



JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS Z 2284 : 1998

Method of elastic-plastic fracture
toughness J_{IC} testing for metallic
materials in liquid helium

ICS 77.040.20

Descriptors : metals, liquids, helium, elastic deformation, rupture stress, duct-tightness tests

Reference number : JIS Z 2284 : 1998 (E)

Z 2284 : 1998

Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of International Trade and Industry through deliberations at Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law:

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

Date of Establishment: 1998-08-20

Date of Public Notice in Official Gazette: 1998-08-20

Investigated by: Japanese Industrial Standards Committee
Divisional Council on Iron and Steel

JIS Z 2284:1998, First English edition published in 2000-04

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 2000

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

Printed in Japan

Method of elastic-plastic fracture toughness J_{IC} testing for metallic materials in liquid helium

1 Scope This Japanese Industrial Standard specifies the method of elastic-plastic fracture toughness J_{IC} testing for metallic materials at very low temperature in liquid helium based on unloading compliance method.

Remarks : Very low temperature in liquid helium used in this Standard is the boiling point of liquid helium at the atmospheric pressure [approximately 4 K (−269 °C)]. Unless otherwise specified, this is called simply “very low temperature”.

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. Normative references described on the most recent editions shall apply.

JIS B 0601 *Surface roughness—Definitions and designation*

JIS B 7507 *Vernier, dial and digital callipers*

JIS B 7721 *Verification of the force measuring system of the tensile testing machine*

JIS G 0303 *General rules for inspection of steel*

JIS G 0306 *Steel forgings—General technical requirements*

JIS Z 2277 *Tensile testing method for metallic materials in liquid helium*

JIS Z 2283 *Method of low cycle fatigue testing for metallic materials in liquid helium*

JIS Z 8401 *Rules for rounding off of numerical values*

3 Definitions For the purpose of this Standard, the definitions given in **JIS Z 2277** and **JIS Z 2283** and the following definitions apply:

- a) **J integral (J)** The integral with respect to an optional line or plane path starting from the lower surface of crack and coming to the upper surface of crack in the form surrounding the tip of crack. It describes the local stress–strain field in the vicinity of the tip of crack.
- b) **elastic-plastic fracture toughness (J_{IC})** The breaking resistance at the time when plane strain type ductile tear fracture of mode I starts from the precracking. Without regard to the size of yield, it is the material constant not depending on the shape and dimension of the test piece and the tensile and bending loading methods.
- c) **stress intensity factor (K)** Dynamic parameter describing a local stress–strain field in the vicinity of the tip of crack when satisfying the small scale yield condition.

- d) **plane strain fracture toughness (K_{IC})** Fracture resistance at the time when a fracture of mode I starts from the precrack, when satisfying the plane strain and the small scale yield condition.

In addition, K_{IC} (J) converted from J_{IC} is K_{IC} corresponding to the ductile tear fracture.

- e) **crack surface direction** Relating to the shape of products, the system to show the surface and direction of the fracture. In the system, the designation is given using code with hyphen in such a way that the first letter expresses the direction perpendicular to the crack surface and the following letter does the expected direction of crack extension.
- f) **crack length (a)** The length from the plane in parallel with the end surface of the test piece and including the loading line to the front edge of crack.
- g) **initial crack length (a_0)** The crack length at the time of starting the fracture toughness testing.
- h) **amount of crack extension (Δa)** An increase of the crack length during the test.
- i) **effective yield strength (σ_Y)** Assumed value of uniaxial yield strength expressing the influence of plastic yield given to fracture toughness testing parameter. In this Standard, σ_Y is specified to be the average value of 0.2 % proof stress and tensile strength.
- j) **tunneling** A phenomenon in which the crack extension is smaller in the neighbourhood of the surface of the test piece and becomes larger at the middle part of the thickness. Namely, a phenomenon that the front edge of the crack is curved.
- k) **compliance** Ratio of a displacement to an increase of test force. Namely, the inverse of the inclination of the test force-displacement curve.
- l) **unloading compliance method** The method of presume the amount of crack extension by detecting the change of rigidity of the test piece resulting from the crack extension. Unloading in the course of applying a load to the test piece for measuring the compliance at the time of unloading to, as a result, presume the crack length.
- m) **blunting line** An approximate straight line of $J-\Delta a$ relation before the time of fracture beginning.
- n) **start of stable crack extension** The start of slow and stable crack extension from the tip of the blunted crack.
- o) **R curve** A logarithmic curve approximation of $J-\Delta a$ relation after the start of the fracture.
- p) **dimensionless crack length (a/W)** Ratio of crack length (a) to width (W) of the test piece. The width of test piece is measured from the loading line to the back end surface of the test piece.

