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Human/human surrogate impact (single shock) testing and evaluation — Guidance on technical aspects

Essais et évaluation des chocs (chocs simples) sur l'homme ou un substitut d'homme — Lignes directrices concernant les aspects techniques

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Contents

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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.

International Standard ISO 10227 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock,* Subcommittee SC 4, *Human exposure to mechanical vibration and shock.*

Annex A of this International Standard is for information only.

Introduction

The vehicular environment in which people are operators or passengers should not only provide comfortable and efficient means of operation and transportation, but should also minimize occupant injury due to impact forces that may be experienced in a crash-type collision. Criteria for the design, testing and evaluation of safe vehicle design requires an understanding of the human and human surrogate/analogue mechanical response to shock and acceleration forces. This response is a complex function of the interaction of the driving forces with the vehicle, the effects of the seating and restraint systems on the propagated forces, and the initial position and orientation of the subject. An understanding of this response involves the experimental impact testing of human subjects and human surrogates.

In experimental testing, the response of a human or human surrogate/analogue is correlated to specific anatomical segments and readily identifiable landmarks, and is usually not restricted to simple linear motion. This demands careful instrumentation and data analysis techniques for an adequate analytical description. Another perplexing technical problem is to assure adequate coupling between the sensor used to monitor responses and the anatomical segment which is being monitored. Additionally, the monitoring procedure may alter the measured response, biasing the dose-response relationship. Interpretations and conclusions regarding response mechanisms, injury modalities and propagated frequencies should reflect an understanding of these issues.

This International Standard is intended to provide guidelines for formulating experimental protocols and reporting experimental results to ease comparisons among various research efforts. It is not intended to limit either the scope of experimental protocols or the exposure levels to which human subjects or human analogues are to be subjected. It does not limit and/or recommend acceleration environments as they relate to comfort, task proficiency, health and safety.

Human/human surrogate impact (single shock) testing and evaluation — Guidance on technical aspects

1 Scope

This International Standard defines technical aspects of experiments dealing with human or human surrogate testing and procedures for collecting and reporting biomechanical data. Recommended practices regarding measurements, instrumentation and reporting of results are outlined. These recommended practices are provided as guide for ease of interpretation and comparison of data among different organizations.

This International Standard is limited to experiments involving indirect (inertial) impact and does not address direct impact with vehicle surfaces or the use of the airbag-type of active restraining device.

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 International Standard 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 5805:— [1], *Mechanical vibration and shock affecting man — Vocabulary.*

ISO 8727:—[2], *Mechanical vibration and shock — Human exposure — Biodynamic coordinate systems.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 5805 and the following definitions apply.

3.1 test subject: Human being or human surrogate (e.g. cadaver, animal, manikin) that serves as the test occupant of the vehicle.

3.2 test subject coordinate system: Right-handed orthogonal coordinate system (x, y, z), in accordance with ISO 8727, which is used to locate the position of the instrumented segments of the test subject.

3.3 vehicle: Structure to which the driving force or impact is delivered. This includes all elements of the system which transmit forces to the test subject, including any integrated support/seat and restraint system.

3.4 vehicle coordinate system: Right-handed orthogonal coordinate system (x, y, z) which is used to locate the occupant position and restraint or impact surface configuration. Its origin should be defined relative to a rigid structure (one that is not significantly deformed during the test) on the vehicle.

4 Measurement requirements

4.1 Initial conditions

All measurements of location and orientation should be transformable to the vehicle coordinate system.

1) To be published. (Revision of ISO 5805:1981)

2) To be published.

4.1.1 The numbers, surveyed locations, orientations, mounting and coupling characteristics of all transducers and photometric targets should be reported.

4.1.2 The initial position of the test subject, the restraint, and support or seat configuration should be described as fully as possible. The restraint system description should include the following:

a) location and orientation of anchor attachment points;

b) angles of belt restraints relative to body contact points and anchor attachment points;

c) distances along webbing from anchor points to the points where the belts contact the occupant;

d) webbing properties, dimensions and type of hardware;

e) webbing retractor characteristics;

f) webbing connector characteristics;

g) preloads on restraint components;

h) webbing force-elongation properties.

