TECHNICAL REPORT

ISO/TR 12353-3

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Road vehicles — Traffic accident analysis —

Part 3: Guidelines for the interpretation of recorded crash pulse data to determine impact severity

Véhicules routiers — Analyse des accidents de la circulation — Partie 3: Lignes directrices pour interpréter l'enregistrement de gravité des chocs

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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.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 12353-3 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 12, *Passive safety crash protection systems*.

ISO 12353 consists of the following parts, under the general title *Road vehicles — Traffic accident analysis*:

— *Part 1: Vocabulary*

— *Part 2: Guidelines for the use of impact severity measures*

— *Part 3: Guidelines for the interpretation of recorded crash pulse data to determine impact severity* [Technical Report]

Introduction

With the completion of ISO 12353-2, an important extension is guidelines for the use and application of the in-vehicle recorded crash pulse data. The aim of ISO/TR 12353-3 is to provide definitions and recommended measurements of impact severity data recording to be used in evaluation and analyses. This will facilitate a comparison of different accident databases, and urge on the work of accident analyses based on impact severity data recording. The higher quality of impact severity determination will improve the accuracy of analyses and development work for the industry, governments and others.

As more advanced active and passive safety technology is introduced in motor vehicles, it is important to continuously evaluate the technology to determine its efficiency. Furthermore, it is essential to explore occupant injury risk and severity for impact severity parameters best correlated to injury risk. Studies of real-life crashes are the most important way to gain such knowledge.

Different types of accident data recorders have been developed and used for the purposes of improving data quality. Car manufacturers also use data from sensors and recording devices in the development process of new safety technology and to verify the effectiveness of existing technology.

Specifically for impact severity parameters, there is a need for definitions of their measurements, recording, and process of calculation. This Technical Report concentrates on the data that can be obtained from crash pulse data recorders for determination of impact severity.

The recorded data may be either acceleration-time data or change of velocity (Δv) time data. This Technical Report includes methods applicable to the interpretation of recorded Δv data from event data recorders (EDR) fulfilling the requirements of United States Code of Federal Regulations 49 CFR Part 563.[1]

This Technical Report focuses on the crash pulse characteristics in Figure 1, the Dose – Response model (also referred to in ISO 12353-2), slightly modified for the purposes of this Technical Report.

As shown in Figure 1 several parameters are influencing the risk of an injury. This Technical Report focuses on the influence of crash pulse characteristics on injury risk.

