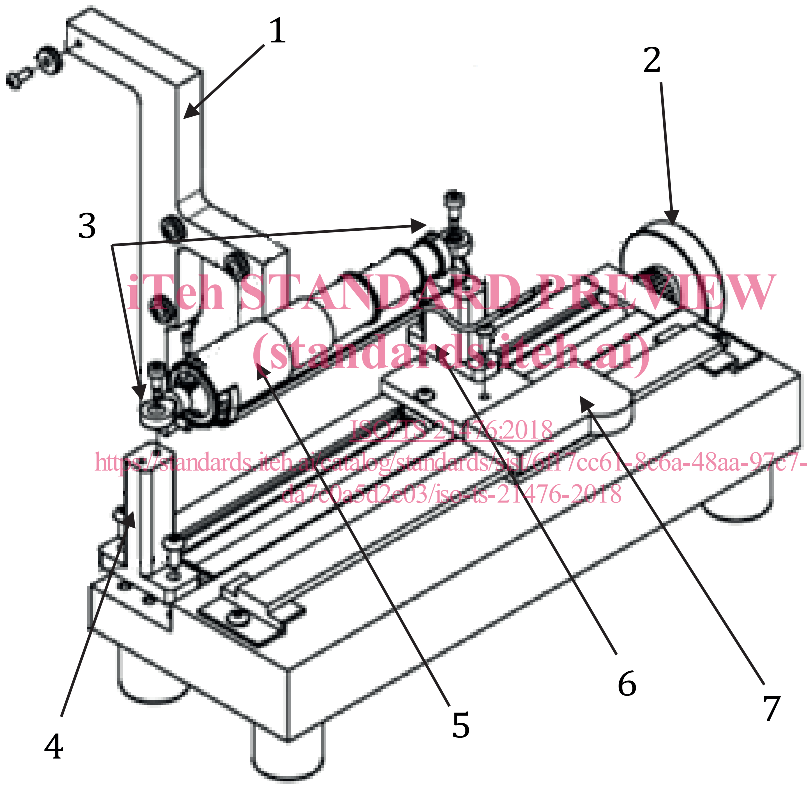
Note 1 to entry: The technology of the transducer was described in a paper by Rouhana et al. [1998][1]. The measurement principle is based on emission of infra-red light by an LED and a phototransistor sensitive to irradiance. The transducer is a non-linear device, as the irradiance and output voltage is proportional to the inverse square of the distance between the emitter and the phototransistor. The distance between the phototransistor and the LED is theoretically proportional to the inverse square root of the phototransistor output voltage: $d = C/\sqrt{U_{IR}}$. The inverse square root of the output voltage can also be written as the output voltage to the power of minus 0,5, therefore $d = C \times U_{IR}^{-0,5}$

3.2
Displacement Calibration
classic compression method where the zero mm starting point is defined close to the extended range of the sensor

Note 1 to entry: When the IR-TRACC overall length decreases (IR-TRACC compresses), its calibrated mm output increases. The IR-TRACC linearized output is negatively proportional to its length. 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 displacement calibration therefore is not an absolute point to point (distance) calibration against a fixed reference. This is not necessary as the chest deflection of the dummy is calculated with respect to the IR-TRACC displacement at time zero. The IR-TRACC displacement output is associated with the ISO MME[2] Code DS for Displacement.

3.3
Displacement Calibration Fixture
fixed head to which the large diameter end of the IR-TRACC is attached through an interface, and a moveable cross head parallel to the sensitive axis of the IR-TRACC to which the small diameter end of the IR-TRACC is attached through another interface

Note 1 to entry: An example of a displacement calibration fixture is shown in Figure 1. The maximum allowable axis parallelism deviation is 1,5 mm[1)]. The minimum distance between the moveable and fixed head interface is less than the collapsed interface distance of the smallest sensor (currently 55 mm) and the maximum exceeds the fully extended interface distance of the largest displacement sensor (currently 201 mm). The interfaces have freedom of rotation about the two axis perpendicular to sensitive axis. The moveable head position is accurately adjustable by means of, for instance, a hand or motor operated screw; the moveable head is linked to a displacement measurement gage parallel to the sensitive axis with a resolution of at least 0,01 mm. The moveable head is linked to the displacement gage without mechanical play. A lateral loading fixture is mounted about half way between the fixed and moving cross head to execute the forced lateral manipulation test.



