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Plastics — Validation of force-time curves obtained from high- speed tensile tests

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Foreword

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This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

This is the first edition of ISO 22183.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The method described by this ISO standard provides criteria for the validation of measurement curves obtained from high-speed tensile tests.

Force, time, travel and strain measurement systems of high-speed tensile equipment is usually calibrated in static mode. Dynamic effects, occurring at such tests, need to be addressed and limits or ranges of use for the obtained assessment parameters need to be set in order to allow the validation of the obtained measurement curves.

This standard contains a method to measure the spectrum of the natural mechanical frequencies of the force transducer and grip arrangement, considering that these frequencies are the most important limiting factor for the range of use of a high-speed tensile test equipment.

Besides, there are further parameters which may play a role for the dynamic quality of the measurement curves, such as the data acquisition frequency, or oscillations generated in the machine frame. These parameters should be carefully supervised and measures need to be taken if such problems occur in a significant way.

In case direct travel or strain measurement is used to generate stress-strain curves or to determine nominal or local strain rates, further parameters, such as the synchronization between force, time and strain channels, need to be supervised.

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Plastics — Validation of force-time curves obtained from high- speed tensile tests

1 Scope

This document specifies procedures for validation of high-speed tensile test data. This document specifies a method to determine the spectrum of the natural oscillation frequencies of the force transducer and grip configuration of the high-speed tensile test equipment. The lowest significant frequency is used for the validation. This validation procedure only applies to force measurement systems used in high-speed tensile testing machines showing a level of resonance influence that could be critical to the obtained result. Once the relevant frequencies of the system and the anticipated strain for the given material are known, this method allows to calculate the theoretical maximum allowed test velocity too.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
unloaded region
time domain prior to the application of the load by the striker

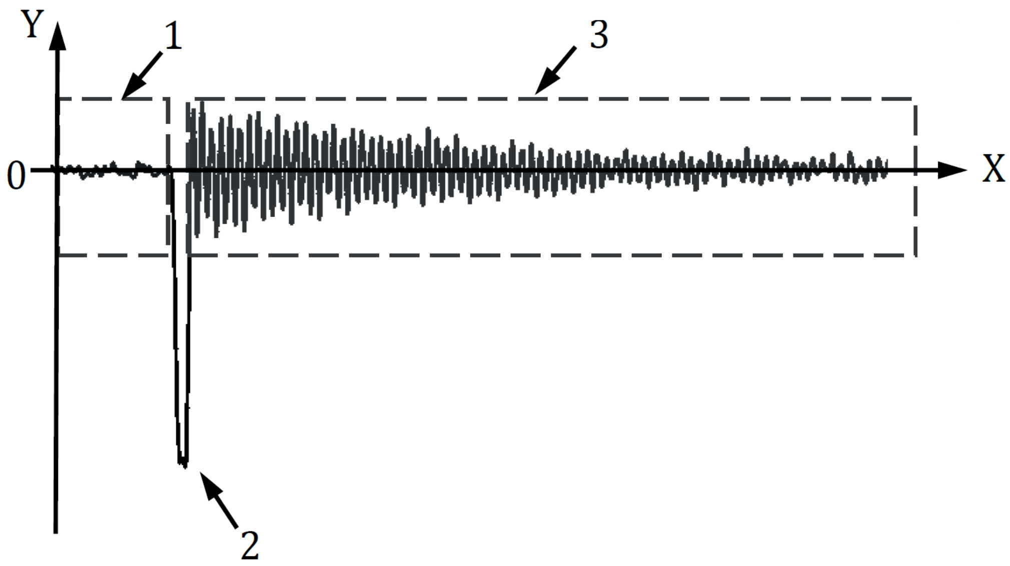
Note 1 to entry: See **Figure 1**.

3.2
striking peak
first force peak generated by the striker hitting the grip

Note 1 to entry: See **Figure 1**.

3.3
residual oscillation
oscillations triggered by the striker. It represents the force on the time domain after the strike of the striker

Note 1 to entry: See **Figure 1**.



Key

X time (ms)

Y force (N)

1 unloaded region

2 striking peak

3 region of residual oscillation

Figure 1 — Typical force-time signal during the impact test

3.4
maximum force within the residual oscillations
$F_{r,max}$
maximum force – intended as absolute value – present in the residual oscillations, excluding the striking peak

Note 1 to entry: It is expressed in Newtons (N).

