

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

Part 3: Motorcyclist anthropometric impact dummy

ICS 43.140

National foreword

This British Standard is the UK implementation of ISO 13232-3:2005+A1:2012. It supersedes BS ISO 13232-3:2005, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to ISO text carry the number of the ISO amendment. For example, text altered by ISO amendment 1 is indicated by **A1** **A1**.

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

Part 3: Motorcyclist anthropometric impact dummy

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

*Partie 3: Mannequin anthropométrique de motocycliste pour essais de
choc*



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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 13232-3 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 22, *Motorcycles*.

This second edition cancels and replaces the first version (ISO 13232-3:1996), 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.

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

Part 3: Motorcyclist anthropometric impact dummy

1 Scope

This part of ISO 13232 specifies the minimum requirements for the:

- biofidelity of the motorcyclist anthropometric impact dummy;
- compatibility of the dummy with motorcycles, helmets, multi-directional impacts, and the instrumentation;
- repeatability and reproducibility of the dummy properties and responses.

ISO 13232 specifies 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 13232-4, *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 13232-6, *Motorcycles — Test and analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles — Part 6: Full-scale impact test procedures*

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

ISO 6487, *Road vehicles — Measurement techniques in impact tests — Instrumentation*

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.

A1 UN/ECE Regulation 22, *Uniform provisions concerning the approval of protective helmets and of their visors for drivers and passengers of motor cycles and mopeds* **A1**

3 Definitions

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:

- abdominal foam insert;
- alternative products;
- certification, compliance;
- knee compliance element;
- load cell simulator;
- lot;
- specimen.

4 Mechanical requirements for the motorcyclist anthropometric impact dummy

4.1 Basis dummy

The basis dummy shall be the Hybrid III 50th percentile male dummy¹⁾. The dummy shall be equipped with:

- the sit/stand construction²⁾;
- the head/neck assembly which is compatible with the six axis upper neck load cell which is specified in 4.4.1.2 of ISO 13232-4²⁾;
- standard, non-sliding knees²⁾.

The basis dummy specified components shall be modified or replaced as described below.

¹⁾ Basis dummy as specified in 49 CFR Part 572, subpart E, or equivalent.

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 ISO 13232 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.

4.2 **Motorcyclist dummy head, head skins, and helmet**

4.2.1 **Head and head skins**

The head skin components shall include the two basis Hybrid III head skins, plus two extensions which provide helmet compatibility. The geometries of the head skins and extensions are shown in Figure A.1, where 1 and 2 are the basis Hybrid III head and rear skull cap skins and 3 and 4 are the jaw and nape extensions which provide helmet compatibility. The masses of the jaw and nape skin extensions shall be $0,27\text{ kg} \pm 0,05\text{ kg}$ and $0,15\text{ kg} \pm 0,05\text{ kg}$, respectively²⁾. The head-neck skin modifications to the Hybrid III head shall be attached by means of any suitable adhesive. Such an adhesive shall be shown to provide a bond between the mating parts in which the parent material will fail under tensile loading before the bond itself. Cyanoacrylate is an example of a suitable adhesive.

The complete assembly of the head, head skins, head skin extensions, head accelerometer mount, head accelerometers and cables, and neck load cell and cables shall have a mass of $5,35\text{ kg} \pm 0,1\text{ kg}$.

4.2.2 **Helmet**

The dummy shall be fitted with a full face MATD test helmet according to the procedures described in ISO 13232-6. The MATD helmet shall have a size designation of either small (56 cm) or medium (58 cm). The helmet shall have a mass of $1,54 \pm 0,02\text{ kg}$. The MATD helmet shall have the overall length and overall width given in Figure 1. The MATD helmet shall meet the resultant acceleration values of UN/ECE Regulation 22-05 for helmets with a non-protective lower face cover, as in UN/ECE 22-05, 6.2 and 7.3.6. Each test helmet shall be from a production lot that has been certified according to clause 5 herein using the procedures in clause 6 herein.

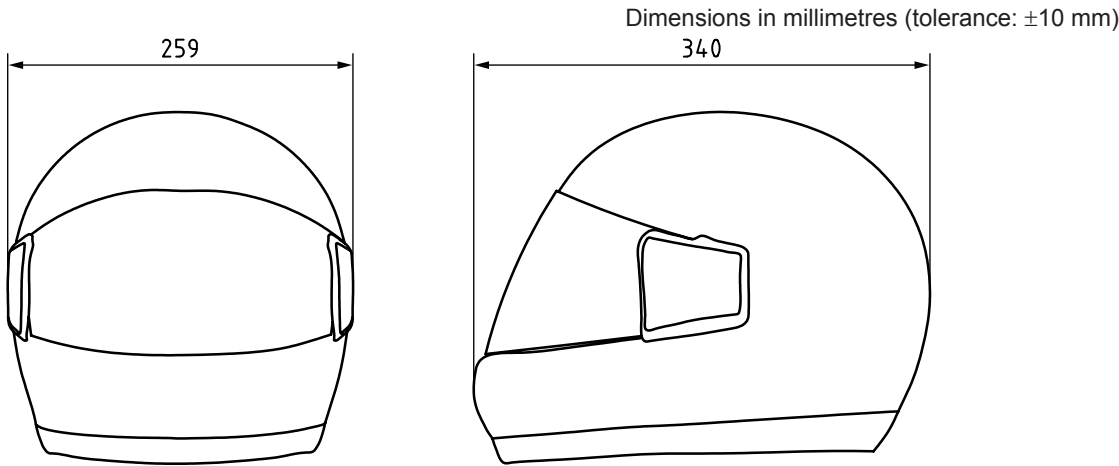


Figure 1 — Full face MATD helmet

When an MATD helmet specimen from a given production lot is tested according to the procedures described in 6.10, the specified peak resultant acceleration values for each test impact location shall be as given in Table 1.

Table 1 — Specified peak resultant acceleration values for certification of MATD helmet

Impact location ^a	Required value
B	236 g
P	263 g
R	234 g
X	190 g

^a Locations as defined in UN/ECE Regulation 22-05.

A1

4.3 Motorcyclist dummy neck components

The complete assembly of the neck, nodding blocks, head attachment pin, bib simulator, and the upper half of the serrated lower neck mount shall have a mass of $1,55 \text{ kg} \pm 0,1 \text{ kg}$.