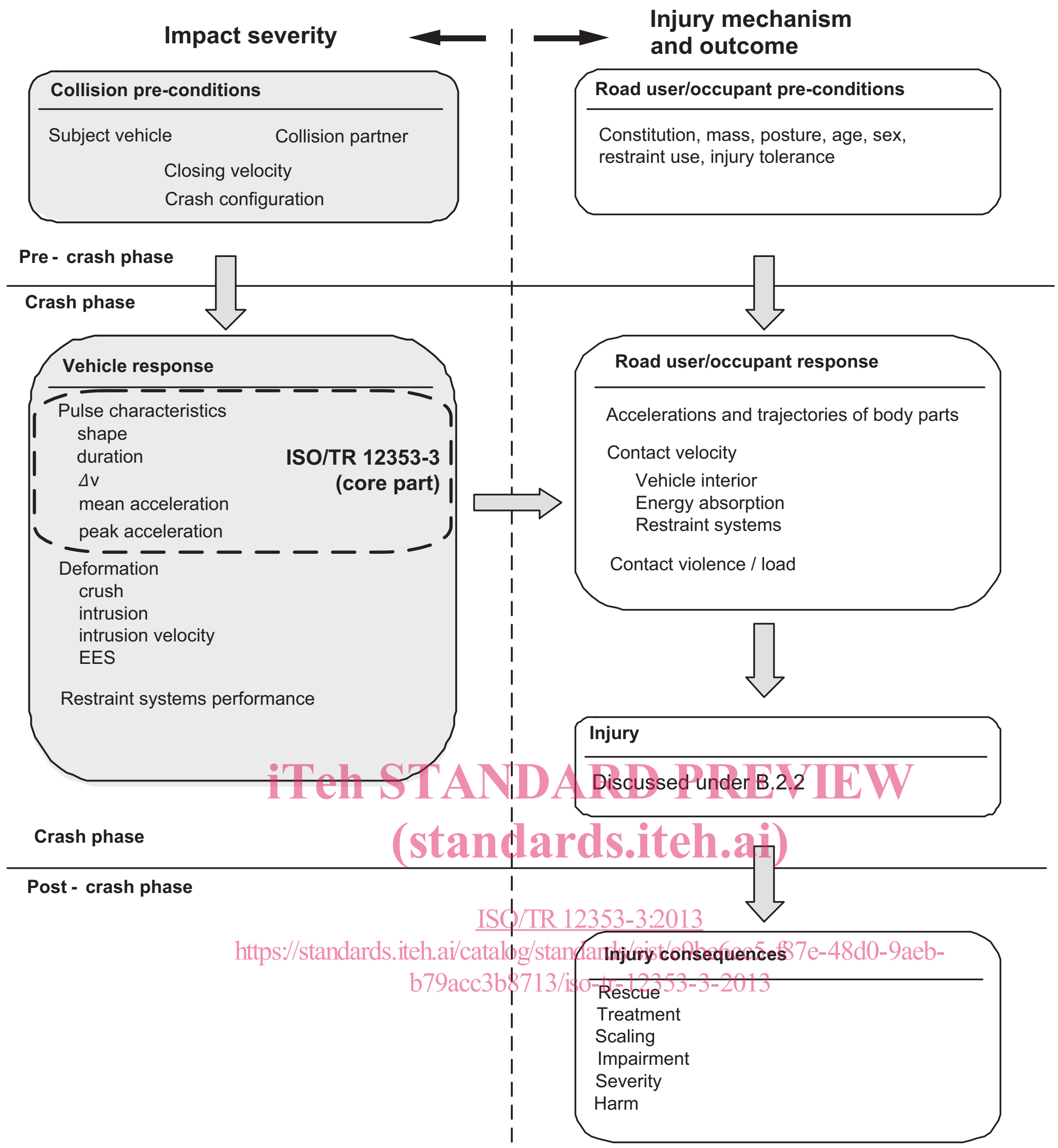


Figure 1 — Impact severity and injury mechanism/outcome (Dose – Response model)

With crash pulse recording techniques, and using a recorder in the undeformed part of the vehicle chassis, it is possible to quantify physical crash pulse parameters during a vehicle crash. This is what the vehicle restraint systems and the vehicle interior will have to handle in order to minimize the loading on the vehicle occupants.

This Technical Report discusses the recorded physical parameters that are relevant to take into account for certain impacts, and also discusses the possible misuse and traps when using crash pulse data.

Road vehicles — Traffic accident analysis —

Part 3: Guidelines for the interpretation of recorded crash pulse data to determine impact severity

1 Scope

This Technical Report describes the determination of impact severity in road vehicle accidents as defined in ISO 12353-2, based on recorded acceleration and velocity data and derived parameters from vehicle crash pulse recorders or event data recorders, including data from self-contained devices or vehicle integrated functionalities. Methods applicable to the interpretation of recorded Δv data from event data recorders fulfilling the requirements of United States Code of Federal Regulations 49 CFR Part 563 are also included.

This Technical Report includes definitions and interpretation of recorded data related to impact severity determination. Some information on application of the data are also provided.

The purpose of this Technical Report is to interpret available recorded crash pulse data. The methods in this Technical Report are applicable to interpretation of crash pulses in both longitudinal and lateral directions. However, based on available data, most examples are given for the longitudinal direction.

This Technical Report does not address aspects such as the pre-crash phase, data element specifications, and data recording and retrieval technology.

2 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 12353-1, *Road vehicles — Traffic accident analysis — Part 1: Vocabulary*

ISO 12353-2, *Road vehicles — Traffic accident analysis — Part 2: Guidelines for the use of impact severity measures*

ISO 4130, *Road vehicles — Three-dimensional reference system and fiducial marks — Definitions*

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

SAE J211-1, *Instrumentation for Impact Test — Part 1: Electronic Instrumentation*

SAE J1698-1, *Vehicle Event Data Interface — Output Data Definition*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4130, ISO 12353-1, ISO 12353-2, SAE J1698-1, and the following apply.

