INTERNATIONAL STANDARD

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Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles —

Part 7:
Standardized procedures for performing computer simulations of motorcycle impact tests

Motocycles — Méthodes d'essai et d'analyse de l'évaluation par la recherche des dispositifs, montés sur les motocycles, visant à la protection des motocyclistes contre les collisions —

Partie 7: Méthodes normalisées de simulation par ordinateur d'essais de choc sur motocycles

Reference number
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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/GRSG), 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*

Annex A forms an integral part of this part of ISO 13232. Annex B 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.

This part of ISO 13232 contains the requirements for impact computer simulation and it is optional because it is not essential for carrying out impact testing. However, computer simulation has become an effective tool for identifying potential failure modes and the associated test configurations, as well as for designating proposed devices. Most importantly, a validated computer simulation is the recommended means to extend the test sample results to the overall population of accidents, thereby reducing the size of the test sample needed for making such overall evaluations and inferences.

Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles —

Part 7:
Standardized procedures for performing computer simulations of motorcycle impact tests

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).

The purposes of this part of ISO 13232 are to provide

- conventions for calibrating and documenting the important features of the simulation models;
- guidelines for definition and use of mathematical models for motor cycle impact simulations, which can be correlated against data for full-scale tests;
- a means for identifying possible additional impact conditions for full-scale testing;
- a standardized tool, of optional use, for risk/benefit analysis of rider crash protective devices fitted to motor cycles, based upon the population of impact conditions identified in ISO 13232-2.

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.

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.

ISO 13232-1: 1996, Motor cycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motor cycles - Part 1 - Definitions, symbols and general considerations.

ISO 13232-2: 1996, Motor cycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motor cycles - Part 2 - Definition of impact conditions in relation to accident data.

ISO 13232-3: 1996, Motor cycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motor cycles - Part 3 - Anthropometric impact dummy.

ISO 13232-4: 1996, Motor cycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motor cycles - Part 4 - Variables to be measured, instrumentation and measurement procedures.

ISO 13232-5: 1996, Motor cycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motor cycles - Part 5 - Injury indices and risk/benefit analysis.

ISO 13232-6: 1996, Motor cycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motor cycles - Part 6 - Full-scale impact-test procedures.

ISO 13232-8: 1996, Motor cycles - Test and analysis procedures for research evaluation of rider crash protective devices fitted to motor cycles - Part 8 - Documentation and reports.

49 CFR Part 572, subpart E: 1993, Anthropomorphic test dummies, United States of America Code of Federal Regulations issued by the National Highway Traffic Safety Administration (NHTSA) Washington, D.C.

ISO 6487: 1987, Road vehicles - Measurement techniques in impact tests - Instrumentation.

3 Definitions

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.

- body;
- failure mode and effects analysis (FMEA);
- maximum thickness;
- motion;
- risk/benefit analysis; overall evaluation;
- system.

4 Requirements

4.1 Modelling

The simulation model shall be based upon accepted laws and principles of physics and mechanics. The model shall consist of portions describing a motor cycle (MC) and the opposing vehicle (OV), as described in ISO 13232-6, the dummy, as described in ISO 13232-3, the dummy mounting position, joint tensions, and helmet, as described in ISO 13232-6, the protective device, if present, and the road surface. In the model, the following impact conditions shall be able to be varied, across the range of conditions described in annex B of ISO 13232-2:

- MC impact speed;
- OV impact speed;
- MC contact point;
- OV contact point;
- relative heading angle.

The model of the dummy should include the following bodies, at a minimum:

a) helmeted head;

b) neck;

c) upper torso;

d) lower torso;

e) left and right:

1) upper legs;

2) lower legs;

3) feet;

4) upper arms;

5) lower arms;

6) hands.

The model of the MC should include the following bodies at a minimum:

- front wheel;
- rear wheel;
- main frame;
- upper front fork assembly;
- lower front fork assembly.

The model of the OV should include the following bodies at a minimum:

- four unsprung assemblies;
- sprung body.

