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Guidelines for specifying Charpy V-notch impact prescriptions in steel specifications

Lignes directrices pour la spécification des prescriptions d'énergie de rupture sur éprouvette Charpy à entaille en V dans les normes d'acier

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Foreword

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This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 20, *General technical delivery conditions, sampling and mechanical testing methods*.

This first edition of ISO/TS 7705 cancels and replaces ISO/TR 7705:1991, which has been technically revised.

Guidelines for specifying Charpy V-notch impact prescriptions in steel specifications

1 Scope

This document gives guidelines for specifying Charpy V-notch impact prescriptions in steel specifications.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 General features of Charpy V-notch impact test

4.1 Toughness testing methods in design codes and in steel specifications

Tests for evaluating the toughness of steel can be divided into two categories: notch toughness tests and fracture toughness tests based on fracture mechanics.

Notch toughness tests are used to measure the ability of a material to absorb energy and deform plastically in the presence of a mechanical notch. The Charpy V-notch impact test and the drop weight test are typical examples of small scale tests which are used for evaluations of notch toughness. They are often used to determine the ductile to brittle transition temperature of a material and to give a qualitative estimate of the material's toughness. Due to relatively good reproducibility and low cost these methods are highly suitable for use as delivery tests for steel consignments.

Fracture toughness tests such as the crack-tip opening displacement (CTOD) test (see ISO 12135) are fracture mechanics tests which are generally concerned with the determination of critical crack sizes which can appear without causing fracture in a material loaded to a specific stress level. Fracture mechanics tests are very complicated and expensive to carry out. They are primarily used to examine the behaviour of pressurized or structural components with respect to safety rules, etc. Therefore, fracture mechanics testing is primarily connected with design codes and not with steel specifications.

For these reasons, only notch toughness tests are dealt with in these guidelines for steel specifications.

4.2 Historical background to the Charpy V-notch impact test

When welded structures, especially heavy ones such as bridges and ships, were first developed on an industrial scale, and especially when the fabrication methods called for joining heavy segments by welding, problems with brittle fractures became more common. This was especially evident during the Second World War when the USA began to produce welded ships of the Liberty and Victory type, where a large number of failures occurred due to brittle fractures.

An empirical relationship based on many tests was found between the Charpy V-notch impact energy and service fractures. The work initiated by the USA was continued by the International Institute of Welding (IIW) who provide recommendations and a classification system for steels according to their susceptibility to brittle fracture after welding.

Originally the USA required an impact energy value of 15 footpounds (ft lb) for a standard 10 mm x 10 mm V-notch impact test piece. This was later increased to 20 ft lb. The IIW converted these figures into metric units and referred the impact energy value to the cross-section under the notch, which gave a figure of 3,5 kg m/cm^2 corresponding to 20 ft lb. Later the units were transformed into SI units. This gave the value of 27 J (20 ft lb).

In 1953 Pellini compared the Charpy V-notch impact test with an explosion crack starter test intended to simulate the service performance of higher quality steels. Pellini recommended impact energy of 20 ft lb (27 J) instead of the earlier used 15 ft lb.

Wells also simulated service conditions at the starting point of a brittle fracture crack by using a wide plate test. The intention of this test, which could not be used as an acceptance test for a steel consignment, was to include in a big plate specimen the stresses existing in a weld, the influence of plate thickness, the type of defect, etc. The results of wide plate tests were also compared with Charpy V-notch impact values.

Today 27 J is generally used for unalloyed steels. In some cases, for instance for fine grain steels or quenched and tempered steel grades, this level can be 27 J or alternatively fixed to a higher level (40 J) according to the requirements for specific steels and intended applications. Impact test requirements are included in the product standard.

4.3 The Charpy V-notch impact test in relation to other tests

Originally the Charpy impact test was performed with a “keyhole” or U-notch test bar. Its purpose was to check that the material was sound as to cleanliness, rolling and heat treatment. In the 1950s interest was concentrated on the risk of brittle fracture in welded structures and the V-notch test bar was introduced as the V-notch test indicates transition behaviour more clearly than the U-notch test.

In addition to the Charpy impact test other impact test methods (e.g. Mesnager, lzod, Schnadt) have also been used.

The drop weight test is a material test which is intended to measure the highest temperature at which steel exhibits brittle fracture. This test can be an alternative or can be required in addition to the Charpy V-notch impact test.

4.4 Factors influencing impact properties

The behaviour of a steel structure subject to impact is not only dependent on the material. It is also dependent on the following:

- material thickness;
- stress state;
- temperature;
- steel type;
- loading rate;
- surface conditions;
- residual stresses;
- yield strength.

In addition, the Charpy V-notch test result is influenced by the following:

— orientation of test piece;

— orientation of notch;

— sharpness of notch;

— specimen position in the product;

— steel type;

— type of impact machine striker.

For these and other reasons the impact energies or transition temperatures determined under the well-defined conditions of an impact test cannot, without any further considerations, be regarded as determinant with respect to temperature and/or thickness for the application of the material.

4.5 The Charpy V-notch impact test as a powerful tool for delivery control in steel specifications

The Charpy V-notch impact test can be used as a means of expressing, in a specification, the susceptibility of a steel to brittle fracture. It is an inexpensive and easily reproducible test method which is empirically related to the susceptibility to brittle fracture and therefore to the weldability of a steel.

Impact test requirements are included in many ISO steel specifications.