The description of the support/seat fixture should include the following:

a) geometry and materials adequate to establish the deformation and friction characteristics of the support/seat surface;

b) dimensions and orientations relative to the vehicle coordinate system;

c) energy absorption or deformation characteristics of support structures between the origin of the vehicle coordinate system and the occupant, if pertinent;

d) location of point of impact.

4.1.3 Ambient environmental factors affecting the outcome of the experiment should be reported.

4.2 Input variables

The input variables include time-dependent displacement, velocity, acceleration and force. All measurements of variables should be transformable to the vehicle coordinate system and should be accomplished in the number of degrees of freedom matching those included in the response measures. Typical amplitude-time histories of the input are desirable; otherwise, a statement of the methodology used to measure these variables should be reported.

4.3 Subject parameters

Measurement of body dimensions are crucial for describing the test subject and estimating mass distribution properties. Mass distribution properties of the whole body and anatomical segments can be obtained directly in cadaveric research but must be estimated for live volunteer subjects. Biomechanical parameters such as segment mass, centre of gravity, moment of inertia, etc., can be used in extrapolating results to populations of interest.

4.3.1 Anthropometric measures

These should include, but need not be limited to, the following:

a) mass;

b) stature;

c) sitting height;

d) shoulder height;

e) head height;

f) head breadth;

g) head length;

h) head circumference;

i) neck circumference;

j) shoulder breadth;

k) shoulder/elbow length;

l) elbow-rest height;

m) elbow/finger tip length;

n) chest circumference;

o) thoracic thickness;

p) popliteal height;

q) buttock/knee length;

r) knee height (sitting).

4.3.2 Condition and prehistory

For live human subjects, complete medical histories including age and gender should be recorded and any anomalies noted. Similar information, where possible, should also be provided for cadavers. Cadaveric experiments should be conducted on specimens free from injuries, wounds, or other anomalies which may interfere with the conduct of the test or interpretation of results. Cadavers should be as fresh as possible and embalming procedures should be completely described. Storage conditions of the cadaver, up to the time of the experiment, should also be described. Any ancillary procedures, such as vascular injection or control of the thoracic volume of cadavers, should be completely defined.

For all types of testing (live human subject, human surrogate), anatomical landmarks should be identified, marked and measured in relation to defined anatomical coordinate systems (in accordance with ISO 8727). If possible, radiographic records of the subjects with instrumentation mounts and measurement scales should be made. Insufficiently visible anatomical landmarks should be enhanced via the use of radio-opaque spheres. Photographs or schematics with dimensions identified should be maintained if radiographic records are not possible.

5 Instrumentation

5.1 Transducers

Data collected from transducers mounted on the subject and within the seat, restraint or other force-transmitting structure, as well as physiological sensors, are used to quantify both the severity of the test and local responses of the anatomy to crash and impact forces, and to delineate transmission characteristics and transfer functions of anatomical segments. Subclauses 5.1.1 to 5.1.6 give the required transducer characteristics.

5.1.1 Transducers and other sensors mounted on the subject should have low mass so as to affect minimally the responses of the monitored anatomical segment.

5.1.2 Transducers and other sensors mounted on the subject should be mounted as solidly as possible to well-defined anatomical structures relative to the skeletal system so that their data are unaffected by relative motion artifact. If solid attachment is not possible (as may be the case in the testing of live human subjects), a complete description of the attachment method should be provided.

5.1.3 Transducers and sensors should have appropriate frequency response with respect to the anticipated phenomena to be measured. In cases where the frequency characteristics of the body segment are not known, broad-band frequency measurements should be attempted, with subsequent analysis conducted to identify the significant frequency content of the signal.

5.1.4 All transducers and other sensors mounted on the subject should be surveyed with respect to the anatomical coordinate system of the particular anatomical segment. If translation to other points of interest is warranted, then both linear and angular response shall be monitored.