The upper leg, knee, and lower leg bodies shall be modelled so that the bone fracture/knee dislocation kinematics effects are simulated (e.g., resulting in reduced bending moment in the leg at the appropriate location after fracture).

If any of the bodies listed in tables 1 and 2 can fracture, the masses of the bodies resulting from the fracture shall be modelled.

For a given MC/protective device combination, the same model formulation shall be used for all impact configurations. The only differences between a model of a MC with a protective device and a model of a MC without a protective device shall be in those portions directly related to the protective device.

4.2 Parameters

For each body listed in 4.1, the parameter values used should correspond to the actual measured

- mass;
- centre of gravity location;
- moments of inertia;
- principal axes orientations;

Table 1 - MC laboratory component tests

Body	Impactor or impact surface [1)]	Test type	Characteristics
MC fuel tank	400 mm cylinder	Dynamic	z_{cyl} force vs z_{cyl} displacement z_{cyl} force vs time
MC seat	400 mm cylinder	Static	z_{cyl} force vs z_{cyl} displacement
Protective device	(As required)	Dynamic	Force vs displacement Force vs time
MC rear spring damper	None	Static	x force vs x displacement
MC rear spring damper	Flat	Dynamic	x_{imp} force vs x_{imp} velocity
MC front wheel	Barrier (as part of the MC laboratory test described in 4.5.2)	Dynamic	$x_{barrier}$ force vs x_{MC} displacement

1) Refer to figure 1.

Table 2 - OV laboratory component tests

Body	Impactor or impact surface [1)]	Test type	Characteristics
OV roof rail	300 mm sphere	Dynamic	x_{sphere} force vs x_{sphere} displacement x_{sphere} force vs time
OV side	Disc (edge)	Static	x_{disc} force vs x_{disc} displacement
OV side	Disc (side)	Static	y_{disc} force vs y_{disc} displacement
OV front bumper	Disc (edge)	Static	x_{disc} force vs x_{disc} displacement
OV front bumper	Disc (side)	Static	y_{disc} force vs y_{disc} displacement
OV rear bumper	Disc (edge)	Static	x_{disc} force vs x_{disc} displacement
OV rear bumper	Disc (side)	Static	y_{disc} force vs y_{disc} displacement
OV bonnet	300 mm sphere	Dynamic	z_{sphere} force vs z_{sphere} displacement z_{sphere} force vs time
OV front windscreen	300 mm sphere	Dynamic	x_{sphere} force vs x_{sphere} displacement x_{sphere} force vs time
OV front suspension	Ground	Dynamic	z_g force vs z_{OV} displacement z_g force vs time
OV rear suspension	Ground	Dynamic	z_g force vs z_{OV} displacement z_g force vs time

1) Refer to figure 1.