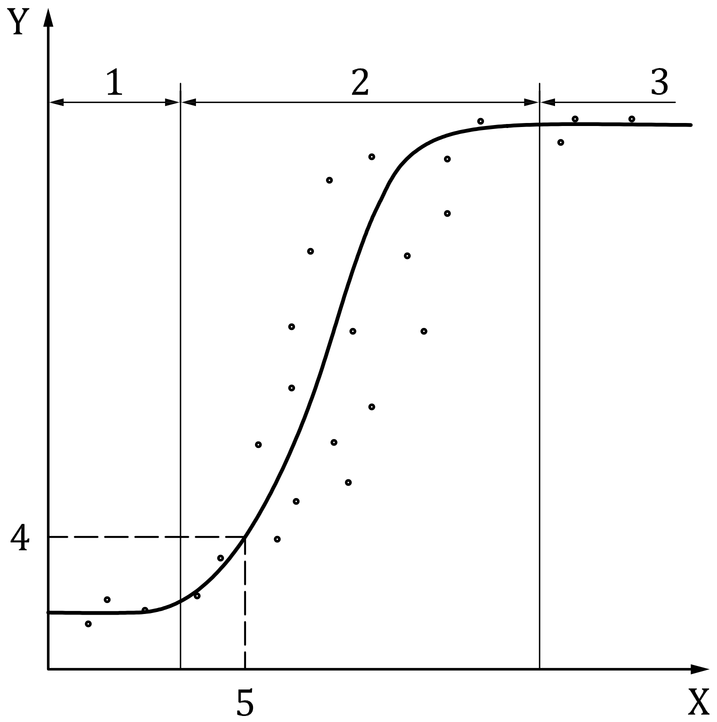
For specimen and notch orientation consult the relevant product standard.

5 Information to be gained from the impact test

Independent of the size of the test piece, the thickness of the material and the type of notch, the impact test carried out for a specified steel of given thickness at different temperatures gives a curve of absorbed energy versus temperature (see Figure 1). This curve can be separated into three parts: one part at higher temperatures and higher energies (upper shelf); one part at lower temperatures and lower energies (lower shelf); and a transition range in between. The scatter of results on the upper and lower shelves is relatively small but the scatter in the transition part of the curve is relatively large. Because of this scatter, the requirement of testing three test pieces and calculating their mean value was chosen.

Austenitic stainless steels are also ductile at very low temperatures, and consequently the impact curve does not show a transition range even at very low temperatures (see Figure 2).

Since the test result depends upon the geometry of the test piece, the thickness, etc., the test is carried out on a standardized test bar and it is irrelevant to refer the impact energy to a cross-sectional area. The energy level should therefore be given in Joules only.



Key

X test temperature, in °C

Y absorbed energy, in J

1 lower shelf

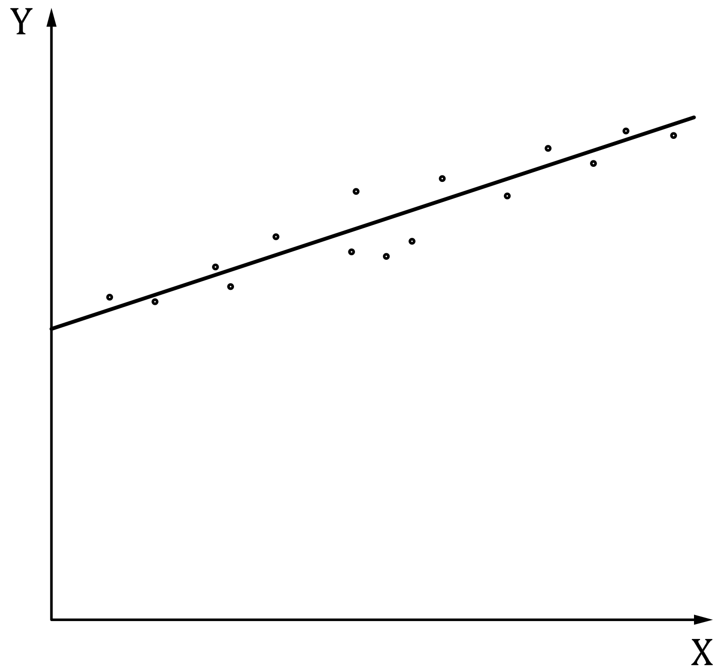
2 transition range

3 upper shelf

4 specified energy

5 specified temperature

Figure 1 — Example of an impact test curve



Key

X test temperature, in °C

Y absorbed energy, in J

Figure 2 — Example of an impact test curve for material without transition range

The impact test is prescribed in material specifications for the following two reasons.

a) To determine indirectly whether the cleanliness, manufacturing process and heat treatment, etc. have been appropriately controlled.

b) To classify a steel according to its susceptibility to brittle fracture.

In this case the result of interest is whether the test result reaches the upper or the lower shelf of the curve and, especially, where the transition range is located on the temperature scale. If the test result corresponds to the upper part of the curve, the conclusion can be drawn that the toughness of the material is considerably better than if the result corresponds to the lower part of the curve. Furthermore, if the transition range of the curve for one steel occurs at a considerably lower temperature than that for another steel, impact test results for the first steel will lie on the upper part of the curve down to lower temperatures than for the other steel and hence the conclusion can be drawn that the first steel has a higher toughness and is more suitable for constructions that are fabricated and/or used at lower temperatures.

The most important information obtained is therefore the temperature range where the change from ductile to brittle fracture occurs, i.e. the transition temperature. There are several methods for determining the transition temperature depending on the material and on the intended use (level of energy or defining the inflexion point of the transition curve or based upon the percentage of brittle zone on the fracture surface).

Other information from the test can also be of importance, such as the fracture appearance and lateral expansion measured after fracture.

It should be observed that as the impact energy is not a material property, a high value only indicates a tougher material, when the comparison is made with the same material having the same thickness and the test is carried out with the same size of test pieces at the same temperature.

