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Metallic materials - Torsional test method at high strain rates - Part 1: Method of test at room temperature

金属材料 高应变速率扭转试验 第1部分：室温试验方法

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Foreword

Issued on 29 August 2016 by the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China and the Standardization Administration of the PRC, and implemented from 1 July 2017. ICS 77.040.10; Chinese classification CCS H 22. The cover carries no replacement note, so this is the first edition of Part 1.

Metallic materials - Torsional test method at high strain rates, together with GB/T 30069.1 Metallic materials - Tensile testing at high strain rates - Part 1: Elastic bar type systems and GB/T 30069.2 Metallic materials - Tensile testing at high strain rates - Part 2:

Servo-hydraulic and other test systems, jointly constitute the test methods for evaluating the performance of materials under different stress states and different strain rate conditions.

GB/T 32967 Metallic materials - Torsional test method at high strain rates is intended to be issued in several parts. This is Part 1.

This part was drafted in accordance with the rules given in GB/T 1.1-2009.

This part was proposed by the China Iron and Steel Association.

This part is under the jurisdiction of the National Technical Committee on Steel Standardization (SAC/TC 183).

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Introduction

During structural impact processes such as stamping, high-speed cutting and vehicle collision, the metallic material in the structure is not only in a complex stress state but is also deformed at a high rate. Under a complex stress state metallic materials readily undergo shear deformation and shear failure, and their shear mechanical properties, such as the shear stress-shear strain curve, are key material parameters in the design and manufacture of metallic structures and are indispensable basic data when metallic structures are analysed and assessed by numerical methods such as finite elements. For many metallic materials the shear mechanical properties, including yield strength, flow stress and failure strain, show a dependence on strain rate or on stress rate. The strain rate concerned reaches as much as 1000 per second, far above the strain rate range of 0.0001 per second to 0.01 per second covered by the test method of GB/T 10128. Obtaining the shear mechanical behaviour of metallic materials at high strain rates by means of a high strain rate torsional test is therefore of considerable importance for the design, optimisation, processing and assessment of metallic structures.

The Hopkinson bar technique is the principal experimental method for studying the mechanical properties of materials at medium and high strain rates, that is at rates not less than 100 per second. Its central idea is that the elastic stress wave propagating in the waveguide bars performs the loading and the measurement at the same time: from the information carried by the stress wave in the bars, the stress-displacement-time relationship at the bar and specimen end faces is solved, and from this the stress-strain relationship of the specimen is obtained. By designing the width of the loading pulse the specimen is kept in a state of local dynamic equilibrium during deformation, so that the analysis of its deformation need not consider wave effects and the stress wave effect is successfully decoupled from the strain rate effect. The mechanical properties of metallic materials in the strain rate range from 0.001 per second to 100 per second may be measured on hydraulic or mechanical testing machines.

1 Scope

Metals do not keep the same shear strength once they are made to deform quickly. In a stamping press, in high-speed machining and above all in a vehicle crash, the metal in a structure is twisted and sheared within milliseconds, and the yield point, the flow stress and the strain at which the material finally fails all move with the rate of deformation. A component sized only on quasi-static data can therefore be badly misjudged: it may absorb far less energy before it tears than the drawing assumed, or it may harden so much that failure migrates to a neighbouring weld. Conventional torsion machines work at strain rates of roughly 0.0001 to 0.01 per second, three to five orders of magnitude below crash conditions, so they cannot supply the shear stress-shear strain curves that finite element models of impact actually need. This part closes that gap. It fixes how a torsional split Hopkinson bar is built and used, in which an elastic shear wave running along the input bar both loads a thin-walled tubular specimen and, through the incident, reflected and transmitted signals, measures what the specimen does, so that wave propagation effects and true strain rate effects can be separated instead of confused.

This part of GB/T 32967 specifies the terms and definitions, symbols, principle of test, testing apparatus, test pieces, test procedure, processing of test data, assessment of the validity of the test results and test report for high strain rate torsional testing of metallic materials by means of a torsional split Hopkinson bar.

This part applies to the determination at room temperature of the shear stress-shear strain curve and other mechanical properties of metallic materials at strain rates in the range from 100 per second to 1000 per second.

NOTE: Other types of test in which high strain rate shear loading can be applied may be carried out by reference to this part.

2 Normative references

The following 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 all amendments, applies.

GB/T 1804 General tolerances - Tolerances for linear and angular dimensions without individual tolerance indications; GB/T 2975 Steel and steel products - Location and preparation of samples and test pieces for mechanical testing; GB/T 10128 Metallic materials - Torsion test method at room temperature; GB/T 10623 Metallic materials -

Mechanical testing - Vocabulary; GB/T 13992 Metallic bonded resistance strain gauges; GB/T 30069.1 Metallic materials - Tensile testing at high strain rates - Part 1: Elastic bar type systems; JJG 623 Resistance strain indicators.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in GB/T 10623 and the following apply.

3.1 stress wave

The form in which a stress disturbance propagates in a medium.

3.2 elastic stress wave

A stress wave propagating in an elastic medium.

3.3 elastic shear wave

An elastic stress wave that propagates shear stress in a medium, the direction of motion of its particles being perpendicular to the direction of wave propagation.

3.4 wave interface

The interface between the region disturbed by the stress and the undisturbed region.

3.5 wave velocity

Symbol Cb. The propagation velocity of the wave front of the elastic shear wave.

3.6 split Hopkinson bar

A device that uses elastic stress waves to load a specimen placed between two long bars and to measure the dynamic mechanical properties of its material. The long bars are called waveguide bars and are divided into the input bar and the output bar.

3.7 torsional split Hopkinson bar

A split Hopkinson bar that uses elastic shear waves to measure mechanical properties such as the shear stress-shear strain curve of a material at high strain rates.

3.8 incident wave

The elastic stress wave generated in the input bar and propagating towards the specimen.

3.9 reflected wave