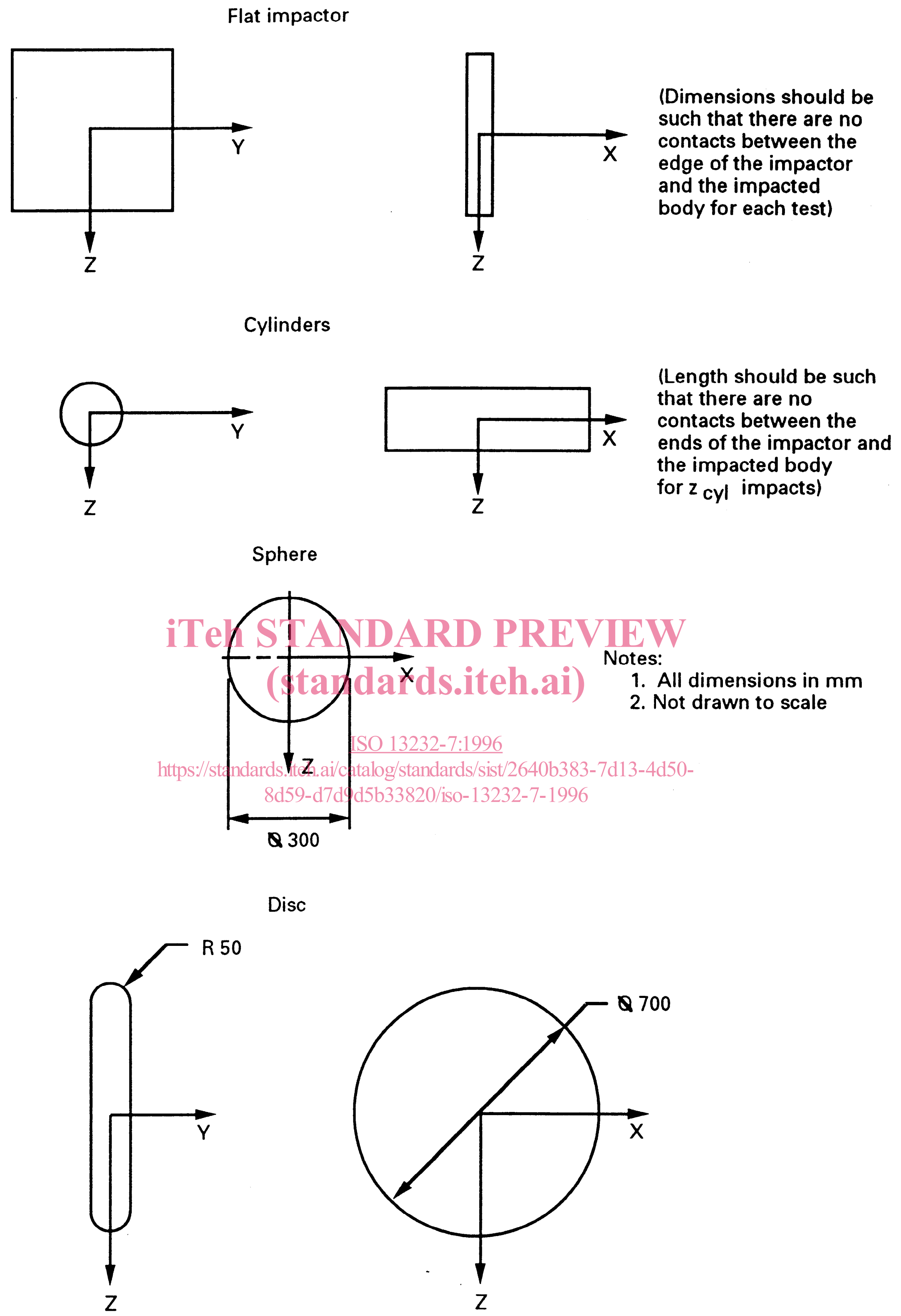

Figure 1 - Impactors and axes to be used for component test

- joint locations;
- joint physical degrees of freedom;
- joint orientations;
- maximum thickness of each undeformed body.

For a given MC/protective device combination, the same parameter values shall be used for all impact configurations. All of the parameter values for a given MC/protective device combination shall correspond to the parameter values used to calibrate the simulation, as described in 4.5. The only difference between a parameter set for a MC with a protective device and a parameter set for a MC without a protective device shall be in those parameters directly related to the protective device.

4.3 Outputs

Force, moment, and motion time histories which are compatible with the injury variables and injury indices listed in ISO 13232-5 shall be output to allow computation of the injury indices. The form shall be consistent with the full-scale test time histories documented as described in ISO 13232-8. The data shall be output and plotted at 0,001 s intervals for the time period up to but not including dummy to ground contact, or 0,500 s after the first MC/OV contact, whichever is sooner.

Indication of frangible damage shall be output for all of the frangible components defined in ISO 13232-3, along with the time at which the damage occurred, for the time period described above. The damage shall be expressed as occurrence of component failure for each frangible femur, knee (varus valgus or torsion), and tibia; and as maximum penetration for the frangible abdominal insert.

The linear and angular displacement and velocity time histories of the MC main frame and helmeted head centres of gravity and the shoulder, pelvis, knee, and ankle targets corresponding to those used in full-scale tests shall be output and plotted, at the intervals and for the time period described above.

