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Contents

Page

Foreword

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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

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

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.

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.

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

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.

5.4.3 2D performance value

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):

$$Q = q_1 \tag{3}$$

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):

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

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, $a_{refdist,r}$, 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, $a_{refdist,r}$, of the reference distance, r, is the ratio between the length measurement error, Δl_r, and the calibrated length, $l_{c,r}$.

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

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

where

$i_{cpc,i}$ 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;

$l_{m,r}(t)$ is the measured length of reference distance, r, as a function of time;

$l_{c,r}$ is the calibrated length of reference distance, r.

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

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

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, $a_{refdist,r}$, is calculated according to Formula (7):

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

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, $a_{refdist,r}$, of all reference distances, r.