5.1.5 Transducers mounted within the seat, restraint system or other force-transmitting structure should be surveyed with respect to the vehicle coordinate system.

5.1.6 Transducers and sensors should be in current calibration. Each data path should also be calibrated to assess the effects of environmental factors such as drift of the data signal, etc.

5.2 Displacement tracking

Data from surface-mounted targets is used to quantify the displacement responses of the anatomy to crash and impact forces. Photographic or video cameras and targets may be used as well as solid-state target tracking systems. Subclauses 5.2.1 to 5.2.5 give the requirements for displacement tracking.

5.2.1 The requirements given in 5.1.1, 5.1.2 and 5.1.4 apply with "target" substituted for "transducers and other sensors".

5.2.2 If motion is confined to one plane, and a camera can be located on an axis perpendicular to this plane, then only one camera is required. Otherwise at least two cameras are needed.

5.2.3 Camera location and orientation should be measured relative to the target and other cameras, in the vehicle coordinate system.

5.2.4 If time-dependent measurements are made from displacement data, then an accurate timing source shall be precisely synchronized to the displacement recording system. Timing signal accuracy and frame rate measurement techniques should be described.

5.2.5 If applicable, the lens type, focal length and aperture opening should be described and calibrated as used in the test.

5.3 Data acquisition

The data channel includes the entire signal path from the transducer to the recording device. All procedures implementing the requirements given in 5.3.1 to 5.3.6 should be documented.

5.3.1 Each data channel should be calibrated against a reference signal traceable to known standards.

5.3.2 The entire data channel should be calibrated as a unit. As a less desirable alternative, each subsystem in the data channel path may be calibrated individually and the overall accuracy of the channel computed from these results.

5.3.3 If used in data analysis, the linearity error of each data channel should be determined.

5.3.4 For each channel, the amplitude-frequency response, phase-frequency response, damping characteristics and the roll-off rate and phase lag should be determined and reported. The cut-off frequency should be consistent with the anticipated frequency response of the anatomical segment monitored.

5.3.5 For each transducer, the cross-axis sensitivity should be determined.

5.3.6 For each transducer, the sensitivity coefficient should be determined. A recommended method is the linear least-squares computation to determine the sensitivity coefficient on the basis of calibration data.

6 Data retrieval and processing

This clause deals with storage, retrieval and processing of data. The guidelines given should be considered the minimum requirements.

6.1 Filtering and recording

The data channel (see 5.3.4) filtering should be compatible with the dynamic range of the recorder, precluding high-frequency saturation of the recorder or aliasing error in the digitizing process.

6.2 Digitization

6.2.1 In cases where the analog signal is digitized, the amplitude resolution should be a minimum of ten bits. Twelve bit or greater resolution is preferred for minimizing digitization error in the analog-to-digital conversion.

6.2.2 The sampling frequency used should be compatible with the cut-off frequency and roll-off rate to minimize aliasing error associated with non-band-limited signals.

6.3 Processing

All filtering of recorded data should be reported in terms of amplitude response, cut-off frequency, roll-off characteristics and phase shift. The cut-off frequency should be consistent with the anticipated frequency response of the anatomical segment monitored.

7 Reporting of results

7.1 Inertial response

The inertial responses used to quantify both the severity of the test and local responses and transfer properties of the anatomy to crash and impact forces should include the results described in 7.1.1 to 7.1.5. Results should be translated to anatomically based reference points to provide a basis for comparison among subjects.

7.1.1 Head inertial response

Results should include

a) orthogonal components of linear acceleration at the centre of gravity of the head along the axes of the head anatomical coordinate system, and

b) angular acceleration or velocity about the anatomical axes of the head.