3.1
crash pulse recorder
device or unit capable of recording acceleration or Δ*v*-time history data during the impact phase

Note 1 to entry: Crash pulse recorder is used as a generic term in this Technical Report to differentiate from Event Data Recorders as defined in 49 CFR Part 563.

3.2
Event Data Recorder
EDR
device or function in a vehicle that records the vehicle's dynamic time-series data during the time period just prior to a crash event (e.g. vehicle speed vs. time) or during a crash event (e.g. Δ*v* vs. time), intended for retrieval after the crash event

Note 1 to entry: The definition is in accordance with 49 CFR Part 563.

Note 2 to entry: Data elements other than time series data are often recorded.

3.3
linear acceleration
acceleration in any direction during an impact event

3.3.1
longitudinal acceleration
acceleration in the vehicle X-axis direction during an impact event

3.3.2
lateral acceleration
acceleration in the vehicle Y-axis direction during an impact event

3.3.3
vertical acceleration
acceleration in the vehicle Z-axis direction during an impact event

3.4
rotational acceleration
acceleration about one of the vehicle axes

3.4.1
yaw acceleration
acceleration around the vehicle Z-axis

3.4.2
pitch acceleration
acceleration around the vehicle Y-axis

3.4.3
roll acceleration
acceleration around the vehicle X-axis

3.5
Δ*v* – time history
cumulative history of developing change of velocity resulting in Δ*v*

3.6
jerk
third derivative with respect to time of the position of an object; equivalently the rate of change of the acceleration of an object

Note 1 to entry: Considered a measure of harshness of vehicle motion.

4 Basic principles of crash pulse and derived measures

The crash pulse time history provides the possibility of a superior determination of impact severity compared to e.g. deformation-based Δv and EES (Energy Equivalent Speed), in several impact types.

The whole crash pulse is not possible to use as a single parameter for impact severity, but certain characteristics of the crash pulse can be useful in interpreting the injury outcome in certain impact types.

Some characteristics can be directly obtained or calculated from the crash pulse, e.g.:

— (maximum cumulative) Δv;

— peak acceleration;

— time to peak acceleration;

— mean acceleration;

— and to some extent, the total duration.

For the calculation of some of these parameters the start and end time of the crash pulse need to be defined, as the pulse duration needs to be defined. This is discussed in detail in 5.2.3.

Distance, velocity, acceleration and jerk time histories, if not directly recorded, can be derived by differentiation or integration.

