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

Part 5: Injury indices and risk/benefit analysis

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 5: Indices de blessure et analyse risque/bénéfice

Reference number
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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

ISO 13232-5 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 22, *Motorcycles*.

This second edition cancels and replaces the first version (ISO 13232-5:1996), which has been technically revised.

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: Motorcyclist 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*

Introduction

ISO 13232 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 motorcycles and intended for the crash protection of riders, have on injuries, when assessed over a range of impact conditions which are based on accident data.

It is intended that all of the methods and recommendations contained in ISO 13232 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 ISO 13232, a clear explanation of how the used procedures differ from the basic methodology should be provided.

ISO 13232 was prepared by ISO/TC 22/SC 22 at the request of the United Nations Economic Commission for Europe Group for Road Vehicle General Safety (UN/ECE/TRANS/SCI/WP29/GRSG), based on original working documents submitted by the International Motorcycle Manufacturers Association (IMMA), and comprising eight interrelated parts.

This revision of ISO 13232 incorporates extensive technical amendments throughout all the parts, resulting from extensive experience with the standard and the development of improved research methods.

In order to apply ISO 13232 properly, it is strongly recommended that all eight parts be used together, particularly if the results are to be published.

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

Part 5: Injury indices and risk/benefit analysis

1 Scope

This part of ISO 13232 provides:

— performance indices which can be correlated with human injuries;

— formulae which relate injury indices to probable injury cost;

— a consistent means of interpreting impact test results;

— a means of relating the results obtained from film analysis and instrumentation of the dummy to injuries sustained in accidents;

— a means of assessing both the combined and relative effects of multiple injuries;

— an objective means of quantifying injury cost using a single index;

— a means of verifying the analysis; and

— a means of doing risk/benefit analysis of protective devices fitted to motorcycles, based upon the population of impact conditions identified in ISO 13232-2.

ISO 13232 specifies the minimum requirements for research into the feasibility of protective devices fitted to motorcycles, which are intended to protect the rider in the event of a collision.

ISO 13232 is applicable to impact tests involving:

— two-wheeled motorcycles;

— 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 motorcycle;

— 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 motorcycles fitted and not fitted with the proposed devices).

ISO 13232 does not apply to testing for regulatory or legislative purposes.

2 Normative references

The following referenced documents are indispensable for the application 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 13232-1, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 1: Definitions, symbols and general considerations*

ISO 13232-2, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 2: Definition of impact conditions in relation to accident data*

ISO 13232-4, *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*

ISO 13232-7, *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*

ISO 13232-8, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 8: Documentation and reports*

AIS-90, Association for the Advancement of Automotive Medicine (AAAM), Des Plaines, IL, USA, *The abbreviated injury scale. 1990 revision*

SAE J211, *Instrumentation for impact tests*, Warrendale, Pennsylvania, USA

SAE J885, *Human tolerance to impact conditions as related to motor vehicle design*, Warrendale, Pennsylvania, USA

3 Definitions and abbreviations

The following terms are defined in ISO 13232-1. For the purposes of this part of ISO 13232, those definitions apply. Additional definitions which could apply to this part of ISO 13232 are also listed in ISO 13232-1:

— abbreviated injury scale (AIS);

— abdomen maximum residual penetration ($p_{A,max}$);

— ancillary costs (AC);

— cost of fatality (CF);

— entire impact sequence;

— generalized acceleration model for brain injury tolerance (GAMBIT, G);

— head injury criterion (HIC);

— injury assessment function;

— injury assessment variable;

— injury costs (IC);

— injury index;

— injury potential variable;

— injury severity probability (ISP);

— lower extremities (lE);

— maximum PAIS;

— medical costs (MDC);

— normalized injury cost (IC_{norm});

— permanent partial incapacity (PPI);

— primary impact period;

— probability of fatality (PF);

— probable AIS ($PAIS$);

— secondary impact period;

— total PAIS;

— upper (or lower) sternum maximum normalized compression ($C_{us,max,norm}$ or $Cl_{s,max,norm}$);

— upper (or lower) sternum maximum velocity-compression ($VC_{us,max}$ or $VCl_{s,max}$);

— upper (or lower) sternum velocity (V_{us} or V_{ls}).