4.3.1 Neck shroud

The neck shroud shall be as specified in Figure A.2²⁾. The upper half of the zipper of the neck shroud shall be attached to the jaw skin extension by means of any suitable adhesive. Such an adhesive shall be shown to provide a bond between the mating parts in which the parent material will fail under tensile loading before the bond itself.

Note - "Loctite® 401"²⁾ cyanoacrylate is an example of a suitable adhesive.

4.3.2 Lower neck mount

When mounting the motorcyclist neck the lower neck mount shall be set at the 5,25 degree extension position. This is appropriate for most dummy rider positioning. However, in cases of extreme dummy posture, the basis Hybrid III lower neck mount may be modified as shown in Figure A.3 to increase head position adjustability²⁾.

4.3.3 Motorcyclist neck

The standard Hybrid III neck and its interfaces with the head and upper torso assembly shall be replaced by the neck shown in Figure A.4²⁾.

NOTE The neck shown in Figure A.4 is designed specifically for use in motorcycle crash testing. Use and limitation information is contained in B.2.5.

4.3.4 Replacement nodding blocks

The standard Hybrid III nodding blocks shall be replaced with the pair of nodding blocks shown in Figure A.4²⁾.

4.3.5 Neck initial conformity of production

For certification of a new neck and nodding block production design, material specification or manufacturing process which otherwise meet the specifications given in Figure A.4, one neck shall be dynamically tested according to the procedures described in 6.8. The neck responses shall be within the corridors described in 6.8 and shown in figures 1, 2, 3, 4, 5, 6, and 7.

4.3.6 Neck subsequent conformity of production

Once a production design, material specification or manufacturing process has been certified according to 4.3.5, each manufactured neck and nodding block assembly produced thereafter shall be tested according to the procedures in 6.9 to verify the characteristics specified in **Table 2**.

Table 2 — Neck subsequent conformity of production specifications

Static Test	Characteristics	Required average value	% Required standard deviation
Flexion	Flexion angle	$17,6 \pm 2,6^\circ$	10% of average value
Flexion	Slider displacement	$14,0 \pm 3,0 \text{ mm}$	10% of average value
Extension	Extension angle	$30,9 \pm 4,6^\circ$	10% of average value
Lateral	Lateral angle	$28,7 \pm 4,3^\circ$	10% of average value
Torsion	Torsion angle	$41,5 \pm 6,2^\circ$	10% of average value

4.4 Motorcyclist dummy upper torso components

4.4.1 Replacement thoracic spine

Either a standard Hybrid III thoracic spine, or a replacement thoracic spine²⁾ shall be used. If a replacement spine is used, then the replacement thoracic spine shall be compatible with the internal data acquisition system described in ISO 13232-4. When combined with the internal data acquisition system, the replacement thoracic spine shall:

- maintain the same interface geometry and overall height as the standard Hybrid III spine box, including the shoulder, rib, lower neck mount, and lumbar spine attachment points;
- not interfere with the motion of the shoulders;
- provide at least 75 mm of sternum deflection in the sagittal plane, measured perpendicularly, relative to the front surface of the spine box;
- not exceed 125 mm in lateral width;
- result in the same upper torso mass and centre of gravity as specified for a standard Hybrid III upper torso except that the centre of gravity tolerance shall be ± 30 mm.

4.4.2 Modified chest skin

With the chest skin properly installed on the upper torso, the back of the chest skin may be modified with four holes which expose the two upper and two lower rib attachment screws in order to enable measurement of the upper torso angle, using a torso inclinometer such as the example shown in ISO 13232-6, Figure C.1.

4.5 Motorcyclist dummy lower torso components

When fully assembled, the lower torso assembly shall result in the same lower torso mass as specified for the standard Hybrid III lower torso³⁾.

4.5.1 Modified straight lumbar spine

For use with either the six-axis or three-axis lumbar load cell, the straight lumbar spine and cable shall be FTSS part numbers 1260004 and 1260005⁴⁾. The lower lumbar spine transducer mount and ballast block shall be replaced with the part shown in Figure A.5 for a six-axis load cell²⁾ and in Figure A.6 for a three-axis load cell²⁾. An

³⁾ Refer to General Motors Hybrid III drawing numbers 78051-70 and 78051-338 in 49 CFR Part 572.

⁴⁾ Parts 1260004 and 1260005 are products supplied by First Technology Safety Systems, Plymouth, Michigan, USA. This information is given for the convenience of users of ISO 13232 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.

abdomen reaction plate, as shown in Figure A.7 revision 1 for the six-axis load²⁾ cell or Figure A.8 for the three-axis load cell²⁾, shall be mounted to the lower lumbar spine transducer mount and ballast block.

When assembling the pelvis and ballast block, if hard contact interference prevents the proper positioning of the parts either part may be trimmed as required to facilitate the assembly.

When using the dummy without either of the permissible lumbar load cells described in 4.4.1.4 of ISO 13232-4, the load cell shall be replaced with a lumbar load cell simulator²⁾.

4.5.2 Motorcyclist dummy abdominal insert

The basis Hybrid III abdominal insert shall be replaced with a frangible solid abdominal insert, as shown in Figure A.9. The replacement insert shall have a mass of $53\text{ g} \pm 3\text{ g}$.

When tested according to the method described in 6.7, the specified values of force shall be as given in **Table 3**.

Table 3 — Specified values for certification of replacement abdominal insert

Deflection mm	Force N
20	1 040
40	1 875
60	2 810

4.5.3 Sit/stand pelvis

The internal data acquisition system may be contained within a sit/stand pelvis which has been suitably modified to accommodate it²⁾. Whether modified or not, the sit/stand pelvis shall:

- maintain the same interface geometry and external dimensions as the standard Hybrid III sit/stand pelvis;
- not interfere with the motion of the legs.

4.6 Arms and modified elbow bushing

The Delrin elbow bushing, Hybrid III part number 78051-199⁵⁾, shall be modified with scribe marks, as shown in Figure A.10.

The masses of the upper and lower arms shall be as specified for a standard Hybrid III.

4.7 Motorcyclist dummy hands

The basis Hybrid III hands shall be replaced with the Itoh-Seiki Co. part number 065-322048⁶⁾.

4.8 Motorcyclist dummy upper leg components

The mass of the upper leg assembly shall be $4,89\text{ kg} \pm 0,2\text{ kg}$.

