
**Road vehicles — Measurement
techniques in impact tests — Optical
instrumentation**

*Véhicules routiers — Techniques de mesure lors des essais de chocs —
Instrumentation optique*

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This third edition cancels and replaces the second edition (ISO 8721:2010), of which it constitutes a minor revision with editorial changes.

Road vehicles — Measurement techniques in impact tests — Optical instrumentation

1 Scope

This document defines performance criteria for an optical data channel used in impact tests on road vehicles, when numerical time and space data are taken from images to analyse impact test results.

The objective of this document is to facilitate comparison between results obtained by different laboratories by specifying minimum quality criteria.

[Annexes A, B, C](#) and [D](#) present a method of measuring several indices like quality parameters of sub processes of the optical data channel, using a calibration target, reference distances and analysis systems.

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

ISO 8721:2018

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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:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

analysis system

system to measure and collect the coordinates of target points in image space as a function of time

Note 1 to entry: The calculation results of the analysis system are 3D coordinates in object space, whereas in the case of 2D analysis, the depth of the target points is known and considered.

3.2

cell size

distance of neighbouring pixels on the sensor of an image recording device

Note 1 to entry: If there are different distance values in the two main directions of the image, the cell size is the maximum of these values.

3.3

control point

point that was determined with a higher accuracy and is further accepted as an error-free point

**3.4
frame rate**

f_r
frequency of renewal of information for a given point, expressed in renewals per second, or in images per second if all points of the image are renewed simultaneously

**3.5
image recording device**

system composed of a camera/lens unit together with a recording system

**3.6
location accuracy**

a_{loc}
desired accuracy of the object or target being measured

**3.7
optical data channel**

system composed of one or more image recording devices and a system for analysing the images, including any analysis procedure and data correction that validate and modify the content of the data

**3.8
reference distance**

known distance between a validation target pair

**3.9
synchronism device**

device to identify the synchronism effect in two or more corresponding image recording devices

**3.10
time base system**

device allowing determination of the time interval elapses between any two recorded events for each image recording device

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**3.11
time origin identification device**

device to identify the instant chosen as the time origin, usually the contact between the test objects

**3.12
validation target pair**

pair of targets placed in the field of view so that the distance separating them remains constant

Note 1 to entry: Both of them are visible during the impact test.

**3.13
accuracy value**

a
value that represents the relative overall accuracy of any point measurement within the optical data channel when the performance value is satisfied

**3.14
accuracy value limit**

r_{avl}
user-defined limit for the accuracy value that represents the relative overall accuracy of any point measurement within the optical data channel when the performance value is satisfied

**3.15
camera position calculation index**

i_{cpc}
index that gives the possibility to evaluate whether the accuracy of the optical data channel determined from one time step is representative for the entire sequence

3.16 camera set-up index

 i_{cs}

index that makes it possible to evaluate whether the set-up of the camera with respect to the movement plane permits a reliable analysis

Note 1 to entry: Only for 2D film analysis.

3.17 control point distribution index

 i_{cpd}

index that makes it possible to evaluate whether the distribution of the control points in the image permits a reliable orientation of the used images

3.18 distortion index

 i_d

index that makes it possible to evaluate whether the interior orientation parameters of the used camera are still valid

3.19 focal length index

 i_{fl}

index that makes it possible to evaluate whether the focal length of the used image recording device is still valid

3.20 index value

value that is determined by its index calculation equation (one value for each index)

Note 1 to entry: For the different index calculation equations see [Annex A](https://standards.iteh.ai/catalog/standards/sist/269c8d2c-2b6d-4cb9-83c8-73d26f1181fd/iso-8721-2018).

Note 2 to entry: The index value is the result of the index determination and is a floating point number.

3.21 index condition condition of the check of the index

Note 1 to entry: The index condition can be true (value 1) or false (value 0). A true or false measure indicating if an index is within its required limits."

3.22 intersection index

 i_i

index that makes it possible to evaluate the intersection geometry of the rays from the image recording devices to the object points

Note 1 to entry: Only for 3D film analysis.