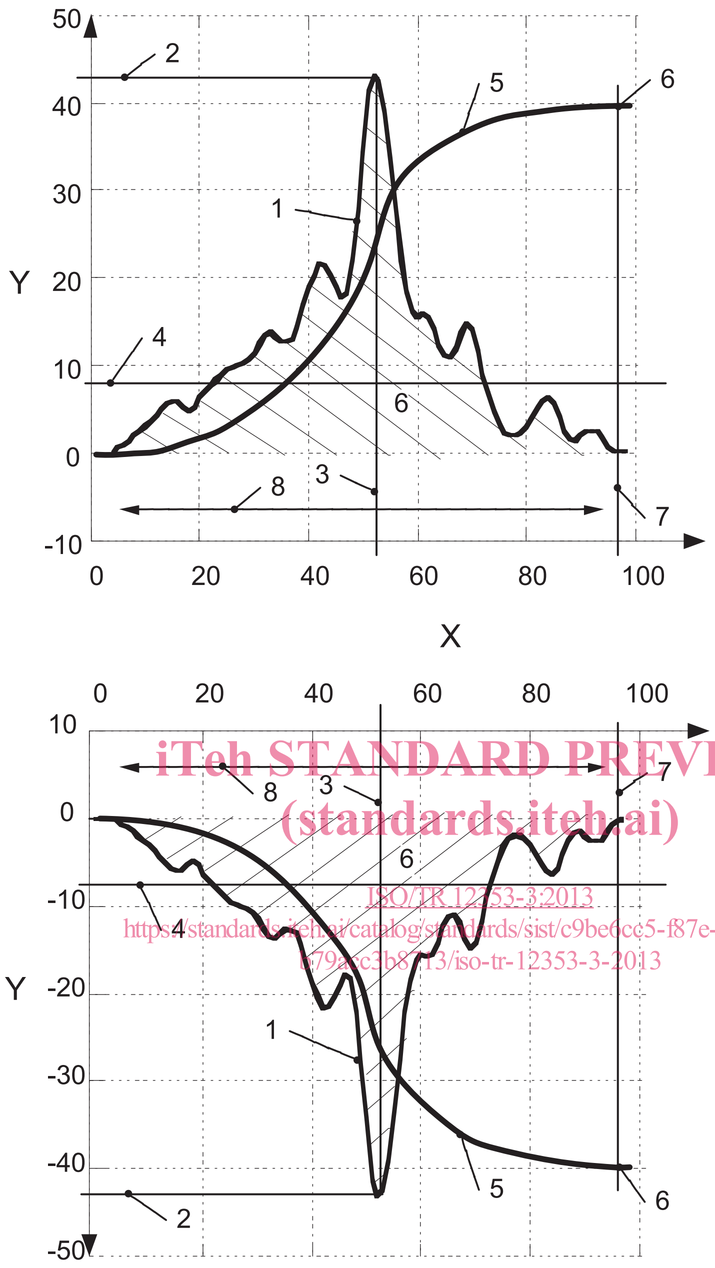
Δv can be obtained as the final value of the Δv-time history curve using the defined pulse duration, also known as the area under the acceleration curve. Details of how to calculate these parameters are further described and discussed in Clause 5.

The Δv-time history, the cumulative history of developing change of velocity, can be derived from the acceleration-time history as the cumulative area under the crash pulse within a specified time period:

$$\Delta v(t) = \int a(t)dt$$

where a is the acceleration (crash pulse).

Figure 2 illustrates a generic crash pulse with main characteristics and some derived parameters. Figure 3 illustrates the same generic crash pulse with corresponding jerk, distance, and velocity curves.



Key

1 acceleration-time history

2 peak acceleration

3 time to peak acceleration

4 mean acceleration

5 Δv-time history

6 Δv (maximum cumulative Δv, also given by the area under the crash pulse)

7 time to maximum, Δv

8 pulse duration, Δt

X time [ms]

Y acceleration [g], change of velocity [km/h]

NOTE The diagram is shown with both positive and negative y-axis, both are commonly used in the literature. This Technical Report does not have a preference for either type of representation, and both types are shown in examples.

Figure 2 — Crash pulse with derived parameters (shown with positive and negative y-axis)

In Figure 3, four parameters are shown, all derived from the recorded acceleration-time history:

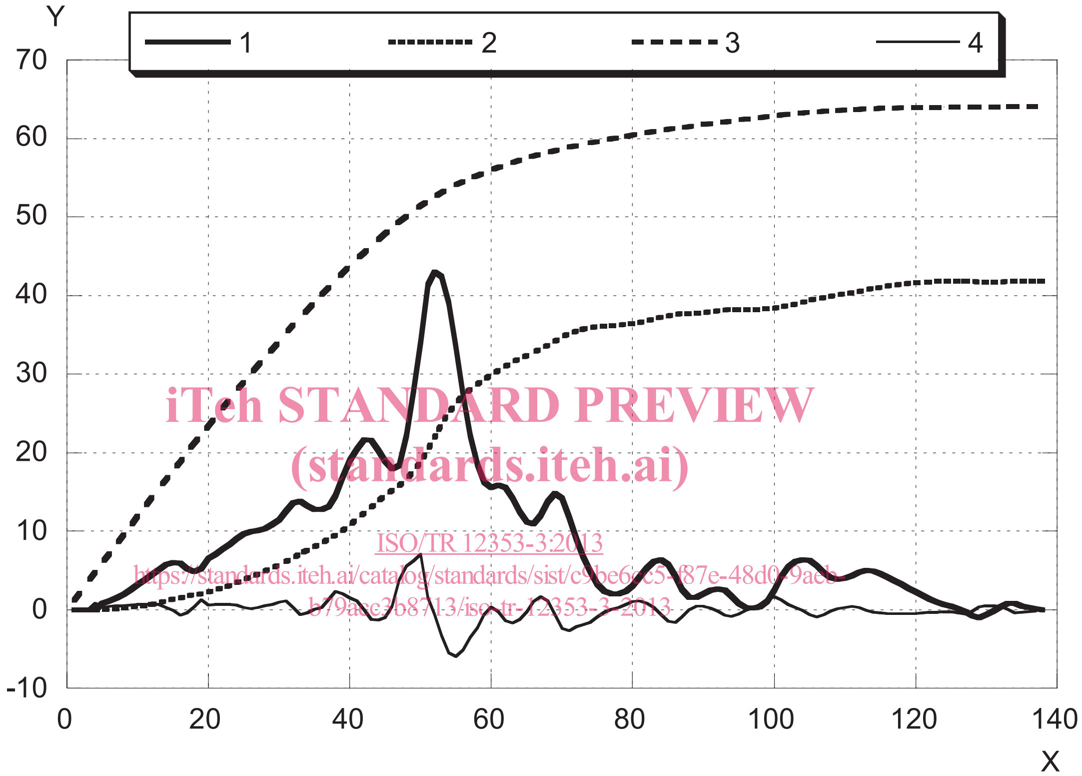
— Acceleration-time history;

— Δ*v*-time history;

— Distance-time history of the centre of gravity (or the crash pulse recorder);

— Jerk-time history.

From these calculated parameters, peak jerk, Δ*v* and Δ*s* can be derived.



Key

1 crash pulse (acceleration-time history) [g]
2 Δ*v*-time history [km/h]
3 distance-time history of the CG (or the crash pulse recorder) [cm]
4 jerk time history [m/s^3] (magnified 10 times)
X time [ms]
Y acceleration [g], change of velocity [km/h], distance [cm], jerk [m/s^3/10]