For each simulation run and for each interaction which occurs between any of the MC bodies in table 1 and any of the OV bodies in table 2, the maximum force and maximum deflection of the MC body and of the OV body, along the directions indicated in table 1 and table 2, shall be output.

If a three dimensional animation is done, then the linear and angular positions of any and all rigid bodies and the positions of any and all finite element nodes, shall be output at equal increments of time.

4.4 Post processing

4.4.1 Three dimensional animation

Three dimensional animation should be used to display, graphically, the motions of the MC, OV, dummy, and protective device. The animation shall display only the actual modelled rigid body surfaces and/or finite elements, in their proper shapes and relative positions and orientations. Additional markers may be provided to assist the comparison between physical tests and simulations. These shall correspond to the photographic targets used in any corresponding full-scale impact test, including those defined in 4.3 of ISO 13232-4. If such markers are added, they shall appear in colours which contrast to the model's rigid body surfaces or finite elements, and a statement of this shall be made preceding the animation sequence.

The animation shall be driven only by the linear and angular position time histories, as described in 4.3. When comparisons are made with full-scale test films, the animations shall use the same viewpoint and focal length as the cameras designated for full-scale testing (see 4.6.2 of ISO 13232-4).

Still photographs of the animation from the perspective of the MC side view camera should be taken and included in the simulation documentation. Photographs shall include the dummy position

- prior to first MC/OV contact;
- at first head/OV contact (if any);
- at 0,250 s and 0,500 s after first MC/OV contact.

4.4.2 Injury analysis

Evaluation of the computer simulation output, in terms of injury indices and injury cost analyses, may be done. If done, such analyses shall use the conventions described in ISO 13232-5.

4.4.3 Risk/benefit analysis and failure mode and effects analysis of proposed crash protective devices

Risk/benefit analysis and/or failure mode and effects analysis of proposed rider crash protective devices fitted to motor cycles, across a range of impact conditions, should be done using computer simulation. If failure mode and effects analysis is done using computer simulation, such analysis shall use the methods described in 5.1. If risk/benefit analysis is done using computer simulation, such analysis shall use the methods described in 5.10 of ISO 13232-5.

If risk/benefit analysis and/or failure mode and effects analysis are done using computer simulation, they shall only include impact configurations in which the simulated forces and deflections of the bodies listed in tables 1 and 2 meet the following criteria:

- for all bodies which can fracture, none of the maximum simulated forces defined in 4.3 may equal or exceed the maximum forces measured in the corresponding laboratory tests defined in 4.5.1 and 4.5.2;
- for all other bodies, none of the maximum simulated forces or maximum simulated deflections defined in 4.3 may equal or exceed the corresponding maximum forces or maximum deflections measured in the laboratory tests defined in 4.5.1 and 4.5.2.

If in any simulated impact configuration, any of the measured forces or deflections occurring between the bodies listed in tables 1 and 2 are exceeded, that impact configuration may only be included in the analyses if additional laboratory tests and simulation calibrations are done on those specific bodies. Each additional laboratory test and simulation calibration shall use an initial speed which corresponds to the maximum relative impact speed of the respective body observed among the simulated impact configurations.

4.5 Simulation calibration

The simulation shall be calibrated with at least the following tests, and the calibration results shall be documented in accordance with ISO 13232-8.

4.5.1 Laboratory component test calibration

The simulation shall be used to calculate the MC, OV, and dummy characteristics listed in tables 1, 2, and 3, respectively, using the methods defined in 5.2. The results shall be documented using the format described in annex A, and in accordance with ISO 13232-8.

If, for any laboratory component test, the test data are used as input parameter values for the simulation, only the relevant test data shall be included in the simulation documentation (since the input parameter values are equal to the test data).

4.5.2 Motor cycle laboratory dynamic test

One MC laboratory test and corresponding simulation shall be performed to calculate the following MC time histories, using the methods defined in 5.3:

- front axle displacement;
- front suspension compression;
- fork bending angle;
- x, y, and z accelerations of the MC (on the left and right sides of the MC, as close as possible to the MC centre of gravity);
- MC centre of gravity x and z displacements;
- MC pitch angle;
- barrier force.