⁵⁾ Refer to General Motors Hybrid III drawing number 78051-199 in 49 CFR Part 572.

⁶⁾ Part number 065-322048 is a product supplied by Itoh-Seiki Co., Tokyo, Japan. This information is given for the convenience of users of ISO 13232 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.

4.8.1 Frangible femur bone and mounting hardware

The frangible femur bone shall be mounted to the knee joint using the adaptor shown in Figure A.11²⁾. The frangible femur bone shall meet the interface and size requirements shown in Figure A.12, and have a mass $85 \text{ g} \pm 10 \text{ g}$. The frangible bone materials and design shall remain constant in the axial direction along the minimum frangible length, as shown in Figure A.12.

When statically tested according to the methods described in 6.1, 6.2, and 6.5, the specified values of the static deflection and strength of the bone shall be as given in **Table 4**. When dynamically fractured according to the methods described in 6.3 and 6.4, the specified values of the peak strength of the bone shall be as given in **Table 4**.

Table 4 — Specified values for certification of frangible femur components

	Static deflection	Dynamic peak strength	Static strength
Bending	5,1 mm	360 N·m	-
Torsion	5,8°	205 N·m	-
Axial loading	-	-	34 680 N

4.8.2 Femur load cell simulator

When using the dummy without the permissible femur load cells described in 4.4.1.5 of ISO 13232-4, the load cell shall be replaced with an upper femur load cell simulator, as shown in Figure A.13²⁾.

4.9 Motorcyclist dummy frangible knee assembly

The frangible knee assembly and the interface with the knee clevis assembly shall be as shown in Figure A.14. The knee assembly shall have a mass of $1,00 \text{ kg} \pm 0,05 \text{ kg}$.

When statically tested according to the methods described in 6.6, the specified values of the rotational angles for the defined moments shall be as given in **Table 5**. The specified values of the rotational angles and moments which indicate peak strength at shear pin failure shall be as given in **Table 5**.

Table 5 — Specified values for certification of frangible knee assembly components

Degree of Freedom	Condition	Specified value
Valgus	Rotation at 89 N·m (pre-failure)	20,0°
	Maximum torque	132 N·m
	Rotation at maximum torque	25,0°
Torsion	Rotation at 35 N · m (pre-failure)	20,0°
	Maximum torque	87 N·m
	Rotation at maximum torque	40,0°

4.10 Leg retaining cables

Each frangible leg bone shall be installed together with leg retaining cables to prevent the loss of portions of the dummy leg when the frangible bone fractures. The total cable mass shall not exceed 200 g for each frangible bone. The cables shall be installed with at least 5 mm of slack²⁾.

4.11 Motorcyclist dummy lower leg components

The mass of the lower leg and foot assembly shall be 5,29 kg $\pm$ 0,2 kg.

4.11.1 Frangible tibia bone and mounting hardware

The frangible tibia bone shall be mounted to the ankle joint using the adaptor shown in Figure A.15²⁾. The bone shall meet the interface and size requirements shown in Figure A.16 and have a mass of 120 g $\pm$ 10 g. The frangible bone materials and design shall remain constant in the axial direction along the minimum frangible length, as shown in Figure A.16.

When statically tested according to the methods described in 6.1 and 6.2, the specified values of the static deflection of the bone shall be as given in **Table 6**. When dynamically fractured according to the methods described in 6.3 and 6.4, the specified values of the peak strength of the bone shall be as given in **Table 6**.

Table 6 — Specified values for certification of frangible tibia components

	Static deflection	Dynamic peak strength
Bending	3,8 mm	280 N·m
Torsion	7,0°	171 N·m

4.11.2 Modified lower leg skin

The basis Hybrid III lower leg skins shall be modified according to Figure A.17, to:

- include a vertically aligned rear surface zipper to permit installation and removal of the skin from the leg;
- conform to the frangible knee structure.

The mass shall be 1,05 kg $\pm$ 0,10 kg.

4.12 Complete motorcyclist dummy

When fully assembled the complete motorcyclist dummy shall have a mass of 75,84 kg $\pm$ 1,64 kg.

4.13 Certification documentation

The manufacturers of dummies or dummy components which are intended to meet ISO 13232, shall provide with the supplied dummies or dummy components, certification that the dummies or dummy components meet the requirements specified below.

5 Sampling of frangible components and MATD test helmets

5.1 Initial conformity of production

For certification of any new design, material specification, or manufacturing process of any frangible component or MATD helmet and for each of the test methods described in clause 6, 10 unused components or helmets shall be tested to establish estimates of the sample's mean and standard deviation. For example, certification of three different test methods would require 30 components to be tested.

The sample mean value shall be within $\pm 5\%$ of the specified value for all strengths, abdominal insert static forces and peak resultant head form accelerations. The sample mean value shall be within $\pm 20\%$ of the specified value for all static deflections. The sample standard deviation shall be less than 7% of the sample mean value for all strengths, abdominal insert static forces and peak resultant head form accelerations. The sample standard deviation shall be less than 10% of the sample mean value for all static deflections.

5.2 Subsequent conformity of production

Once a sample involving a specific design, material specification, and manufacturing process have been certified, three components from each lot which is identically manufactured shall be tested to verify the applicable characteristics specified in **Table 7**.

Table 7 — Frangible component subsequent conformity of production characteristics

Component	Characteristic
Frangible abdominal insert	Forces at 40 mm deflection
Frangible leg bone	Dynamic bending strength
Knee shear pin	Failure moments given in Table 5
Knee compliance element	Pre-failure rotations given in Table 5
MATD test helmet	Peak resultant head form accelerations given in Table 1

6 Test methods

6.1 Frangible bone static bending deflection test

Using pins, attach rigid extensions of equal length, as shown in Figure A.18, to each end of the frangible bone such that the minimum combined length of the bone and extensions is as given in **Table 8**. Support the specimen radially at both ends, at the distances given in **Table 8**. Place a 25 mm diameter solid rigid cylindrical bar at the mid-span location, perpendicular to the specimen axial axis with the curved surfaces of the bone and bar in contact with each other. Apply a radial load as given in **Table 8**.

Table 8 — Frangible bone static bending deflection test specifications

	Minimum combined length mm	Distance between supports mm	Applied radial load N
Femur	355	341	1 350 $\pm$ 25
Tibia	300	286	1 450 $\pm$ 25

Measure the perpendicular linear deflection at the mid-span location of the specimen relative to the supported ends.