3.5
maximum force in the unloaded state
$F_{u,max}$
maximum absolute force value in the unloaded region

Note 1 to entry: It is expressed in Newtons (N).

3.6
natural oscillation spectrum
frequency spectrum obtained as a result of a Fast Fourier Transform Analysis of the residual oscillation, normalized to the largest amplitude present

3.7
frequency
f
frequency of a relevant peak in the natural frequency spectrum

Note 1 to entry: It is expressed in kilohertz (kHz).

3.8
normalized intensity of the frequency
I
normalized intensity of frequency peak in the natural oscillation spectrum

3.9
lowest relevant frequency
f_{low}
frequency of the first relevant peak in the natural oscillation spectrum

Note 1 to entry: It is expressed in kilohertz (kHz).

3.10
event time
t_e
time from the start point of the force-time curve to the point of the relevant event to be measured.

Note 1 to entry: The relevant event is either the yield point, or the break point or any other defined point.

Note 2 to entry: It is expressed in milliseconds (ms).

3.11
threshold number of waves in the event
$w_{N,th}$
minimum number of waves of the relevant lowest frequency within the event time.

3.12
gripping distance
L
initial length of the part of the specimen between the grips

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: See **Annex A**.

3.13
grip displacement
ΔL
displacement of the grip pulled to tensile direction of specimens from the beginning of the test

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: Most of the loading mechanics of the high-speed tensile test device have the one side pulled and the other end fixed, as shown in **Annex A**.

3.14
nominal strain
ε_t
grip displacement divided by the initial gripping distance

Note 1 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

3.15
nominal test speed
v
rate of separation of the gripping jaws

Note 1 to entry: It is expressed in meters per second (m/s).

3.16
maximum force
F_{max}
maximum force observed in the whole force-time curve during the whole high-speed tensile test

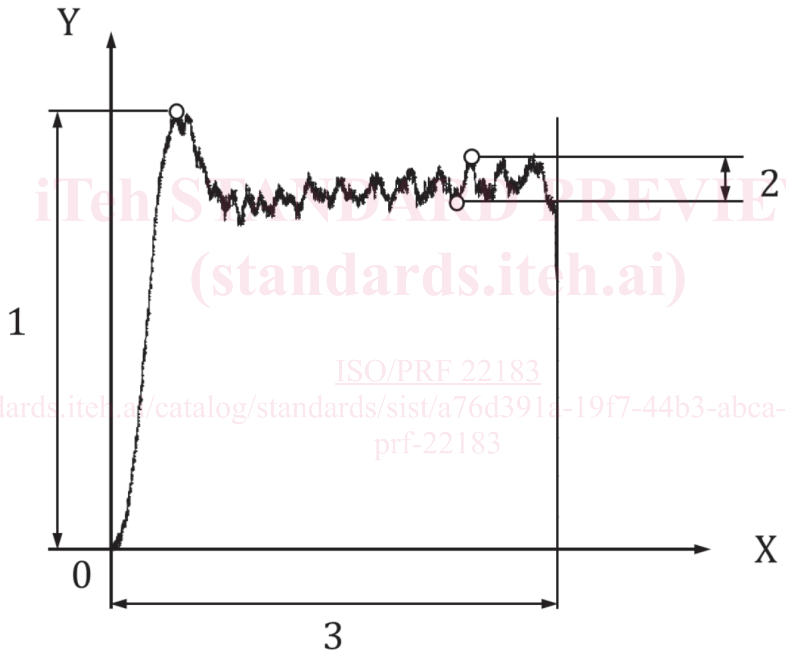
Note 1 to entry: See **Figure 2**.

Note 2 to entry: It is expressed in Newtons (N).

3.17
maximum amplitude of oscillations
$\Delta F_{a,max}$
largest peak-to-peak amplitude of oscillations, observed over a small portion of the curve during the high-speed tensile test, ignoring single spikes of electronic noise

Note 1 to entry: See **Figure 2**.

Note 2 to entry: It is expressed in Newtons (N).