Figure 3 — Crash pulse with corresponding jerk, distance, and velocity curves

5 Guidelines for basic interpretation of crash pulse recorder data

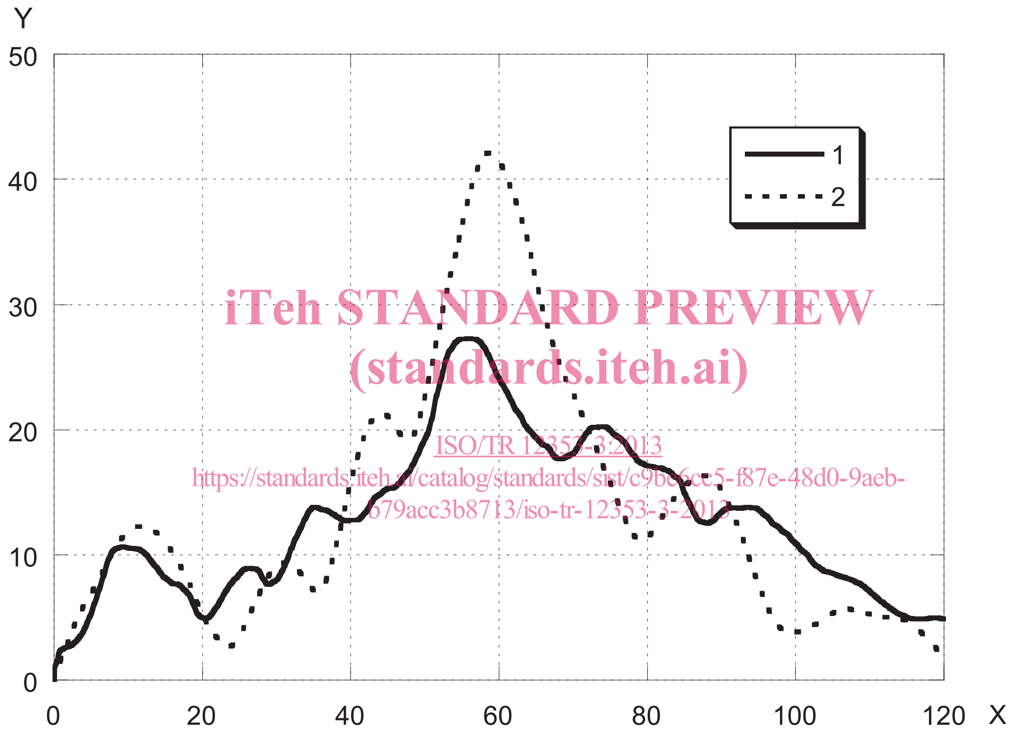
5.1 General

The procedure of exactly how to describe impact severity is still an open issue although ISO 12353-2 has defined parameters relevant to certain crash configurations.

Most of the world-wide acting in-depth accident investigation teams use the change of velocity, Δ*v*, or the Energy Equivalent Speed (EES), as a parameter for impact severity when presenting results of the injury outcome versus impact severity.

There is a wide scatter of the results when the correlation of Δ*v* or EES and injury outcome is analysed. One of the reasons for the scatter of injury outcome is the injury severity scaling system itself. Other reasons are the variability in human-related parameters such as age, gender or body weight.

Another reason is that even at identical parameter values for impact severity like Δ*v*, the acceleration crash pulse can be significantly different. The latter can be demonstrated by comparison of, e.g. the dummy chest loading for different crash tests with identical Δ*v* and EES values but significantly differing acceleration crash pulses. For a meaningful comparison, all other important parameters such as vehicle crash performance and restraint systems have to be identical. These conditions are effectively fulfilled for a series of four frontal impacts shown in D.1. Figure 4 illustrates an example from those.



Key

1 car-to-car impact with 57 % overlap and a closing velocity of 110 km/h

2 impact against a rigid barrier with 50 % overlap at 55 km/h

X time [ms]

Y acceleration [g]

Figure 4 — Acceleration crash pulses of two different crashes with identical Δ*v* and EES