6.2 Frangible bone static torsional deflection test

Apply a torsional load of 69 N · m to the femur and 48 N · m to the tibia. Measure the torsional deflection of one end of the bone relative to the other end.

6.3 Frangible bone dynamic bending fracture test

Using pins, attach rigid extensions and support the specimen as described in 6.1, using the bone extensions shown in Figure A.18 and the specimen supports shown in Figure A.19. Align the specimen so that it is perpendicular to both the cylindrical bar and the direction of motion of the impactor head, shown in Figure A.20. Attach the impactor head to the impactor device, which is shown in Figures A.21 through A.24. Impact the specimen at 7,5 m/s ± 0,2 m/s at mid-span, using the impacting mass shown in Figure A.21.

Measure the impactor linear acceleration from just before bone contact until just after bone fracture, with an Endevco accelerometer, model 2262A-1000⁷⁾ rigidly mounted to the impactor at the location shown in Figure A.21. Filter the data with an analog filter such that the data is attenuated by at least 40 dB at and above a frequency of 7 kHz. Sample the data at 10 kHz and filter the digital data such that the frequency response of the data output to the unfiltered analog input is in accordance with ISO 6487, CFC 600. Determine the peak linear acceleration related to the impact with the bone. Calculate the maximum bending moment as shown for this example:

$$M_{x,max} = (0,25) (9,807) d_s m a_{m,max}$$

where

$M_{x,max}$ is the maximum bending moment, in Newton-metres;

d_s is the distance between supports, in metres;

m is the mass of the impactor, in kilograms;

$a_{m,max}$ is the maximum linear acceleration of the impactor mass, in g units;

9,807 is a conversion factor from g units to newtons.

6.4 Frangible bone dynamic torsional fracture test

Attach a rigid extension to each end of the frangible bone and restrain one end of the resulting specimen with a Denton load cell, model B-2193⁸⁾. Attach a rigid moment arm to one of the rigid extensions, such that it extends perpendicularly from the axial axis of the specimen. Impact the moment arm at 7,5 m/s ± 0,2 m/s at a distance 0,150 m ± 0,005 m from the axial axis of the specimen. Impact with a solid rigid cylindrical bar with a diameter of 0,025 m ± 0,003 m and a total impacting mass greater than 50 kg. Orient the cylindrical bar to be perpendicular to the direction of travel and to the moment arm.

Measure the bone torque using the load cell and filtering and sampling according to the method described in 6.3. Determine the maximum torsional moment.

⁷⁾ Model 2262A-1000 is a product supplied by Endevco Corp., San Juan Capistrano, California, USA. This information is given for the convenience of users of ISO 13232 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.

⁸⁾ Load cell model B-2193 is a product supplied by Robert A. Denton, Inc., Rochester Hills, Michigan, USA. This information is given for the convenience of users of ISO 13232 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.

6.5 Frangible femur bone static axial load fracture test

Attach a rigid fixture to each end of the frangible bone such that any compressive load is transferred to the bone through the bone mounting bolt. Place the specimen in a hydraulic press, as shown in Figure A.25, such that the centre line is aligned with the centre line of the hydraulic plunger and the lower end fixture is centred on a Denton load cell, model B-2193⁹⁾. Apply a continually increasing load at a rate of $6\,500\text{ N/s} \pm 2\,000\text{ N/s}$ until failure occurs. Electronically record the applied load until the time of failure.

6.6 Frangible knee static strength and deflection test

6.6.1 Apparatus

Use either the apparatus shown in Figure A.26, or the equivalent, including a

- lever arm with minimum length of 0,5 m;
- load cell located at the load application point;
- rotational potentiometer.

6.6.2 Procedure

Apply a continually increasing moment to the frangible knee valgus or torsional axis, at a rate of $30\text{ N} \cdot \text{m/s} \pm 5\text{ N} \cdot \text{m/s}$. Record the rotational angle and applied moment until shear pin failure occurs.

6.7 Frangible abdomen test

Use the apparatus shown in Figure A.27, or the equivalent. Apply a continually increasing load to the centre of an unused frangible abdominal insert at a rate of $450\text{ N/s} \pm 150\text{ N/s}$. Record the crush deflection and applied load up to a load greater than 3 300 N.

6.8 Motorcyclist neck dynamic test for initial conformity of production

6.8.1 Dynamic extension test

Assemble a Hybrid III lower neck mount (set at 5,25 degrees extension), the motorcyclist neck to be tested (with nodding blocks and without the shroud), a Denton upper neck load cell (model 1716⁹⁾) and a standard Hybrid III head. Set the mid neck angle adjustment to the full forward (flexion) position.

Mount the assembly on an acceleration sled and apply an acceleration to the base of the neck which meets the criteria of [Table 9](#). Measure the upper neck M_y moment with the Denton 1716 load cell⁹⁾ and the change in head pitch angle.

⁹⁾ 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 ISO 13232 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.

Table 9 — Neck extension sled pulse criteria

Peak acceleration	$5,8 \pm 0,5 \text{ G}$
Average acceleration above 1.0 G	$4,3 \pm 0,5 \text{ G}$
Overall velocity change	$4,5 \pm 0,3 \text{ m/s}$

Measure the change in head pitch angle directly with an external goniometer, or by high-speed photographic means.

Use high-speed film or video with a minimum frame rate of 1 000 frames per second. Use target decals on the dummy head for this measurement, correcting for parallax error. Synchronize the time-base of this data recording with that of the M_y data.

Process the moment data according to SAE J211, CFC600. Process the electronic angle measurement according to SAE J211, CFC180.

Plot the neck moment (M_y) versus change in head pitch angle on a graph, along with the corridor described in Table 10, and shown in Figure 1.