Key

X time (ms)
Y force (N)
1 F_{max} the maximum force (N)
2 $\Delta F_{a,max}$ the maximum amplitude of oscillation (N)
3 t_e the event time (ms)

Figure 2 — Typical force-time curve during tensile test at high speed

4 Principle

The principle of this standard is based on the following two acceptance criteria:

1) The measurement of the natural oscillations of grip and force transducer configuration (see **clause 6.1**).

The natural oscillation frequencies of the force transducer and grip arrangement in the testing instrument are measured after a defined impact. These frequencies are analysed by means of a Fast Fourier Transform (FFT) and presented by their intensity over the relevant frequency range. The highest intensity observed is used to calculate a normalized intensity. The lowest frequency of a relevant normalized intensity will be used to establish the validation criterion.

2) The maximum allowed intensity (see **clause 6.2**)

The intensity of oscillations superimposed on the force – time curve is calculated by the ratio between the oscillation amplitude and the maximum force observed during the test.

5 Measurement of the natural oscillation spectrum of the grip and force transducer configuration

5.1 Measurement of natural oscillation frequencies

5.1.1 Set-up of the high-speed tensile equipment

The force transducer and the grip shall be well tightened and installed according to the equipment manufacturer's advice. If the jaw faces of the grips cannot be tightened without clamping a test specimen, as it may be the case when using wedge-type grips, use a small part of a rigid test specimen to ensure the jaw faces to be in a fixed and tightened situation.

5.1.2 Set-up of the striker

Use the striker capable of creating a defined single centric impact to the grip in the direction of the machine axis. It is recommended to use a tool that allows variation of the impact intensity and to adjust the striking position.

NOTE 1 A typical device of the striker and its striking position is shown in **Annex B**.

The mass and the impact speed of the striker shall be such to ensure that the maximum force within the residual oscillations $F_{r,max}$ is higher than 10 % of the full-scale value of the selected force measurement range and greater than 200 N.

NOTE 2 Preliminary tests to achieve these conditions are detailed in subclause **5.1.3**.

The impact force shall not exceed the capacity of the force transducer.

The direction of stroke shall coincide with the machine axis and be centric to it to within ±5 mm.

If it is not possible to create a centric impact due to the design of the grip, perform the impact at the closest possible position providing the least lateral oscillations and report the striking position with the results.

NOTE 3 Influence of the striking position on the natural oscillation spectrum is shown in **Annex C**.

5.1.3 Measurement procedure

Carry out preliminary impacts to adjust the impact speed of the striker in a way to ensure that the maximum force within the residual oscillations $F_{r,max}$

— is higher than 10 % of the full-scale value of the selected force measurement range;

— is at least 200 N;

— is at least 3 times higher than the maximum force in the unloaded state $F_{u,max}$.

Adjust the zero-point of the force measurement system.

Adjust the sampling rate in such way to be at least twice the natural oscillation frequency to be analyzed. A minimum sampling rate of 100 kHz is recommended.

Select the suitable range of the amplifier.

Measure the force resulting from the natural frequency oscillation over a time between 5 ms and 12 ms, in order to have enough measurement points for the FFT evaluation.

Perform three measurement strikes in accordance with the defined conditions and record the force-time data in the unloaded state and after the impact for each impact.

Note the amplifier range, the cut-off frequency and the data acquisition frequency being used.

Determine $F_{r,max}$ and $F_{r,max}$ and ensure that the required relationship is achieved.

5.2 Determination of the natural oscillation spectrum

Use FFT to acquire the amplitude spectrum from the force-time curve acquired from the impact test.

Determine the length of the time-window to be used in the calculations of FFT.

In the case of acquiring the amplitude spectrum, data from 1,5 cycles after the force peak during impact test shall be used.

Select the appropriate window function and record the window function used.

Compare the frequency spectra obtained from the three measurements and check if the peaks occur at about the same frequencies and with similar intensities. If not, check for any loose parts and for the correct introduction of the impact strike and repeat the measurement.

The natural oscillation spectrum shall be plot as the normalized intensity of the amplitude spectrum as a function of the frequency (see **Figure 3**). The spectrum to be reported is an average value, obtained from the spectrum results of each impact test.

Select the lowest frequency in the natural oscillation spectrum showing a normalized intensity of 50 % or more. This is the lowest relevant frequency f_{low} which is to be used for the validation (see Figure 3).

NOTE **Annex B** indicates example of measurements of the natural oscillation spectrum of a testing machine.