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Hardmetals — Palmqvist toughness test

Métaux durs — Méthode d'essai de dureté de Palmqvist

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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.

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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.

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Introduction

Good test methods are those which enable a user or manufacturer to clearly discriminate between different materials.

Fracture toughness values are required for three reasons:

a) for product design and performance assessment;

b) for selection of materials;

c) for quality control.

A specific International Standard for the toughness of hardmetals [1)] has not been developed to date, primarily because of the difficulty of introducing stable precracks into these tough but hard materials. However, Palmqvist tests for toughness are widely used because of their perceived apparent simplicity. Cracks are formed at the corners of Vickers hardness indentations and these can be used to calculate a nominal surface toughness value. This value is sensitive to the method of measurement and to the method of surface preparation of the sample. This International Standard outlines good practice to minimize uncertainties due to these issues.

There are several possible methods for the measurement of the fracture toughness of hardmetals. The results can be expressed either as a stress intensity factor, in $MN \cdot m^{-3/2}$, or as a fracture surface energy, in $J \cdot m^{-2}$. The range of values for typical WC/Co hardmetals is from 7 $MN \cdot m^{-3/2}$ to 25 $MN \cdot m^{-3/2}$. There is a general inverse trend of hardness against fracture toughness (see [1] and [2] in the Bibliography).

When applied unqualified to hardmetals, “toughness” can have several meanings.

a) Plane-strain fracture toughness, K_{Ic}, in $MN \cdot m^{-3/2}$, is a value obtained from tests on specimens with appropriate geometries for plane-strain conditions and containing a well-defined geometry of crack. There is no standard method for hardmetals and different organizations use different test methods for introducing the precrack.

b) Strain-energy release rate (or work of fracture), G, is an alternative expression for toughness, often obtained by converting plane-strain toughness, K, to G [i.e. $G = K^2/E(1 - \nu^2)$, where E is Young's modulus and ν is Poisson's ratio]. G has units of $J \cdot m^{-2}$. Again, there is no standard method.

c) Palmqvist toughness, W, is a value obtained by measuring the total length of cracks emanating from the four corners of a Vickers hardness indentation. For a given indentation load, the shorter the crack, the tougher the hardmetal.

d) Finally, toughness is also widely used, in a loose sense, to describe the empirical relation between perceived resistance to dynamic impacts. This is neither standardized nor quantified, but is clearly important for many industrial applications of hard materials. Also, principally for hardmetals, it can be more realistically assessed through either fatigue tests or high-rate strength tests, rather than a conventional fracture toughness test.

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1) Terminology — There is a range of terms used for this type of material, especially including cemented carbides and/or cermets, as well as hardmetals. The word “hardmetals” has been used in this document. It includes all hard materials based on carbides that are bonded with a metal. In ISO 3252 terminology, “hardmetal” is stated to be “a sintered material characterized by high strength and wear resistance, comprising carbides of refractory metals as the main component together with a metallic binder phase”. “Cemented carbide” is synonymous with “hardmetal”. A “cermet” is defined as “a sintered material containing at least one metallic phase and at least one non-metallic phase, generally of a ceramic nature”.

There is a considerable body of published information on Palmqvist toughness tests for hardmetals (see [5] to [29] in the Bibliography). Palmqvist toughness, W, is a toughness value obtained by measuring the crack lengths at the corners of a Vickers indentation. It can be evaluated by making indentations either at a single load, usually 30 kgf, or from the inverse of the slope of a plot of crack length against load for a range of applied loads. For hardmetals, the crack depth profile is normally of the Palmqvist type, i.e. independent shallow arcs emanating from each indentation corner. The measurement of surface crack length is, however, open to operator error. It is widely recognized that test surfaces are carefully prepared to remove the effects of residual surface stresses (see [8] in the Bibliography). The test also has a poor fracture-mechanics pedigree because of the uncertainties associated with residual stresses introduced by the indentation.

One advantage of the Palmqvist method is that parallel measurements are made of sample hardness, which is required for quality-control purposes. The crack length, and thus toughness measurements, do not therefore require much more effort and can yield equally useful material characterization data, provided the measurements are obtained carefully in line with the methods proposed in this International Standard.

This International Standard is based on a “Good Practice Guide for the Measurement of Palmqvist Toughness” published by the UK National Physical Laboratory in 1998. This International Standard recommends good practice to minimize levels of uncertainty in the measurement process. The procedure has been validated through underpinning technical work within the VAMAS [2)] framework (see [29] in the Bibliography). An interlaboratory exercise was conducted to generate underpinning technical information on toughness tests for hardmetals. More than ten industrial organizations participated, either by correspondence, supply of materials or by conducting tests. Eight organizations were able to complete Palmqvist tests. Good statistics were obtained on the Palmqvist data that enabled a quantitative assessment of uncertainties to be performed for this relatively simple test. Single-edge precracked beam data was thought to be closest to the “true” value, and the mean values from the Palmqvist test data compared reasonably well with these results. However, care was needed in test piece preparation to ensure a good correlation between data from the Palmqvist tests and the single-edge precracked beam results.

2) VAMAS, Versailles Project on Advanced Materials and Standards, supports trade in high technology products through international collaborative projects aimed at providing the technical basis for drafting codes of practice and specifications for advanced materials. The scope of the collaboration embraces all agreed aspects of enabling science and technology, i.e. databases, test methods, design methods, and materials technology, which are required as a precursor to the drafting of standards for advanced materials. VAMAS activity emphasises collaboration on pre-standards measurement research, intercomparison of test results, and consolidation of existing views on priorities for standardization action. Through this activity, VAMAS fosters the development of internationally acceptable standards for advanced materials by the various existing standards agencies.