5.2 Crash pulse definitions

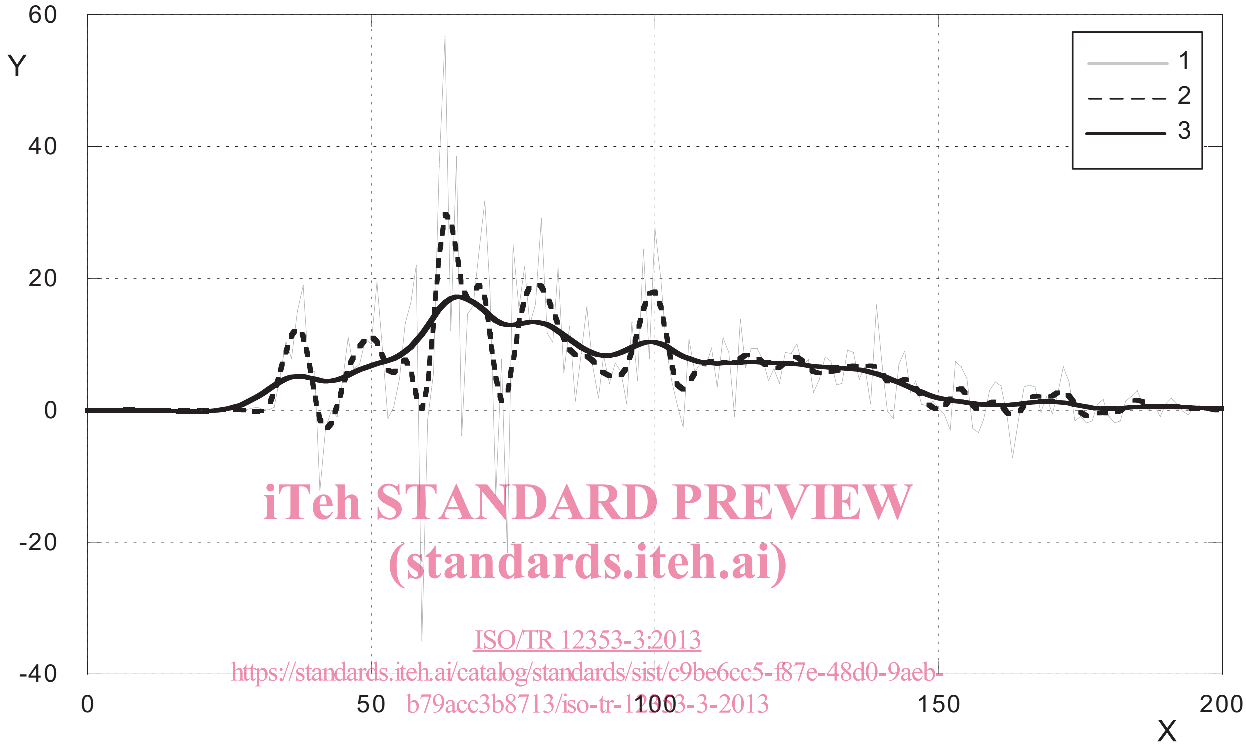
5.2.1 General

According to ISO 12353-1, the crash pulse is defined as the acceleration-time history during the impact phase.

NOTE It is also common to refer to the Δ*v*-time history as the crash pulse.

5.2.2 Sampling and filtering

The general recommendation (according to ISO 6487 and SAE J211-1) is that the sampling frequency should be at least ten times the channel frequency class applied, e.g. a CFC60 filter can be applied to a sampling frequency of 600 Hz or higher. According to SAE J211-1, CFC60 should be applied to vehicle crash acceleration data. A filtering example is shown in Figure 5, where a curve showing CFC60 and CFC20 filtering of the same pulse has been applied. The CFC20 filtering will also be used in 5.2.3.3.



Key

1 original unfiltered acceleration data (1000 Hz)

2 CFC60 filtered (60 Hz 4 pole Butterworth)

3 CFC20 filtered (20 Hz 4 pole Butterworth)

X time [ms]

Y acceleration [g]

NOTE Each level of filtering / averaging contains less information.

Figure 5 — Effects of different filtering applied to an acceleration crash pulse

5.2.3 Determination of beginning (t_0) and end (t_{end}) of crash pulse

In many cases (for example for the determination of mean acceleration) it is crucial to define when the crash pulse actually starts and ends, and very often this can be hard to determine.

The start and end of the crash pulse need to be determined in different ways depending on the data available.

The definitions of t_0 and t_{end} could be determined either with respect to the crash pulse characteristics or with respect to characteristics of derived measures such as Δv. Either of the following methods is recommended according to this Technical Report.

NOTE See Annex E for calculation processes related to the respective methods.

5.2.3.1 Method A: Determination based on Δ*v* – time history

This method is consistent with the determination of t_0 and t_{end} according to SAE J1698-1, referenced in 49 CFR Part 563 for continuously running algorithms. Using time of deployment will not allow an appropriate determination of t_0.

Definition of t_0: Time when the cumulative Δ*v* of over 0,8 km/h is reached within a 20 ms time period in the longitudinal direction for a frontal/rear event, or within a 5 ms time period in the lateral direction for a side impact event. See Figure 6.