Key

1 Lateral loading fixture
2 Screw to position cross head
3 Interfaces
4 Fixed head
5 IR-TRACC
6 Moving cross head
7 Linear gauge

Figure 1 — Example Displacement Calibration Fixture (exploded view)

1) Generally a 1,5 mm crosshead parallelism deviation causes less than 0,01 mm displacement deviation.

3.4
Nominal Linearization Exponent
theoretical parameter to linearize the phototransistor voltage output as an inverse square root function, or the voltage output U_{IR} to the power of −0,5

Note 1 to entry: See 3.1. The theoretical linearization exponent is -0,5 [–]. During inception of the IR-TRACC it was found based on a certain quantity of examples or prototypes that in practise the exponent to linearize IR-TRACCs was not −0,5, but was close to −0,428 57.

Note 2 to entry: $d = C * U_{IR}^{-0{,}428\,57}$

Note 3 to entry: This value has been used for some time as a fixed exponent to linearize the voltage output, but due to minimal individual differences of IR-TRACC components, this fixed value did not give the smallest linearization error for each individual transducer. Up to this date this value is now applied as a starting exponent for optimization of the exponent (see 3.5 and 3.6).

3.5
Optimized Linearization Exponent
calibration parameter based on the actual calibration data (output voltage over calibration range) of one individual sensor, giving the least linearization error over the entire calibration range

3.6
Exponent Optimization
optimization of the Linearization Exponent by applying data processing, for instance (but not limited to) numerical optimization

Note 1 to entry: The method finds the best linearization exponent that minimises the linearization errors over the entire calibration range. The result of the process is the optimized linearization exponent EXP, Calibration Factor C_{IR}, Displacement Intercept I_{DS}, Sensitivity S_{IR} and Displacement Intercept Voltage I_{DSV}. The optimization method is explained in 6.3.

3.7
Forced Lateral Manipulation Test
test implemented to ensure an IR-TRACC is not overly sensitive to bending of the tubes in a direction perpendicular to the axis of displacement measurement

Note 1 to entry: The test is executed at the zero displacement point. A force of 4,45 N ± 0,15 N is exerted to the IR-TRACC tube pulling perpendicular to the axis of compression about halfway between the fixed head and the moving cross head (the distance of the lateral loading point does not have to be exact, as the applied force is adequate to manipulate the tubes in bending extremes). The IR-TRACC lateral test output voltages ($U_{IR\text{-}LAT}$) are recorded pulling in four directions spaced 90 degrees.

3.8
Tubes In-Out Calibration Method
calibration procedure that takes two extreme tube position conditions into account at each calibration interval (tubes-in and tubes-out position) to ensure an IR-TRACC is not overly sensitive to the individual positions of the telescope tubes

Note 1 to entry: Tubes-in: all free tubes are moved to the largest diameter end (to fixed cross head); Tubes-out: all free tubes are moved to the smallest diameter end (to moving cross head).

Note 2 to entry: In any length of the IR-TRACC displacement range (except fully extended/fully collapsed) the intermediate telescope tubes are free to move position.

4 Symbols and abbreviated terms

A list of symbols, abbreviated terms, units and definitions is given in Table 1. The output of analogue sensors in V and the output of digital sensors in LSB (Least Significant Bit) are handled in the same way, hence the same parameters and symbols apply to analogue and digital sensors throughout this document. The only difference is the amount of decimals used to express the values, as the analogue output are generally low values (0,060 0 - 2,000 0 V) and digital output are generally high values (1 000,0 - 32 000,0 LSB).