Table 10 — Neck extension bending corridor

Change in head angle (degrees)	Extension moment, M_y (Nm)
0	0
0	7
-10	7
-60	-15
-60	-34
0	0

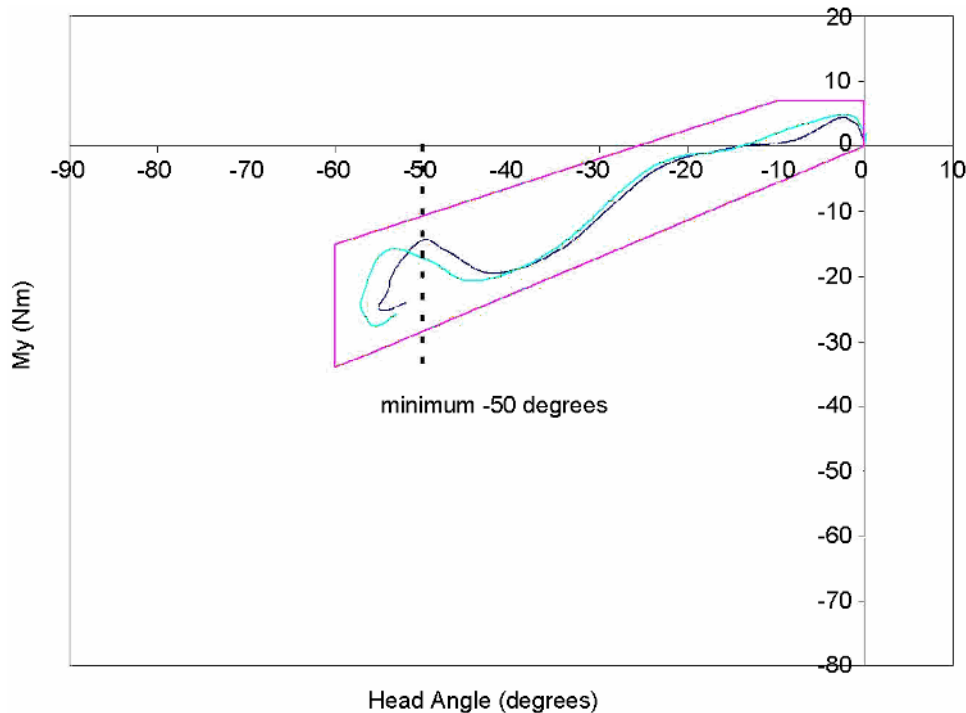


Figure 1 — Extension moment vs. head angle

6.8.2 Dynamic flexion test

Assemble a Hybrid III lower neck mount (set at 5,25 degrees extension), the motorcyclist neck to be tested (with nodding blocks and without the shroud), a Denton upper neck load cell (model 1716⁹⁾) and a standard Hybrid III head. Set the mid neck angle adjustment to the full forward (flexion) position.

Mount the assembly on an acceleration sled and apply an acceleration to the base of the neck which meets the criteria of **Table 11**.

Table 11 — Neck flexion sled pulse criteria

Peak acceleration	24,0 ± 1,5 g
Average acceleration above 1.0g	12,4 ± 1,0 g
Overall velocity change	16,8 ± 0,3 m/s

Measure the following variables:

- upper neck M_y moment with the Denton 1716 load cell,⁹⁾
- change in head pitch angle,
- x and z position of occipital condyle pin,
- x and z position of head centre of gravity.

Measure the change in head angle directly with an external goniometer, or by high-speed photographic means.

Use high-speed film or video with a minimum frame rate of 1 000 frames per second. Use target decals on the dummy head for this measurement, correcting for parallax error. Synchronize the time-base of this data recording with that of the M_y data.

Process the moment data according to SAE J211, CFC600. Process the electronic angle measurement according to SAE J211, CFC180.

Measure the neck angle based on a virtual line connecting the occipital condyle coordinates and T1 (virtual location of anterior tip of first thoracic vertebra). Consider T1 to be a fixed point located nominally 129,5 mm below and 11,3 mm behind the initial coordinate of the occipital condyle. Consider that the change in angle of this line to be the change in neck angle.

Plot the neck moment (M_y) versus head pitch angle, head centre of gravity and occipital condyle Z position versus X position, and neck angle versus head pitch angle on graphs, along with the corridors described in **Table 12** to **Table 15**, and shown in Figures 2 to 4.

Table 12 — Neck flexion bending corridor

Change in head angle (degrees)	Flexion moment, M_y (Nm)
0	11,5
17,5	11,5
50	45
65	57
65	0
35	0
20	-20
0	-25

Table 13 — Neck flexion head centre of gravity corridor

Head c. of g. (x mm)	Head c. of g. (z mm)
11	148
80	121
130	23
115	7
68	98
6	124
11	148

Table 14 — Neck flexion occipital condyle corridor

Occipital condyle (x mm)	Occipital condyle (z mm)
30	195
108	167
183	66
169	46
96	144
23	172
30	195

Table 15 — Neck flexion change in neck angle vs. change in head angle corridor

Change in head angle (degrees)	Change in neck angle (degrees)
0	21
20	40
40	50
55	77
65	77
65	62
45	38
15	20
5	0