3.23 length measurement error

value that represents the absolute overall accuracy of any point measurement within the optical data channel when the performance value is satisfied

3.24 motion blur index

 i_{mb}

index that allows one to evaluate whether the exposure time used in the test is small enough with respect to the appropriate object movement, in order to ensure a reliable point identification and point measurement in the images

3.25

performance value

numerical value indicating suitable general conditions for the estimation of the accuracy of the optical data channel

Note 1 to entry: It is derived from all indices which describe the performance of the optical data channel.

3.26

plane scale index

i_{ps}
index used to rate the appropriateness of evaluating the scale constellation in the movement planes (scale in each movement plane)

Note 1 to entry: Only for 2D film analysis.

3.27

point motion index

i_{pm}
index used to rate the appropriateness of the frame rate in regards to test requirements

3.28

scale index

i_s
index used to rate the appropriateness of the scale constellation to control the system scale (presence of independent reference distances)

3.29

synchronism index

i_{sy}
index used to rate the appropriateness of the synchronization method for the data analysis in regards to the test requirements

Note 1 to entry: Only for 3D film analysis.

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3.30

target detection index

i_{td}
index used to rate the appropriateness of the measuring accuracy of the image coordinates in regards to test requirements

3.31

target size index

i_{ts}
index used to rate the appropriateness of the target size for a reliable point identification and point measurement in the images

3.32

time base index

i_{tb}
index used to rate the appropriateness of the used time base system in regards to the test requirements

3.33

time origin identification index

i_{toi}
index used to rate the appropriateness of the used time origin identification device in regards to the test requirements

4 Symbols and abbreviated terms

| Symbol | Definition |
|-----------------|---|
| A_{cf} | control point formed area |
| A_i | image area |
| a | accuracy value of the optical data channel |
| a_{alaid} | allowed location accuracy in depth |
| a_{clad} | current location accuracy (distortion) |
| a_{claf} | current location accuracy (focal length) |
| a_{clai} | current location accuracy (intersection) |
| a_{claid} | current location accuracy in depth |
| a_{clat} | current location accuracy (target) |
| a_{clatb} | current location accuracy (time base) |
| a_{clatoi} | current location accuracy (time origin identification) |
| a_d | distortion accuracy |
| a_{fl} | focal length accuracy |
| a_{fr} | frame rate accuracy |
| a_{loc} | location accuracy |
| $a_{refdist,r}$ | accuracy value of the reference distance, r |
| a_{td} | target detection accuracy |
| d | object distance |
| e | exposure time |
| f | focal length |
| f_r | frame rate |
| i_{cpc} | camera position calculation index |
| i_{cpd} | control point distribution index |
| i_{cs} | camera set-up index |
| i_d | distortion index |
| i_{fl} | focal length index |
| i_i | intersection index |
| i_{mb} | motion blur index |
| i_{pm} | point motion index |
| i_{ps} | plane scale index |
| i_s | scale index |
| i_{sy} | synchronism index |
| i_{tb} | time base index |
| i_{td} | target detection index |
| i_{toi} | time origin identification index |
| i_{ts} | target size index |
| ΔL | length measurement error of the optical data channel |
| Δl_r | length measurement error of reference distance, r |
| l_{aed} | asynchronism effect in viewing direction |
| l_{aep} | asynchronism effect perpendicular to the viewing direction |
| l_{apm} | allowed point motion between two sequenced images in object space |
| $l_{c,r}$ | calibrated length of reference distance, r |
| l_{cb} | camera base |

