Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 4: Variables to be measured, instrumentation and measurement procedures
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

This part of ISO 13232 was prepared by Technical Committee ISO/TC 22, Road vehicles, Subcommittee SC 22, Motorcycles.

At the request of the United Nations Economic Commission for Europe, Group for Road Vehicle General Safety (UN/ECE/TRANS/SCI/WP29/GP6), this International Standard has been prepared by ISO/TC 22/SC 22, Motorcycles, as eight interrelated parts, on the basis of original working documents submitted by the International Motorcycle Manufacturers Association (IMMA).

This is the first version of the standard.

ISO 13232 consists of the following parts, under the general title Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles:

- Part 1: Definitions, symbols and general considerations
- Part 2: Definition of impact conditions in relation to accident data
- Part 3: Anthropometric impact dummy
- Part 4: Variables to be measured, instrumentation and measurement procedures
- Part 5: Injury indices and risk/benefit analysis
- Part 6: Full-scale impact-test procedures
- Part 7: Standardized procedures for performing computer simulations of motorcycle impact tests
- Part 8: Documentation and reports

Annexes A, B and C form an integral part of this part of ISO 13232. Annex D is for information only.
Introduction

This International Standard has been prepared on the basis of existing technology. Its purpose is to define common research methods and a means for making an overall evaluation of the effect that devices which are fitted to motor cycles and intended for the crash protection of riders, have on injuries, when assessed over a range of impact conditions based on accident data.

It is intended that the methods and recommendations contained in this International Standard should be used in all basic feasibility research. However, researchers should also consider variations in the specified conditions (for example, rider size) when evaluating the overall feasibility of any protective device. In addition, researchers may wish to vary or extend elements of the methodology in order to research issues which are of particular interest to them. In all such cases which go beyond the basic research, if reference is to be made to this International Standard, a clear explanation of how the procedures used differ from the basic methodology should be provided.

In order to apply this International Standard properly, it is strongly recommended that all eight parts be used together, particularly if the results are to be published.

To the extent, if any, that any products identified in this International Standard may be subject to patent rights, and to the extent, if any, that licenses may be available relative to such patents, potential manufacturers of such products are advised that individual patent inquiries should be made and alternative products considered. A record of patent holders' statements, if any, regarding their willingness to negotiate licenses under patent and like rights with applicants throughout the world under reasonable terms and conditions, is on file with the ISO Central Secretariat.
Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles —

Part 4:
Variables to be measured, instrumentation and measurement procedures

1 Scope

This International Standard specifies the minimum requirements for research into the feasibility of protective devices fitted to motor cycles, which are intended to protect the rider in the event of a collision.

This International Standard is applicable to impact tests involving:
- two wheeled motor cycles;
- the specified type of opposing vehicle;
- either a stationary and a moving vehicle or two moving vehicles;
- for any moving vehicle, a steady speed and straight line motion immediately prior to impact;
- one helmeted dummy in a normal seating position on an upright motor cycle;
- the measurement of the potential for specified types of injury by body region;
- evaluation of the results of paired impact tests (i.e., comparisons between motor cycles fitted and not fitted with the proposed devices).

This part of ISO 13232 specifies requirements for the:
- repeatability and reproducibility of the dynamic measurement procedures for the motor cycle, the opposing vehicle, and the dummy;
- dummy instrumentation.

This International Standard does not apply to testing for regulatory or legislative purposes.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 13232 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

3 Definitions, symbols, and abbreviations

For the purposes of this part of ISO 13232, the definitions given in ISO 13232-1 apply, of which the following are of particular relevance to this part of ISO 13232.