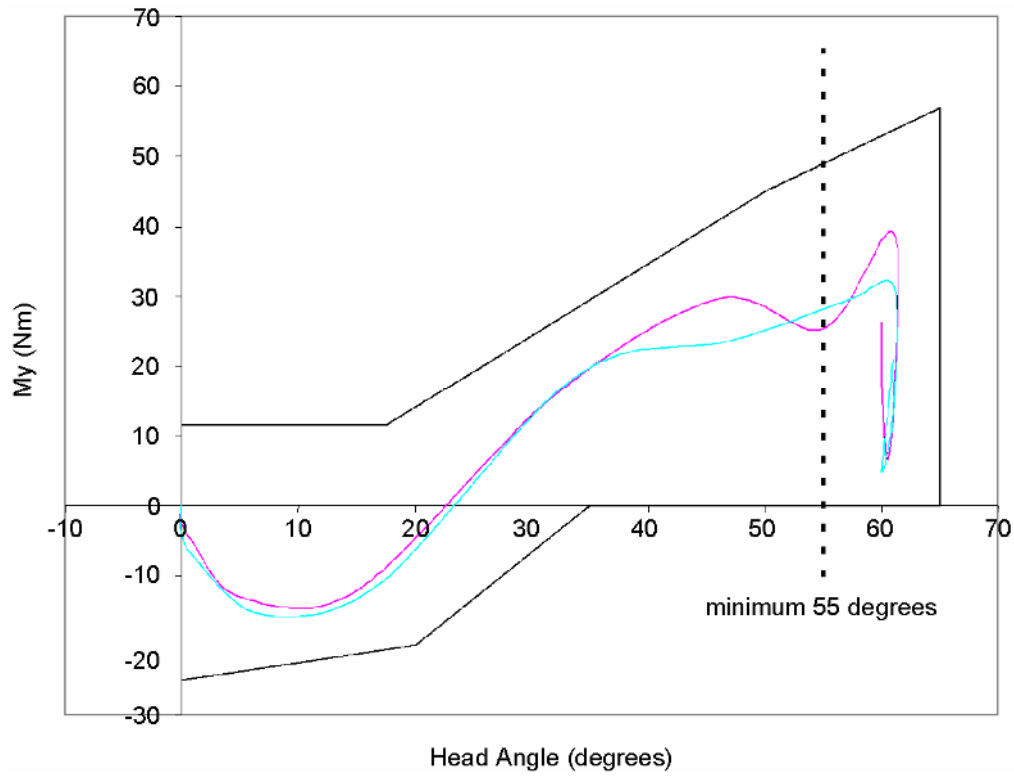


Figure 2 — Neck flexion bending moment vs. head angle

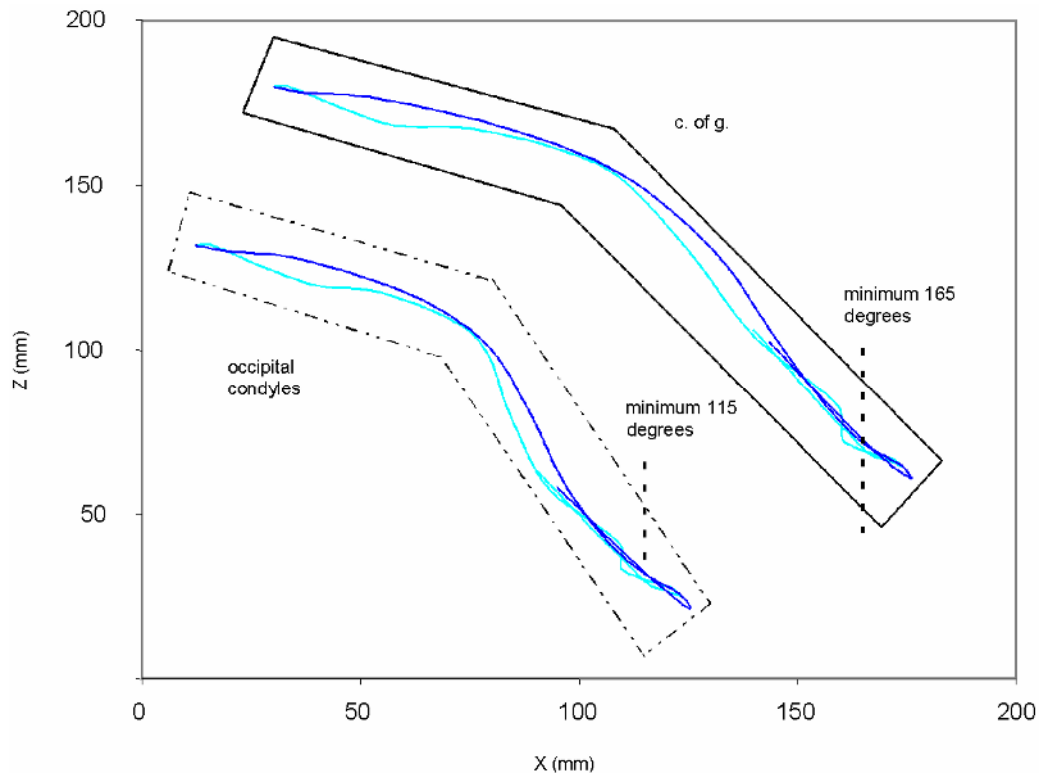


Figure 3 — Neck flexion occipital condyle and head centre of gravity position

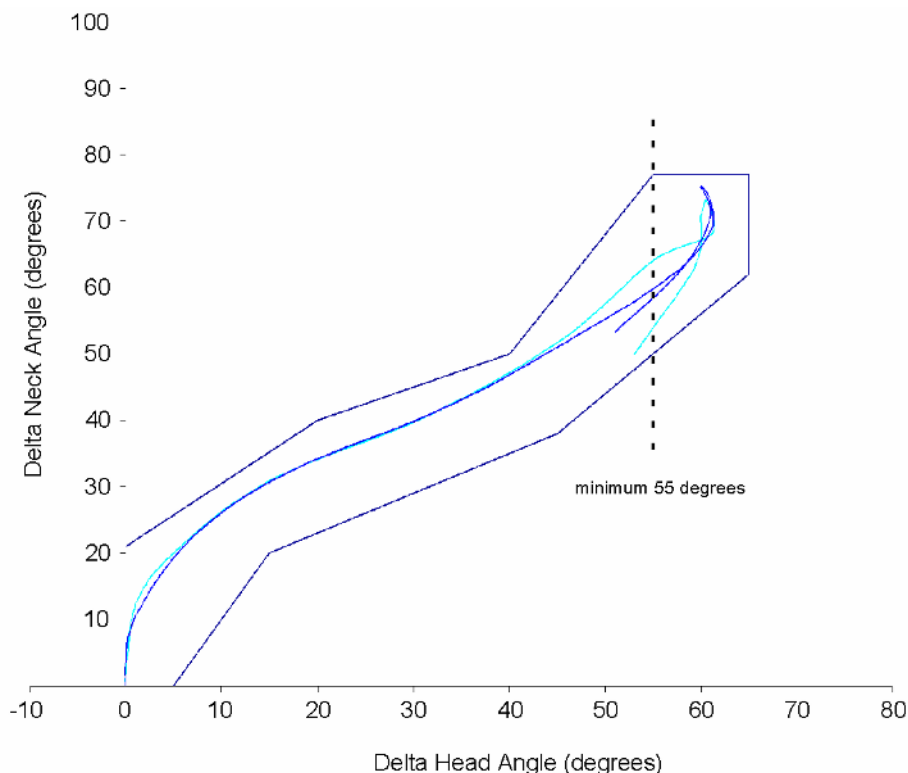


Figure 4 — Flexion neck angle vs. head angle

6.8.3 Dynamic lateral test

Assemble a Hybrid III lower neck mount (set at 5,25 degrees extension), the motorcyclist neck to be tested (with nodding blocks and without the shroud), a Denton upper neck load cell (model 1716⁹⁾) and a standard Hybrid III head, set the mid neck angle adjustment to the full forward (flexion) position.

Mount the assembly on an acceleration sled and apply an acceleration to the base of the neck which meets the criteria of [Table 16](#).