| Symbol | Definition |
|--------------|--|
| l_{cmbv} | current motion blur value |
| l_{cpm} | current point motion between two sequenced images in object space |
| l_{cs} | cell size |
| l_{ctd} | current target diameter |
| l_{dco} | distance camera base to object |
| l_{fpd} | fix point distance |
| l_{ih} | image height |
| l_{iw} | image width |
| $l_{m,r}(t)$ | measured length of reference distance, r , as a function of time |
| l_{mdi} | maximum displacement in image space |
| l_{mdo} | maximum displacement in object space |
| l_{rtd} | required target diameter |
| l_{ttd} | theoretical target diameter |
| p | 3D performance value of the optical data channel |
| p_{cpa} | control point area |
| p_{cpd} | control point distribution |
| $p_{dtp,i}$ | distance to plane of motion i |
| p_{np} | number of planes of motion |
| $p_{rd,r}$ | reference distance |
| $p_{rd,i}$ | reference distance in direction i |
| $p_{rdp,i}$ | reference distance in plane of motion i |
| p_{siap} | scale information in all planes of motion |
| $p_{sip,i}$ | scale information in plane of motion i |
| p_{syd} | synchronism index in viewing direction |
| p_{syp} | synchronism index perpendicular to the viewing direction |
| $p_{t,i}$ | target in image section i |
| p_{tpc} | type of camera set-up |
| p_{tpd} | type of position determination |
| Q | performance value of the optical data channel |
| q_i | 2D performance value of the image recording device i |
| r_{aar} | allowed accuracy relation |
| r_{avl} | accuracy value limit |
| r_{car} | current accuracy relation |
| t_b | beginning of the analysed time interval |
| t_c | user-defined time within the analysed time interval |
| t_{ca} | current asynchronism |
| t_{dtz} | difference between t_0 -image and -signal |
| t_e | end of the analysed time interval |
| t_{int} | time interval |
| t_{td} | time drift |
| t_{ttd} | total time drift |
| v | velocity |

5 Performance

5.1 General requirements

The performance of the optical data channel shall be evaluated initially to establish performance levels. This evaluation shall be repeated whenever the system is modified to an extent which could cause a change in accuracy. This shall be done with an offline procedure.

It is also possible to measure the performance of the optical data channel during an impact test. This is called the online procedure.

The performance of the optical data channel shall be estimated using 2D performance values, or 3D performance values, or both. These values consist of different performance indices depending on the test constellation. To verify the estimated performance values, an accuracy value shall be determined using two or more reference distances.

If a film analysis is carried out using the image sequences of on-board cameras, the used equipment (camera and lens) shall correspond to the expected shock.

Further details are described in the annexes.

The determination methods for several indices are described in [Annex A](#) and shall be used for the index calculation.

Details for the two measurement methods (online and offline procedure) are listed in [Annex B](#).

A complete list of all used parameters with short text, long text and the type is in [Annex C](#).

The matrix structure in [Annex D](#) presents the dependencies between the indices and the parameters.

5.2 Reference distance

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The reference distances shall be determined 10 times more precisely than the desired location accuracy. The determination of the reference distances shall be done before the test.

The reference distances shall be located on approximately perpendicular (90 ± 10)° lines (see [A.3.2](#)). For 3D analysis, all three directions in space shall be covered. See [Annex A](#) for additional information.

5.3 Time base system

The time base shall be determined 10 times more precisely than the desired time accuracy.

5.4 Performance of the optical data channel

5.4.1 General

The performance of the optical data channel consists of different indices (see [Table 1](#)). The determination depends on the application (2D or 3D).

5.4.2 Performance indices

Each index value shall be at least 0,5. If this minimum requirement is not fulfilled for every index, then the impact test does not conform to this document. The index condition of a certain index is 0 if the requirements for this index (see [Annex A](#)) are not fulfilled; otherwise the index condition is 1.

Table 1 — Performance indices

| Index | 2D | 3D | Number per optical data channel | Comment |
|--|----|----|---------------------------------|---------------------------------------|
| Focal length index | a | a | one per image recording device | in a suitable image |
| Distortion index | a | a | one per image recording device | in a suitable image |
| Target detection index | a | a | one per image recording device | worst target used in the analysis |
| Target size index | a | a | one per image recording device | worst target used in the analysis |
| Motion blur index | a | a | one per image recording device | at maximum object speed |
| Point motion index | a | a | one per image recording device | at maximum object speed |
| Control point distribution index | a | a | one per image recording device | in a suitable image |
| Time base index | a | a | one per image recording device | — |
| Time origin identification index | a | a | one per image recording device | — |
| Camera set-up index | a | b | one per image recording device | — |
| Plane scale index | a | b | one per image recording device | — |
| Intersection index | b | a | one | best pair of image recording devices |
| Synchronism index | b | a | one | worst pair of image recording devices |
| a Index value is used for the performance value. b Index value is not used for the performance value. | | | | |