4 Requirements

4.1 Injury variables

4.1.1 Injury assessment variables

The following injury assessment variables shall be evaluated over the primary impact period and also over the entire impact sequence using the calculations presented in 5.1 and the measurement methods given in 5.2.1 and 5.2.3.3 of ISO 13232-4:

— head maximum GAMBIT (G_{max});

— head injury criterion (HIC);

— head maximum resultant linear acceleration ($a_{r,H,max}$);

— neck injury index (NII);

— upper sternum maximum normalized compression ($C_{us,max,norm}$);

— lower sternum maximum normalized compression ($C_{ls,max,norm}$);

— upper sternum maximum velocity-compression ($VC_{us,max}$) for $V_{us} \geq 3$ m/s;

— lower sternum maximum velocity-compression ($VC_{ls,max}$) for $V_{ls} \geq 3$ m/s;

— abdomen maximum residual penetration ($p_{A,max}$).

4.1.2 Injury potential variables

The following injury potential variables shall be determined by evaluating them using the methods described in 5.2.4.2 of ISO 13232-4. The variables shall be evaluated over the interval from 0,050 s before first MC/OV contact until first helmet/OV contact, or until the helmet leaves the field of view, whichever occurs sooner, unless otherwise stated. In order to calculate velocities, the results shall be differentiated according to 5.1.7 of this part of ISO 13232, over this same time interval. The specific values listed below shall be identified from the velocity time histories:

— helmet trajectory in initial longitudinal-vertical plane of MC travel (z_h versus x_h);

— helmet resultant velocity at first helmet/OV contact ($V_{r,h,fc}$);

— helmet longitudinal velocity at first helmet/OV contact ($V_{x,h,fc}$);

— helmet lateral velocity at first helmet/OV contact ($V_{y,h,fc}$);

— helmet vertical velocity at first helmet/OV contact ($V_{z,h,fc}$).

4.2 Lower extremity injuries

The following lower extremity injuries shall be evaluated, based on observations and measurements of the frangible components, as described in 5.2.3 of ISO 13232-4:

— non-displaced bone fractures;

— displaced bone fractures;

— knee partial dislocations;

— knee complete dislocations.

4.3 Injury severity probabilities

The following injury severity probabilities (ISP) shall be determined for each severity level, AIS ≥ 1 through the highest level, using the methods described in 5.3:

closed head ISP_H;

upper neck combined loading ISP_n;

upper sternum compression $ISP_{C,us}$;

lower sternum compression $ISP_{C,ls}$;

upper sternum velocity-compression $ISP_{VC,us}$;

lower sternum velocity-compression $ISP_{VC,ls}$;

intra-abdominal penetration ISP_{A}.

4.4 Injury indices

The probability of each discrete AIS injury severity level shall be calculated for each of the five body regions: the head, upper neck, thorax, abdomen, and lower extremities, using the procedures described in 5.4.

The medical and ancillary costs associated with injuries to each of the five body regions shall be calculated using the procedures described in 5.5.1 and 5.5.2, respectively. The cost of fatality shall be determined as defined in Annex A.

The probability of fatality shall be calculated using the procedures described in 5.6.

The risk of life threatening brain injury shall be calculated from HIC using the procedures described in 5.6.4.

The probable AIS ($PAIS$) shall be determined by body region, using the procedures described in 5.7.1. The maximum PAIS and total PAIS shall be determined across all body regions using the procedures described in 5.7.2 and 5.7.3, respectively.

The normalized injury costs of survival and fatality and the total normalized injury cost shall be determined using the procedures described in 5.8.

NOTE The term "cost" is used in this subclause in a specific and limited sense, and for test comparison purposes only (see def 3.5.7 of ISO 13232-1 for specific cost definitions). The "costs," as used here, represent average costs based on a simplified model of samples of bioeconomic data; collected over a particular time period and region; and for a limited range of specific injury types, severities, and body regions, which are able to be monitored in crash tests, and which can exclude the majority of the types, severities, and locations of human body injuries, and some types of cost components. In no way do such injury costs consider, nor are they intended to consider, the market level costs of a proposed protective device. The "costs" described herein are only intended to provided a convenient, common basis for combining and comparing across body regions and crash tests and on a relative basis, different types, locations, and severities of injuries. For the foregoing reasons, such costs have limited applicability and are not intended nor appropriate for calculating, for example, the actual cost of a specific real accident, or the total societal or economic cost of a given device or design.