- q) **adiabatic heating** Internal heating in the test piece generated by reason that the heat generated by plastic work in fracture toughness testing cannot transmit immediately to the surrounding coolant.

4 Principle of test This test is to apply a tensile test force at very low temperature to a test piece to which a precrack is introduced to obtain the fracture toughness at the time when the plane strain ductile tear fracture starts from the fatigue precrack.

5 Testing apparatus and instruments The fracture toughness test shall be carried out using a testing apparatus such as a testing machine of the displacement speed control type equipped with cryogenic apparatus specified in 5.2 and displacement gauge in 5.4.

5.1 Testing machine The testing machine shall conform to at least grade 1 specified in JIS B 7721 and have sufficient rigidity.

5.2 Cryogenic apparatus The apparatus for applying a load to the test piece in an ambience of very low temperature shall be as follows:

- a) The cryogenic apparatus is of the structure consisting of a dewar for storing liquid helium and test jig for holding the test piece in it and loading it. Fig. 1 gives an example of the cryogenic apparatus.
- b) The dewar has sufficient insulation layer enough to keep the test piece at very low temperature.
- c) The cryogenic apparatus is provided with a transfer tube having insulation layer for supplying liquid helium to the dewar.

5.3 Test jig The test jig made of the material having a sufficient mechanical properties at very low temperature shall be used. As shown in Fig. 2, the pin hole surface (flat surface) which touches the loading pin shall not be more than $0.80 \mu m R_a$ specified in JIS B 0601, in order to allow the test piece to rotate during the test and to reduce friction.

5.4 Displacement gauge The displacement gauge shall be as follows:

- a) The displacement gauge which has been calibrated, in accordance with Annex 1, in advance of the test is used.
- b) The displacement gauge is mounted on the test piece.

5.5 Level gauge The dewar of the cryogenic apparatus shall be equipped with a level gauge suitable for monitoring the surface of liquid helium in order to confirm that the test piece is completely within the liquid helium.