- aim point;
- blur;
- cursor;
- detachable external cables;
- digitizing surface;
- film analysis frame;
- frame width;
- helmet centroid point;
- high speed photography;
- leading edge;
- magnification;
- motion analyser grid;
- oblique camera;
- off axis;
  - output signal voltage;
- overall accuracy of the film analysis;
  - primary axis;
- signal gain;
- trailing edge;
- visual resolution.
4 Requirements

4.1 Electronically recorded variables

4.1.1 Required

The variables listed below shall be recorded in all full-scale impact tests from at least 0.100 s before first MC/OV contact until at least 3,000 s after first MC/OV contact, using the sensors described in 4.4.1.

a) first MC/OV contact occurrence;

b) head (nine linear accelerations):
   1) bottom centre acceleration in three axes ($a_1$, $a_4$, $a_7$),
   2) top centre acceleration in two axes ($a_3$, $a_6$),
   3) bottom left acceleration in two axes ($a_5$, $a_8$),
   4) bottom right acceleration in two axes ($a_2$, $a_9$);

c) chest:
   1) sternum upper left displacement ($l_{UL}$),
   2) sternum upper right displacement ($l_{UR}$),
   3) sternum lower left displacement ($l_{llL}$),
   4) sternum lower right displacement ($l_{llR}$).

4.1.1.1 Additionally required for head protective device evaluation

- upper neck antero-posterior shear force ($F_{x,n}$);
- upper neck lateral shear force ($F_{y,n}$);
- upper neck tension/compression force ($F_{z,n}$);
- upper neck flexion/extension moment ($M_{y,n}$);
- upper neck torsional moment ($M_{z,n}$).

4.1.1.2 Additionally required for leg protective device evaluation

a) left and right upper femur:
   1) axial force ($F_{z,UF}$),
   2) lateral bending moment ($M_{x,UF}$),
   3) antero-posterior bending moment ($M_{y,UF}$);

b) left and right upper tibia:
   1) lateral bending moment ($M_{x,UT}$),
   2) antero-posterior bending moment ($M_{y,UT}$).

4.1.2 Not recommended

The variables listed below should not be recorded because of motor cyclist anthropometric impact dummy biofidelity limitations:

- chest accelerations;
- pelvic accelerations.

4.1.3 Permissible

In addition to the required variables listed in 4.1.1, the variables listed below may be recorded:
a) upper neck:
1) antero-posterior shear force \( F_{x,n} \),
2) lateral shear force \( F_{y,n} \),
3) tension/compression force \( F_{z,n} \),
4) flexion/extension moment \( M_{x,n} \),
5) torsional moment \( M_{z,n} \),
6) lateral bending moment \( M_{x,n} \)

b) lumbar spine:
1) antero-posterior shear force \( F_{x,l} \),
2) lateral shear force \( F_{y,l} \),
3) axial force \( F_{z,l} \),
4) lateral bending moment \( M_{x,l} \),
5) antero-posterior bending moment \( M_{y,l} \),
6) torsional moment \( M_{z,l} \)

c) left and right upper femur:
1) axial force \( F_{z,UF} \),
2) lateral bending moment \( M_{x,UF} \),
3) antero-posterior bending moment \( M_{y,UF} \),
4) torsional moment \( M_{z,UF} \)

d) left and right lower femur:
1) axial force \( F_{z,LF} \),
2) lateral bending moment \( M_{x,LF} \),
3) antero-posterior bending moment \( M_{y,LF} \),
4) torsional moment \( M_{z,LF} \)

e) left and right upper tibia:
1) lateral bending moment \( M_{x,UT} \),
2) antero-posterior bending moment \( M_{y,UT} \),
3) torsional moment \( M_{z,UT} \)

f) left and right lower tibia:
1) axial force \( F_{z,LT} \),
2) lateral bending moment \( M_{x,LT} \),
3) antero-posterior bending moment \( M_{y,LT} \)

4.2 Mechanically recorded variables

The variables listed below shall be recorded in all full-scale impact tests using the sensors described in 4.4.2 and the procedures described in 5.2.3:
- abdomen maximum residual penetration \( \rho_{A,max} \);
- left and right femur fracture occurrence;
- left and right knee varus valgus dislocation occurrence;
- left and right knee torsional dislocation occurrence;
- left and right tibia fracture occurrence.
4.3 Photographic targets to be digitized

The targets listed below shall be digitized at first MC/OV contact, unless otherwise stated.

The high speed photographic data shall be analysed using a motion analyser for which the ratio of the overall accuracy to the magnification is 0,007 or less.