Table 16 — Lateral sled pulse criteria

Peak acceleration	13,5 ± 1,0 G
Average acceleration above 1.0 G	5,9 ± 1,0 G
Overall velocity change	7,4 ± 0,5 m/s

Measure the head roll angle, and the y position and z position of the head centre of gravity.

Measure the head angle and centre of gravity position by high speed photographic means. Do not use an external goniometer for displacement measurement due to the non-planar motion of the neck in lateral bending. Do not use external targets on the head for locating the centre of gravity due to large amounts of head twist during this event. Insert a slender metal rod (nominally 350 mm long and 1,5 mm diameter) laterally through the centre of gravity holes in the skull, centre the rod, and affix targets to each end. Ensure that both targets remain visible to the camera throughout the test, such that the centre of gravity position may be resolved as a mid-point between the targets. Measure head angle by referencing a line between the targets.

Use high-speed film or video with a minimum frame rate of 1 000 frames per second. Correct for parallax error.

Plot the head the head roll angle vs. time and z position vs. head y position on graphs, along with the corridors described in [Tables 17 and 18](#), and shown in Figures 5 and 6.

Table 17 — Lateral head angle vs. time corridor

Time (sec)	Head angle (degrees)
0	0
0,098	77
0,128	77
0,157	70
0,157	32
0,12	60
0,098	60
0,025	0

Table 18 — Lateral head centre of gravity corridor

Head c. of g. (y mm)	Head c. of g. (z mm)
0	10
50	6
90	-10
120	-29
140	-53
150	-71
135	-84
120	-57
100	-37
60	-17
0	-7