7.1.2 Neck inertial response

Neck response can be characterized by the relationship between the measured accelerations at T1 (first thoracic vertebral body) and the accelerations at the occipital condylar point computed from the head inertial response. The shear and axial forces, as well as the equivalent torque at the occipital condyles, can be calculated using results which should include

a) linear and angular head accelerations translated to the occipital condylar point,

b) orthogonal components of linear acceleration at the origin, and along the axes, of the T1 anatomical coordinate system, and

c) angular acceleration or velocity about the T1 anatomical axes.

7.1.3 Thorax inertial response

For live human subjects, the thorax is not rigid so is not easily instrumented, and measurements are subject to inaccuracies. Invasive methods have been used in the case of human surrogates to improve the coupling between the transducer and the bony anatomical landmark. Since tissue and bone properties may be affected, resulting data may be less valid than those obtained from rigid anatomical segments such as the head. Documented procedures should be used to minimize these effects. Results should include the orthogonal components of the linear accelerations at the chosen anatomical locations.

7.1.4 Pelvis inertial response

The pelvis, although rigid, poses unique problems in mounting transducers, due to its complex interaction with the seating and restraint system. These interactions can severely degrade the mechanical coupling between the transducers and the bony anatomy, introducing measurement errors. Documented procedures should be used to minimize these effects.

Invasive methods (i.e. rigidly mounting transducers to bony anatomical features) have been used in the case of human surrogate testing. Results should include

a) orthogonal components of linear accelerations at the origin, and along the axes, of a well-defined anatomical coordinate system, and

b) angular accelerations or velocities about the y-axis, used to define pelvis-lap belt interaction (possible submarining, etc.).

7.1.5 Additional inertial responses

The inertial response of body segments other than the head, neck, thorax or pelvis should include

a) orthogonal components of linear accelerations at the origin, and along the axes, of a well-defined anatomical coordinate system, and

b) when appropriate, angular acceleration or velocity about well-defined anatomical axes.

7.2 Force transmission

If the transmission of forces through the restraint system, seat and other supporting structures is measured, the data should include the force components with respect to the vehicle coordinate system.

7.3 Displacement

If displacement results are reported, the considerations regarding transducer placement discussed in 7.1.1 to 7.1.4 also apply to target placement.

7.3.1 Head displacement

Results should include

a) orthogonal components of linear displacement with respect to the initial location of the head anatomical coordinate system, and

b) angular displacement about the initial location of the head anatomical axes.

7.3.2 Neck displacement

Neck displacement can be characterized by the relative displacement between T1 and the occipital condylar point. Results should include

a) head linear and angular displacements (see 7.3.1) translated to the occipital condylar point with respect to the initial location of the T1 anatomical coordinate system, and

b) orthogonal components of the linear and angular displacements at the origin of the T1 anatomical coordinate system with respect to the initial location of the T1 anatomical coordinate system.

7.3.3 Thorax displacement

Results should include the orthogonal components of the linear displacements at the chosen anatomical locations with respect to the initial locations of well-defined anatomical coordinate systems.

7.3.4 Pelvis displacement

Results should include

a) orthogonal components of linear displacements with respect to the initial location, and along the axes, of a well-defined anatomical coordinate system, and

b) angular displacements about the initial location of the y-axis, used to define pelvis-lap belt interaction (possible submarining, etc.).

7.3.5 Additional body segment displacement

The displacement of body segments other than the head, neck, thorax or pelvis should include

a) orthogonal components of linear displacements with respect to the initial location, and along the axes, of well-defined anatomical coordinate systems, and

b) when appropriate, angular displacements about the initial location of well-defined anatomical axes.

7.4 Physiological data

Physiological data collected during tests with live human subjects or live human surrogates should be reported where these data represent deviations from the normal range for the measurement. Other physiological data should be reported in the form of a summary.

7.5 Subjective data

Written or verbal data collected from live human subjects to determine their subjective response to the test variables should be collected in a reliable and consistent manner. This should enable comparison with physical and physiological data.

7.6 Medical findings

Observations of injury, physiological changes or other indications of medical significance should be reported. Records of these findings should be permanently maintained for each live subject used in impact tests.