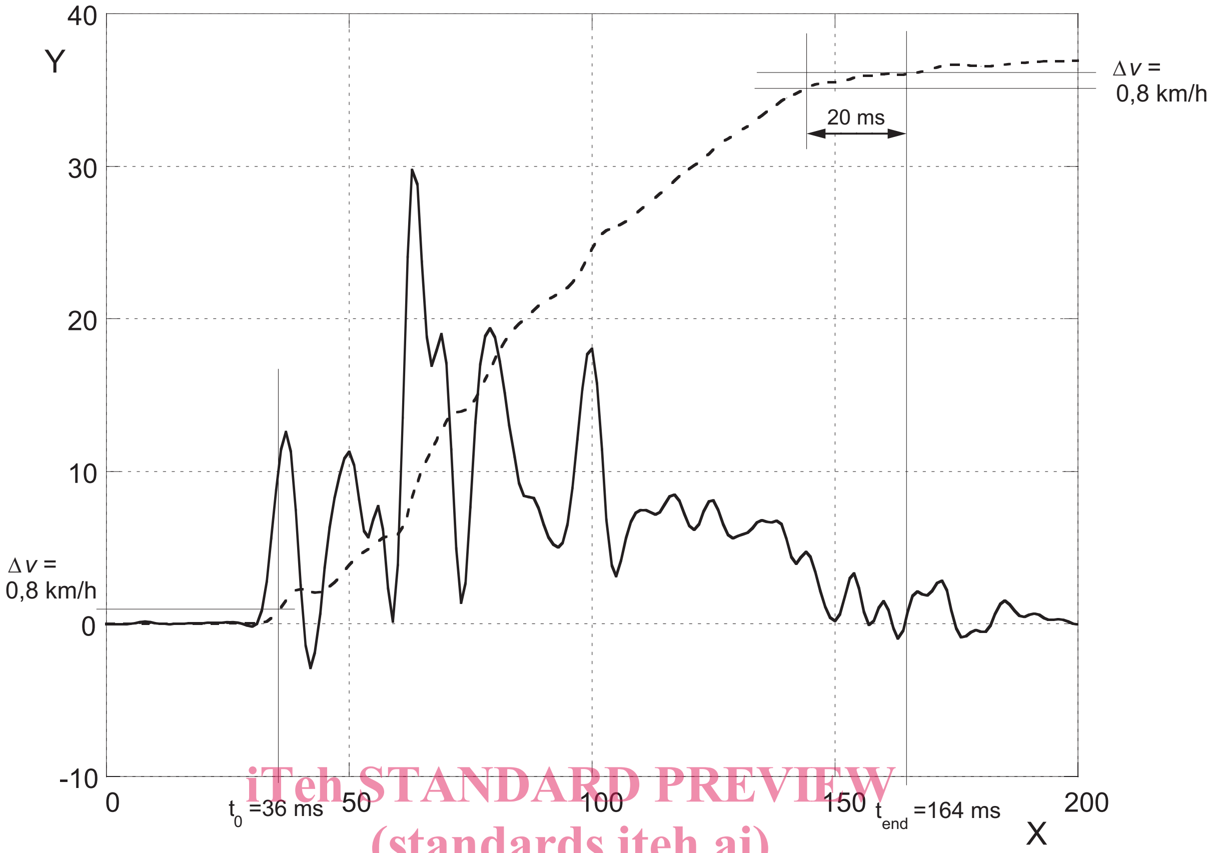
NOTE 1 According to 49 CFR Part 563, for systems with wake-up occupant protection control algorithms, the time at which the occupant protection control algorithm is activated may be used to define t_0.

Definition of t_{end}: Time where the end of an impact event (t_{end}) is at the moment when the longitudinal, cumulative Δ*v* within a 20 ms time period becomes 0,8 km/h or less.

NOTE 2 If t_{end} was not captured, the time to maximum Δ*v*, if available, may be substituted for t_{end} when a) the recorded crash pulse time-history is truncated (cut short) before meeting the 0,8 km/h change of velocity within 20 ms criterion, and b) the time to maximum Δ*v* is longer than the truncated crash pulse recording time period. The same logic is applied to side and rear impact events.

NOTE 3 In special cases, it may be possible to draw sufficiently secure conclusions from the acceleration-time history curve so that t_0 and/or t_{end} can be determined directly. Examples showing determination of t_0 and t_{end} for specific crash pulses are given in Annex E.

NOTE 4 Special attention has to be drawn to this when there are multiple impacts or more than one crash pulse in a crash sequence.



Key

X time [ms]

Y acceleration [g], change of velocity [km/h]

NOTE This figure shows Method A applied to a longitudinal crash pulse.

Figure 6 — Definition of t_0 and t_{end}, Method A

5.2.3.2 Method B: Determination based directly on acceleration – time history

This method directly uses a CFC60 filtered acceleration pulse, see Figure 7.

Draw one line representing 10 % of peak acceleration, and another line representing 90 % of peak acceleration. Determine the intersections of the crash pulse and the above lines. This will form a triangle.

Definition of t_0: Time where the left intersection line meets the zero line.

Definition of t_{end}: Time where the right intersection line meets the zero line.

NOTE For some acceleration pulses it is not obvious if the first or a later intersection should be used. Below a later intersection is shown. In case of doubt, Method C can be used.