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5.4.3 2D performance value

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The performance value for every image recording device is estimated by all 2D related index conditions (see Table 1). The 2D performance value, q_i , is the ratio of the achieved sum to the possible sum of index conditions with respect to the test requirements, and is calculated as shown in Formula (1):

$$q_i = \frac{\sum_{j=1}^n x_{ji}}{n} \tag{1}$$

where

- i is the image recording device number;
- j is the 2D performance index number;
- x_{ji} is the index condition of the 2D performance index, j , of the image recording device, i ;
- n is the number of 2D performance indices (2D film analysis: $n = 11$; 3D film analysis: $n = 9$).

5.4.4 3D performance value

The 3D performance value of the optical data channel, p , is calculated as shown in Formula (2):

$$p = \sum_{k=1}^m y_k \tag{2}$$

where

k is the 3D performance index number;

y_k is the index condition of the 3D performance index, k , of the optical data channel;

m is the number of 3D performance indices ($m = 2$).

5.4.5 Performance value of the optical data channel

For 2D analysis, the performance value of the optical data channel, Q , is identical to the 2D performance value, q_1 , as shown in [Formula \(3\)](#):

$$Q = q_1 \quad (3)$$

For 3D analysis with only one image recording device, the intersection index and the synchronism index are not defined. In this case, the performance value of the optical data channel, Q , is equal to the 2D performance value, q_1 .

For 3D analysis, the performance value of the optical data channel, Q , is the ratio of the achieved sum to the possible sum of all index conditions, calculated according to [Formula \(4\)](#):

$$Q = \frac{\left(n \times \sum_{i=1}^u q_i \right) + (p \times u)}{(n \times u) + (m \times u)} = \frac{\left(\frac{n}{u} \times \sum_{i=1}^u q_i \right) + p}{n + m} \quad (4)$$

where

i is the image recording device number;

q_i is the 2D performance value of the image recording device, i ;

u is the number of image recording devices;

n is the number of 2D performance indices (2D film analysis: $n = 11$; 3D film analysis: $n = 9$);

m is the number of 3D performance indices ($m = 2$);

p is the 3D performance value of the optical data channel.

5.5 Accuracy of the optical data channel

5.5.1 Accuracy indices

The accuracy indices are shown in [Table 2](#).

Table 2 — Accuracy indices

| Index | Number per optical data channel | Comment |
|-----------------------------------|---------------------------------|---------------------|
| Camera position calculation index | one per image recording device | — |
| Scale index | one | indispensable index |

5.5.2 Length measurement error and accuracy value of a reference distance

The length measurement error and accuracy value of a reference distance are defined as follows:

- the length measurement error, Δl_r , of the reference distance, r , is the maximum difference between the measured length, $l_{m,r}(t)$, and the calibrated length, $l_{c,r}$, within the analysed time interval;
- the accuracy value, $a_{\text{refdist},r}$ of the reference distance, r , is the maximum relative difference between the measured length, $l_{m,r}(t)$, and the calibrated length, $l_{c,r}$, within the analysed time interval.

All used image recording devices shall be used for the calculation of the reference distances.

If the index condition of the camera position calculation index, i_{cpc} , of all used image recording devices is fulfilled, the length measurement error, Δl_r , can be determined at a single time step within the analysed time interval. If the index condition of only one image recording device is not fulfilled, the length measurement error, Δl_r , shall be calculated for every time step within the analysed time interval. The accuracy value, $a_{\text{refdist},r}$ of the reference distance, r , is the ratio between the length measurement error, Δl_r , and the calibrated length, $l_{c,r}$.