4.5 Risk/benefit analysis

Any risk/benefit analysis of a proposed rider crash protective device fitted to a motorcycle, which forms a part of the overall evaluation described in ISO 13232-2 or which may be used to identify potential failure modes of a proposed device for purposes of further testing, shall use the methods described in 5.10.

5 Procedures

5.1 Injury variables

Compute the maximum values of the variables over time, for example, $G_{max\ (t)}$.

5.1.1 Resultants

Calculate the head resultant linear and angular accelerations, using the time histories of the linear and angular accelerations as calculated in 5.2.1 of ISO 13232-4, and shown in the example for the resultant linear acceleration, given below:

$$a_r = \left(a_x^2 + a_y^2 + a_z^2\right)^{1/2}$$

where

a_r is the resultant linear acceleration, in g units;

a_x is the linear acceleration in the x direction, in g units;

a_y is the linear acceleration in the y direction, in g units;

a_z is the linear acceleration in the z direction, in g units.

Where only two components are included in a resultant, calculate the resultant of those two components, as shown in the example for the resultant shear force, given below:

$$F_{xy} = \left(F_x^2 + F_y^2\right)^{1/2}$$

where

F_{xy} is the resultant force, in kilonewtons;

F_x is the force in the x direction, in kilonewtons;

F_y is the force in the y direction, in kilonewtons.

5.1.2 GAMBIT

Calculate GAMBIT using the equation given below:

$$G = \left(\left(\frac{a_{r,H}}{250}\right)^2 + \left(\frac{\alpha_{r,H}}{25000}\right)^2\right)^{1/2}$$

where

— G is GAMBIT

— $a_{r,H}$ is the head resultant linear acceleration, in g units;

— $\alpha_{r,H}$ is the head resultant angular acceleration, in radians per second squared.

— 250 is the normalization factor for linear acceleration in GAMBIT, in g units;

— 25 000 is the normalization factor for angular acceleration in GAMBIT, in radians per second squared.

— Identify the maximum value of GAMBIT, G_{max}

5.1.3 HIC

Calculate HIC using the equation given below[1]:

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1) SAE J885, July 1986.

$$HIC = \max\left((t_2 - t_1)\left(\frac{1}{t_2 - t_1} \int_{t_2}^{t_1} a_{r,H}(t)\,dt \right)^{2,5} \right)$$

where

HIC is the head injury criterion;

$a_{r,H}$ is the head resultant linear acceleration, in g units;

HIC values are only calculated during periods of head contact as defined by head engagement (t_e) and head disengagement (t_d) times determined according to ISO Technical Report TR 12351.

t_1 and t_2 (in seconds) are all possible initial and final times for each contact interval which are separated by not more than 0,015 s, and where $t_1 >= \tau_\varepsilon$ and $t_2 <= t_d$.

An example computer code for the calculation of head contacts is found in Annex I.

5.1.4 Upper and lower sternum compression

Use the upper and lower sternum displacement time histories recorded and reduced as described in 4.4.1.3 and 5.2.1 of ISO 13232-4. Calculate the upper and lower sternum deflections and compressions, as shown in the example equations for the upper sternum, given below and referring to Figure 1:

$$D_{y,us} = \frac{(l_{uL} + \Delta l_{uL})^2 - (l_{uR} + \Delta l_{uR})^2}{2W_{L,R}}$$

$$D_{x,us} = \left((l_{uR} + \Delta l_{uR})^2 - \left(\frac{W_{L,R}}{2} - D_{y,us} \right)^2 \right)^{1/2} - d_{us}$$

$$C_{us,norm} = \frac{-D_{x,us}}{187,5} \times 100$$

where

$D_{y,us}$ is the upper sternum deflection in the *y* direction, in millimetres;

l_{uL} is the cable length of the upper left string pot, in millimetres;

Δl_{uL} is the change in cable length of the upper left string pot (positive is longer), in millimetres;

l_{uR} is the cable length of the upper right string pot, in millimetres;

Δl_{uR} is the change in cable length of the upper right string pot (positive is longer), in millimetres;

$W_{L,R}$ is the lateral distance between the left and right string pots, in millimetres;

$D_{x,us}$ is the upper sternum deflection in the x direction, in millimetres;

d_{us} is the undeformed perpendicular distance from the plane containing the string pot pivot axes to the upper sternum, at the centre of rib 2 where the strings are attached, in millimetres;