4.3.1 Helmet centroid point

The following helmet centroid point variables shall be determined for the time frame and using the procedures defined in 5.2.4 and annex A:

- inertial longitudinal position ($x_h$);
- inertial lateral position ($y_h$);
- inertial vertical position ($z_h$).

4.3.2 Motor cycle

Motor cycle targets which shall be digitized include the following:

- upper and lower targets on the top to bottom centre line, visible from the rear view, or front view if only the front camera is used;
- front and rear target on the front to rear centre line, visible from the MC top view;
- main frame front and rear reference, visible from the MC side view, from at least 10 film analysis frames before first MC/OV contact until at least first MC/OV contact.

4.3.3 Opposing vehicle

The opposing vehicle targets which shall be digitized and their locations are given in table 1.

<table>
<thead>
<tr>
<th>Target</th>
<th>Locations</th>
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<tbody>
<tr>
<td>Bonnet centre line</td>
<td>100 mm rearward from the bonnet leading edge</td>
</tr>
<tr>
<td></td>
<td>100 mm forward from the bonnet trailing edge</td>
</tr>
<tr>
<td>Roof centre line</td>
<td>100 mm rearward from the roof leading edge</td>
</tr>
<tr>
<td>Boot lid centre line</td>
<td>100 mm forward from the boot lid trailing edge</td>
</tr>
<tr>
<td></td>
<td>100 mm rearward from the boot lid leading edge</td>
</tr>
<tr>
<td>Body side reference(^1)</td>
<td>Visible from OV side view camera</td>
</tr>
</tbody>
</table>

1) From at least 10 film analysis frames before first MC/OV contact until at least first MC/OV contact.

\(^1\) A list describing one or more example products which meet these requirements is maintained by the ISO Central Secretariat and the Secretariat of ISO/TC 22/SC 22. The list is maintained for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the products listed. Alternative products may be used if they can be shown to lead to the same results.
4.3.4 Ground

At least two targets shall be fixed on the ground and shall be visible in each camera prior to and at first MC/OV contact. They shall be at least 2 m apart. The z locations of all target centres shall be equal. At least one of the ground fixed targets shall be visible and undisturbed in each camera from at least 10 film analysis frames before first MC/OV contact until at least first MC/OV contact. Multiple targets should be used to increase the likelihood that at least one is visible and undisturbed during the entire film analysis sequence.

4.3.4.1 MC side view and MC top view

The ground fixed targets which are visible in the MC side view and MC top view cameras shall be aligned such that a line connecting the targets is parallel to the pre-impact centre line or path of the MC.

4.3.4.2 MC rear or MC front view

The ground fixed targets which are visible in the MC rear view or MC front view camera shall be aligned such that a line connecting the targets is perpendicular to the pre-impact centre line or path of the MC.

4.3.4.3 OV side view

The ground fixed targets which are visible in the OV side view camera shall be aligned such that a line connecting them is parallel to the pre-impact centre line or path of the OV.

4.3.5 Dummy

The dummy joint target locations, as defined in 5.3.6 of ISO 13232-6, shall be digitized in the film frame immediately preceding first MC/OV contact, according to 5.3.6 of this part of ISO 13232.

If the test data are to be used for simulation comparison, according to 4.5.4 of ISO 13232-7, then these target locations shall also be digitized according to the procedures defined in 5.2.4 of this part of ISO 13232.

4.4 Sensor specifications

4.4.1 Electrical

4.4.1.1 Head accelerometers

The head linear accelerations listed in 4.1.1 shall be measured using Endevco accelerometers, model 7264 2000, mounted using an accelerometer block as shown in figure 1. The mounting block shall be attached to the Hybrid III head using a mounting base as shown in figure 2.

4.4.1.2 Upper neck load cell

The neck variables listed in 4.1.1.1 and 4.1.3 shall be measured using a Denton load cell, model 1716.

1) Accelerometer model 7264-2000 is a product supplied by Endevco Corp, San Juan Capistrano, California, USA. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Alternative products may be used if they can be shown to lead to the same results.

2) A list describing one or more example products which meet these requirements is maintained by the ISO Central Secretariat and the Secretariat of ISO/TC 22/SC 22. The list is maintained for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the products listed. Alternative products may be used if they can be shown to lead to the same results.