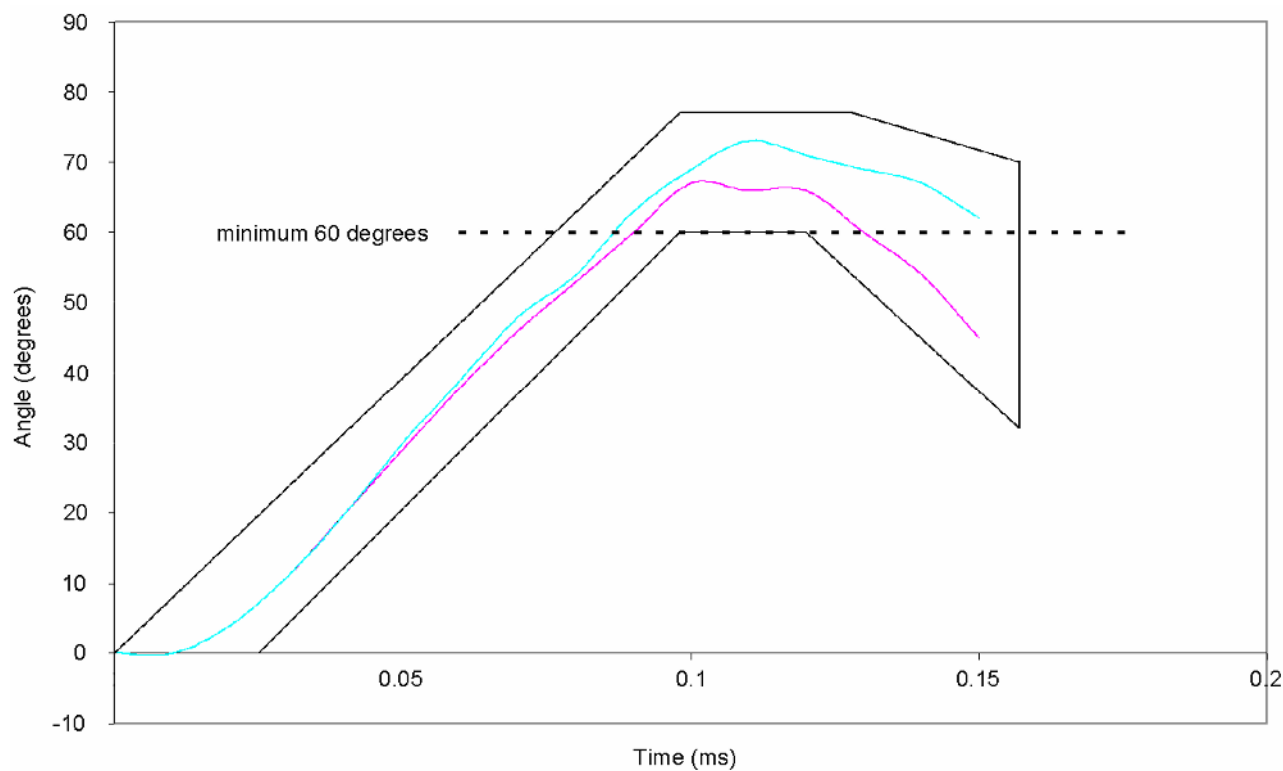


Figure 5 — Lateral head angle vs. time

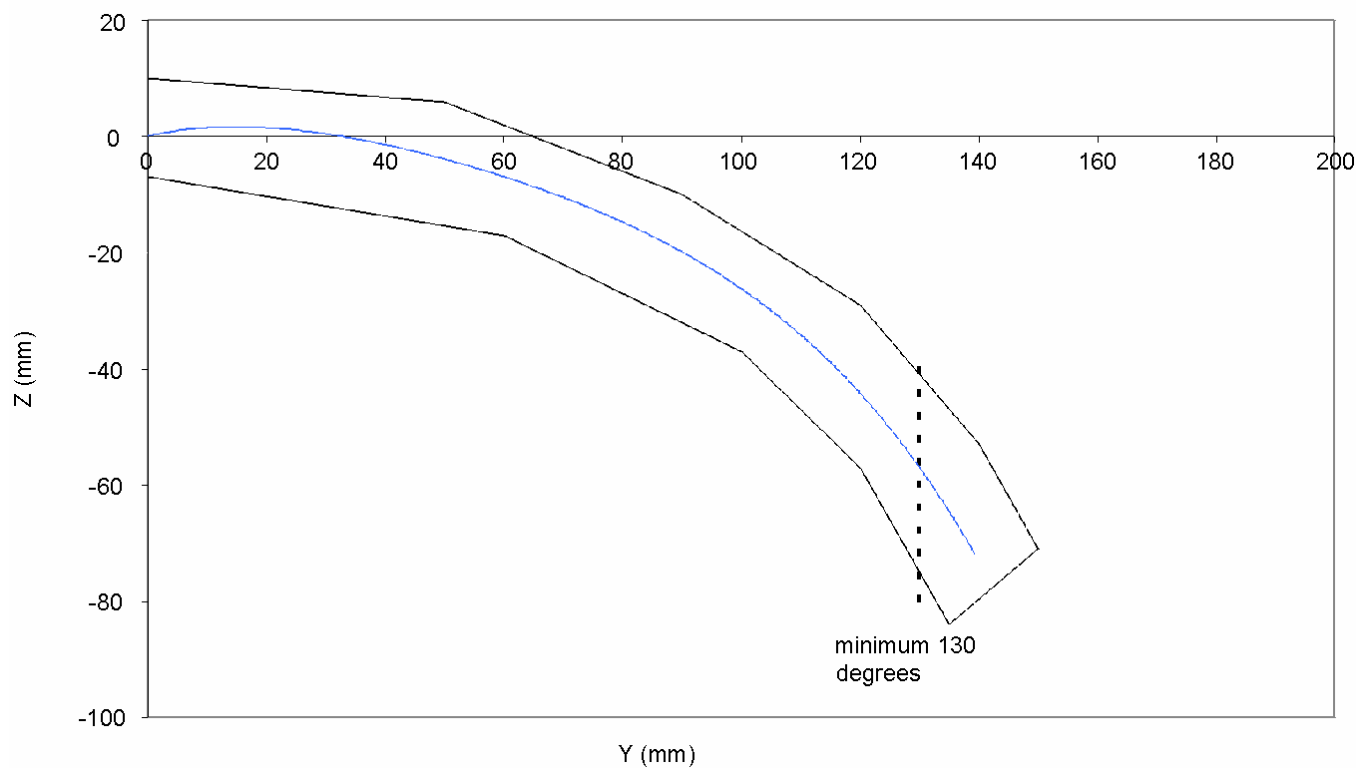


Figure 6 — Lateral head centre of gravity position

6.8.4 Dynamic torsion test

Assemble a Hybrid III lower neck mount (set at 5,25 degrees extension), the motorcyclist neck to be tested (with nodding blocks and without the shroud), and a Denton upper neck load cell (model 1716⁹⁾). Do not use a dummy head. Set the mid neck angle adjustment to the full forward (flexion) position.

Use either the pendulum fixture shown in Figure A.28 or equivalent. Release the pendulum so that its velocity at the bottom of the swing is 4,2 m/s ± 0,2 m/s. Measure the pendulum velocity in the last 10° before the vertical position. Measure the torque at the top of the neck, using a Denton load cell, model 1716⁹⁾). Measure the rotation of the neck mount using a potentiometer or other suitable device.

Process moment data according to SAE J211, CFC600. Process electronic angle measurement according to SAE J211, CFC180.

Plot the neck torque vs. the rotation angle of the lower neck mount on a graph, along with the corridor described in [Table 19](#), and shown in Figure 7

Table 19 — Neck torsion stiffness corridor

Rotation (degrees)	Neck torque M_z (Nm)
0	10
125	55
140	44
13	0

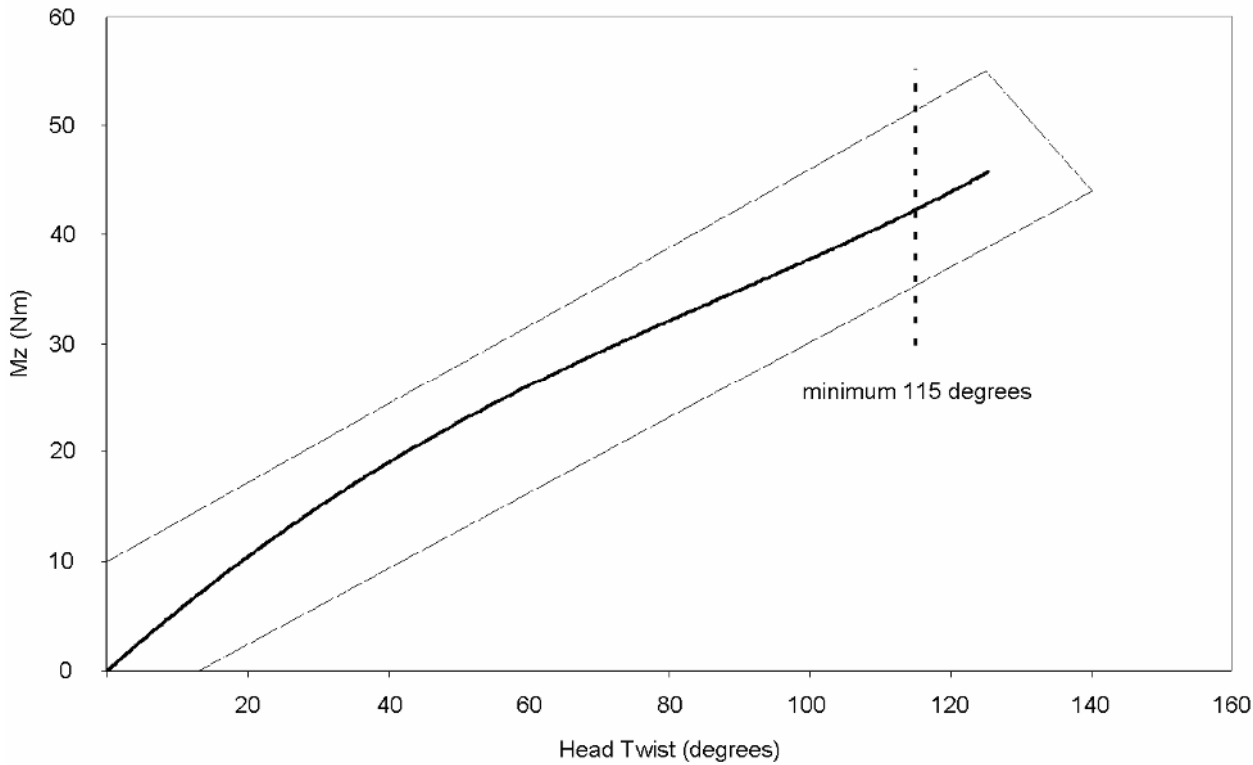


Figure 7 — Neck torsion stiffness