If every $i_{\text{cpc},i} \geq 1$, then the length measurement error, Δl_r , is calculated according to [Formula \(5\)](#):

$$\Delta l_r = |l_{m,r}(t_c) - l_{c,r}| \tag{5}$$

where

- $i_{\text{cpc},i}$ is the index value of the camera position calculation index of the image recording device, i ;
- i is the image recording device number;
- r is the reference distance number; [ISO 8721:2018](#)
- $l_{m,r}(t)$ is the measured length of reference distance, r , as a function of time; <https://standards.iteh.ai/catalog/standards/sist/269c8d2c-2b6d-4cb9-83c8-7bed024b4183/iso-8721-2018>
- $l_{c,r}$ is the calibrated length of reference distance, r .

If any $i_{\text{cpc},i} < 1$, then the length measurement error, Δl_r , is calculated according to [Formula \(6\)](#):

$$\Delta l_r = \max |l_{m,r}(t) - l_{c,r}|_{t_b}^{t_e} \tag{6}$$

where

- t_b is the beginning of the analysed time interval;
- t_e is the end of the analysed time interval;
- t_c is a user-defined time within the analysed time interval.

The accuracy value, $a_{\text{refdist},r}$, is calculated according to [Formula \(7\)](#):

$$a_{\text{refdist},r} = \frac{\Delta l_r}{l_{c,r}} \tag{7}$$

5.5.3 Length measurement error and accuracy value of the optical data channel

- The length measurement error of the optical data channel, ΔL , is the maximum of the length measurement errors, Δl_r , of all reference distances, r .
- The accuracy value of the optical data channel, a , is the maximum of the accuracy values, $a_{\text{refdist},r}$, of all reference distances, r .

$$\Delta L = \max(\Delta L_r) \quad (8)$$

$$a = \max(a_{\text{refdist},r}) \quad (9)$$

5.6 Types of procedure

5.6.1 General

Conformity with this document can be verified by different types of procedure, depending on the desired complexity. The different types of procedure are shown in [Table 3](#).

Table 3 — Types of procedure

| Type of procedure | Before the real impact test | | During the real impact test | |
|-------------------|-----------------------------|---|---|---|
| | Performance value | Accuracy value | Performance value | Accuracy value |
| Online | — | — | $Q \geq 0,7$ | $\Delta L \leq a_{\text{loc}}$ $a \leq r_{\text{avl}}$ |
| Offline | $Q \geq 0,8$ | $\Delta L \leq a_{\text{loc}}$ $a \leq r_{\text{avl}}$ | Synchronism index $i_{\text{sy}} \geq 1$ (only 3D analysis) | $\Delta L \leq a_{\text{loc}}$ $a \leq r_{\text{avl}}$ |

Key

Q performance value of the optical data channel

ΔL length measurement error of the optical data channel

a accuracy value of the optical data channel

r_{avl} user-defined accuracy value limit of the optical data channel

a_{loc} user-defined location accuracy of the optical data channel

5.6.2 Type of procedure — Online

5.6.2.1 The online procedure is of the highest complexity. All work shall be done for every impact test. The performance and the accuracy of the optical data channel can be checked during the test.

This procedure can be used, if the equipment of the optical data channel will often be changed essentially between the impact tests, or if no prior information about the optical data channel is available.

The user has the possibility to evaluate every component of the optical data channel for every impact test.

5.6.2.2 Tasks during the impact test are specified below.

- All described performance and accuracy indices shall be calculated during the real impact test.
- All described performance index values shall be at least 0,5.
- The performance value of the optical data channel, Q , shall be greater than 0,7.
- The length measurement error of the optical data channel, ΔL , shall be lower than the location accuracy, a_{loc} .
- The accuracy value of the optical data channel, a , shall be lower than the accuracy value limit, r_{avl} .

5.6.3 Type of Procedure — Offline

5.6.3.1 The offline procedure is of middle complexity. The main part of the calculation shall be done once in the preliminary test. The performance of the optical data channel can only be checked in this test.