3) Load cell model 1716 is a product supplied by Robert A. Denton, Inc., Rochester Hills, Michigan, USA. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Alternative products may be used if they can be shown to lead to the same results.
Notes:
1. Denotes accelerometer's sensitive axis
2. All sensitive axes, per plane, are located 40.6 apart orthogonally
3. All hidden threaded holes are not shown
4. Break all edges and sharp corners
5. Mounting holes and location of sensitive axes are indicated for Endevco Series 7284—2000 piezoresistive accelerometers
6. Positive head x acceleration should produce negative signals for $\alpha_1$, $\alpha_2$, $\alpha_3$, $\alpha_4$, $\alpha_5$, $\alpha_6$

Figure 1 - Nine accelerometer block with accelerometer mounting locations and orientations.
Notes:
1. Denotes accelerometer's sensitive axis
2. All sensitive axes, per plane, are located 40,6 apart orthogonally
3. All hidden threaded holes are not shown
4. Break all edges and sharp corners
5. Mounting holes and location of sensitive axes are indicated for Endevco Series 7264-2000 piezoresistive accelerometers
6. Details not shown in perspective view
7. Positive head z acceleration should produce positive signals for $a_y, a_z, a_g$

Bottom view

Perspective view
Scale 1:1

Figure 1 (concluded) - Nine accelerometer block with accelerometer mounting locations and orientations
Figure 2 - Nine accelerometer block mounting base
4.4.1.3 Chest potentiometers

The chest displacements listed in 4.1.1 shall be measured using Space Age Control string potentiometers, models 160 321 VL and 160 321 VR\(^1\), mounted as shown in figure 3\(^2\).

4.4.1.4 Lumbar load cell

The lumbar spine forces and moments listed in 4.1.3 shall be measured using a Denton load cell, model 1708\(^3\) for six axes or model 1891\(^3\) for three axes.

4.4.1.5 Upper femur load cells

The upper femur forces and moments listed in 4.1.1.2 and 4.1.3 shall be measured using Denton load cells, model 2693\(^3\).

4.4.1.6 Frangible leg bone strain gauges

The strain gauges used to measure the lower femur and upper and lower tibia forces and moments listed in 4.1.1.2 and 4.1.3 shall conform to the specifications listed in table 2. They shall be mounted on the bones at the locations shown in figure 4.

Table 2 - Frangible leg bone strain gauge specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration</td>
<td>Half or full bridge</td>
</tr>
<tr>
<td>Resistance</td>
<td>350 ohms</td>
</tr>
<tr>
<td>Excitation</td>
<td>2.05 V ± 0.05 V to 2.50 V ± 0.05 V</td>
</tr>
<tr>
<td>Maximum cross axis sensitivity</td>
<td>5%</td>
</tr>
<tr>
<td>Gauge factor</td>
<td>2</td>
</tr>
</tbody>
</table>

Each frangible bone strain gauged variable recorded in each full-scale test shall be calibrated according to 5.2.2.

NOTE - Frangible bone strain gauges which have been properly mounted and calibrated can provide useful additional information in crash tests regarding the general magnitude, direction and timing of bone forces, prior to or in the absence of bone fracture. However, because they are exposed to damage from various sources, and because of possible installation variations, they might not be reliable in all cases, in particular for the time period during and after a bone fractures. In addition, like load cells, they sense force in only one location, whereas the force components elsewhere in the bone can be much larger. For these and other reasons, they are not considered appropriate for injury evaluation or frangible bone conformity of production tests.

1) String potentiometer models 160-321VL and 160-321VR are products supplied by Space Age Controls, Inc., Palmdale, California, USA. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Alternative products may be used if they can be shown to lead to the same results.

2) A list describing one or more example products which meet these requirements is maintained by the ISO Central Secretariat and the Secretariat of ISO/TC 22/SC 22. The list is maintained for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the products listed. Alternative products may be used if they can be shown to lead to the same results.

3) Load cell models 1708, 1891, and 2693 are products supplied by Robert A. Denton, Inc., Rochester Hills, Michigan, USA. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of the product named. Alternative products may be used if they can be shown to lead to the same results.

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