Table 1 — List of symbols

Nr	Parameter	Symbol	Unit	Definition/Description
1	Zero displacement point	d_S	mm	Starting point of displacement calibration d=0 (fully compressed + calibration range + 2 mm)
2	Calibration range	d_e	mm	End point of displacement calibration
3	Displacement	d	mm	Displacement from zero displacement point
4	Lateral manipulation displacement	d_{LAT} $d_{LAT-MAX}$ $d_{LAT-MIN}$	mm	Calculated displacement under forced lateral manipulation, maximum and minimum
5	IR-TRACC output	U_{IR}	V (LSB)	IR-TRACC output voltage (or digital output)
6	Tubes-IN voltage	U_{IR-IN}	V (LSB)	(Digital) output voltage at certain displacement with all floating tubes pushed IN
7	Tubes-OUT voltage	U_{IR-OUT}	V (LSB)	(Digital) output voltage at certain displacement with all floating tubes pushed OUT
8	Average In-Out voltage	U_{IR-AVE}	V (LSB)	Average of Tubes-IN and Tubes-OUT (Digital) voltage
9	Forced lateral manipulation voltage	U_{IR-LAT}	V (LSB)	(Digital) output voltage at forced lateral manipulation
10	Nominal Linearization exponent	EXP_{NOM}	—	IR-TRACC linearization optimization routine starting value: -0,428 57 (fixed)
11	Optimized exponent	EXP	—	IR-TRACC linearization exponent resulting from optimization routine
12	Linearized voltage (or linearized digital output)	U_{LIN}	(V_{LIN}) (LSB_{LIN})	IR-TRACC output voltage (or digital output) to power of exponent (The linearized voltage (digital output) is a calculated parameter, not a physical quantity)
13	Calculated nominal displacement	d_{NOM}	mm	Displacement calculated using average In-Out voltage (or digital output)
14	Nominal linearity error	E_{NOM}	%	Error of calculated displacement using average in-out voltage w.r.t. calibration displacement
15	Calculated deviation-In	Δ_{IN}	mm	Deviation calibration displacement and calculated displacement using Tubes-In voltage
16	Calculated deviation-Out	Δ_{OUT}	mm	Deviation calibration displacement and calculated displacement using Tubes-Out voltage
17	Maximum variation	Δ_{MAX}	mm	Difference calculated deviation-In and calculated deviation-Out
18	Maximum Variation error	Var_{MAX}	%	Maximum variation divided by calibration range
The measurement techniques applied in this procedure shall be in accordance with ISO 6487.				

Table 1 *(continued)*

Nr	Parameter	Symbol	Unit	Definition/Description
19	Maximum Linearity error	E_{MAX}	%	Maximum error of calculated displacement using tubes-in voltage or tubes-out voltage (highest error from the two) w.r.t. calibration displacement
20	Maximum variance lateral displacement	Δ_{LAT}	mm	Maximum variance of lateral displacement: $\Delta_{LAT\text{-}MAX}$ minus $\Delta_{LAT\text{-}MIN}$
21	Maximum Lateral Variance Error	E_{LAT}	%	Maximum error of lateral variance w.r.t. calibration range
22	Calibration factor	C_{IR}	(mm/V_{LIN}) (mm/LSB_{LIN})	IR-TRACC mm displacement per linearized voltage (or linearized digital output) pertaining to optimized exponent
23	Sensitivity	S_{IR}	(V_{LIN}/mm) (LSB_{LIN}/mm)	IR-TRACC linearized voltage (or linearized digital output) per 1mm displacement pertaining to optimized exponent
24	Sensitivity	S_{NOM}	(V_{LIN}/mm) (LSB_{LIN}/mm)	IR-TRACC linearized voltage (or linearized digital output) per 1 mm displacement pertaining to nominal exponent EXP_{NOM}
25	Displacement Intercept	I_{DS}	mm	Calculated displacement at U_{LIN} = 0
26	Displacement intercept voltage	I_{DSV}	(V_{LIN}) (LSB_{LIN})	Linearized Voltage (or linearized digital output) at 0 mm displacement
The measurement techniques applied in this procedure shall be in accordance with ISO 6487.				

5 Displacement Calibration Procedure

This clause describes the procedure for displacement calibration of IR-TRACCs. This calibration is run according to the classic compression method: the zero mm starting point is defined at the extended range of the sensor: at full length the compression is close to zero mm and with increasing compression the IR-TRACC gets shorter until almost fully compressed (=highest mm output) the IR-TRACC is shortest.

The procedure shall be performed on a linear calibration fixture, see example in Figure 1. In this procedure, calibration data shall be obtained in two conditions at each calibration interval: with IR-TRACC free intermediate tubes fully compressed in and fully extended out (Tubes In-Out). The calibration data shall be entered in data processing software, which shall calculate the optimized linearization exponent and linear sensitivity based on the input data, taking into account data from both tube conditions at each displacement interval. The software shall calculate the maximum linearity error per calibration interval and the maximum variation per calibration interval.

An example of the calibration software is available as template and is presented in Annex B. If users choose to apply other calibration fixtures or calibration software, some of these instructions may not directly apply. However, the manner in which the IR-TRACC is manipulated through the calibration increments shall apply, as shall the use of the calibration software.

The displacement calibration procedure is detailed in 5.1 through 5.6; the calibration data processing procedure is detailed in Clause 6.