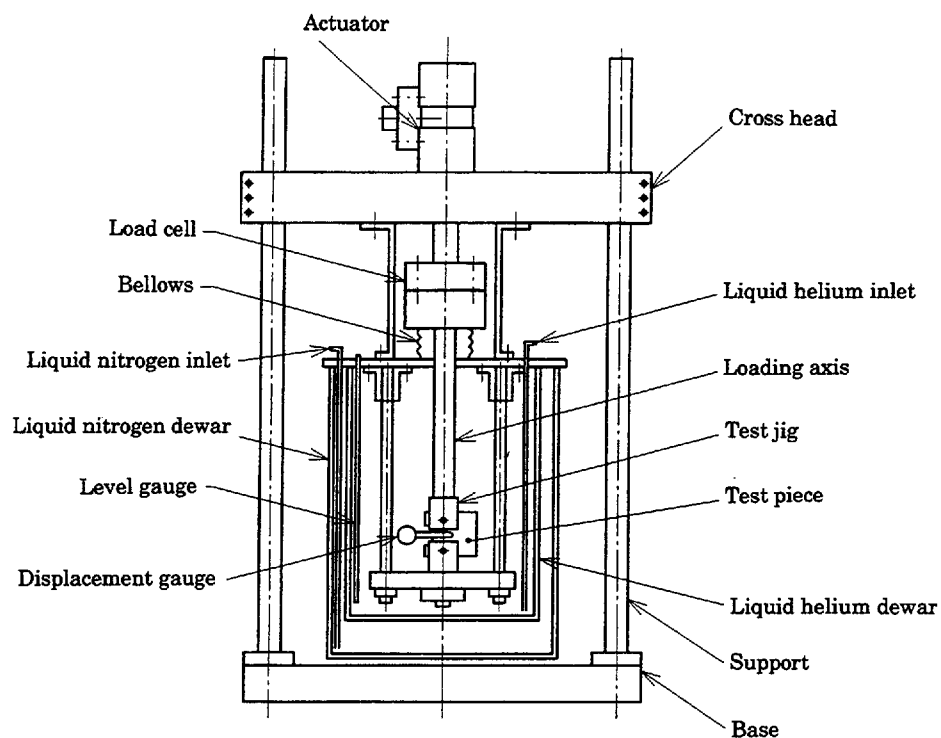


Fig. 1 Example of cryogenic apparatus

Unit : mm

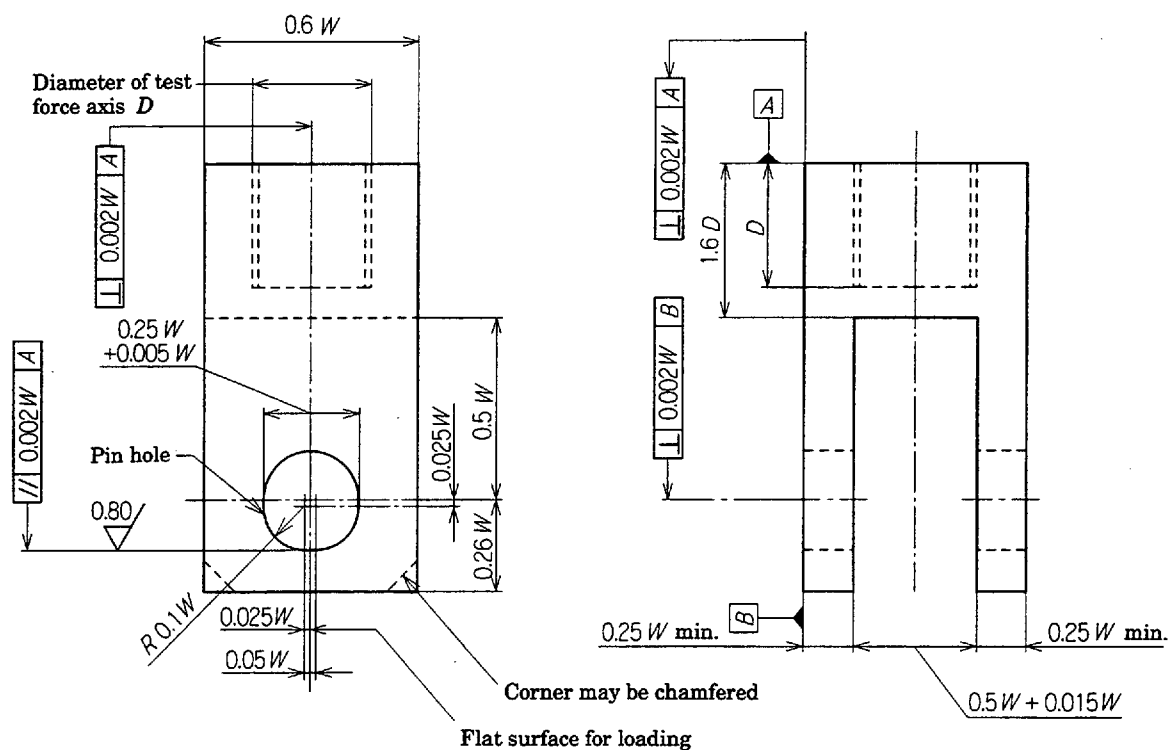


Fig. 2 Example of test jig

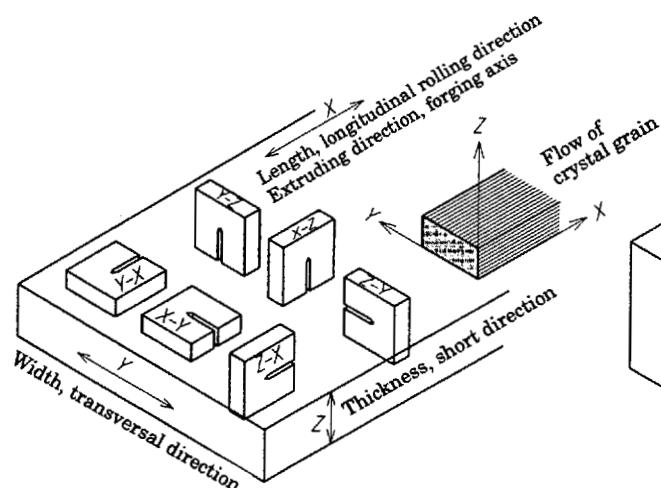
5.6 Dimension measuring instruments The instruments for measuring dimensions shall be as follows:

- a) **Vernier calliper** The vernier calliper which is for measuring the width and thickness of the test piece is of the maximum measuring length 150 mm and the minimum reading value 0.05 mm specified in **JIS B 7507** or those equivalent or superior thereto in accuracy.
- b) **Reading microscope** The reading microscope which is for measuring the crack length is of the reading accuracy of 0.05 mm or those equivalent or superior thereto in accuracy.

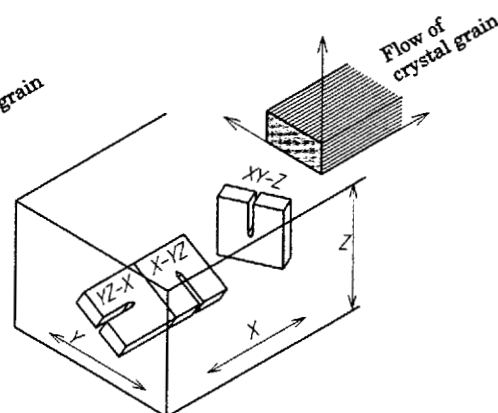
6 Test pieces

6.1 Sampling of test pieces The sampling of test piece shall be as follows:

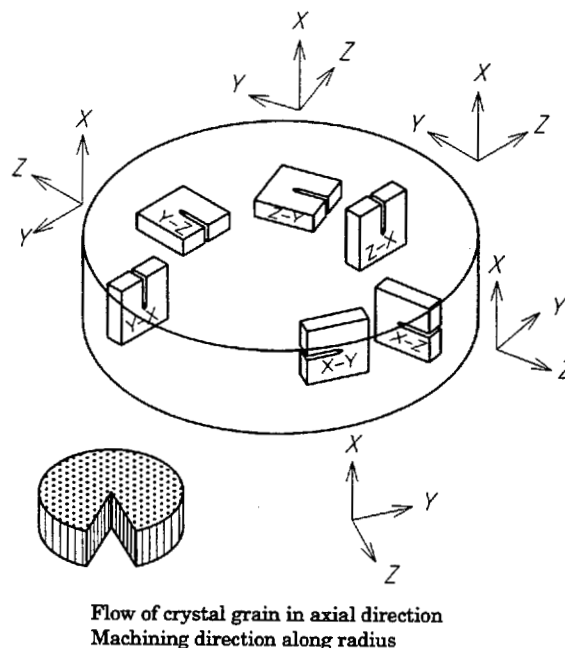
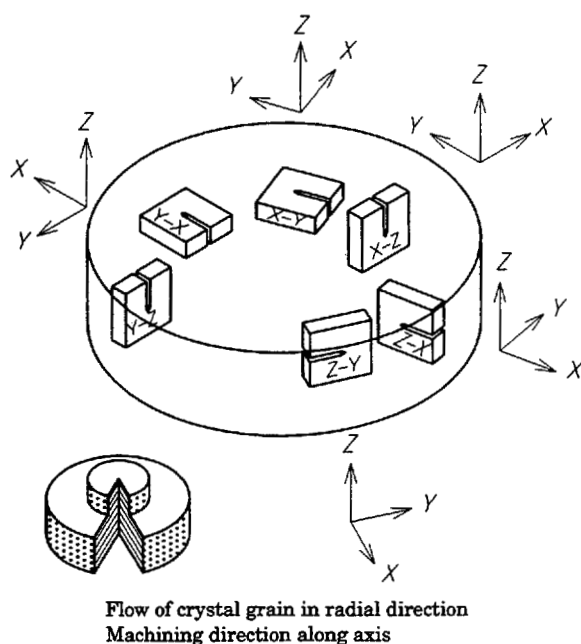
- a) **Sampling position of specimen** Unless otherwise specified, **JIS G 0303** and **JIS G 0306** apply to the sampling of specimen and test pieces.
- b) **Crack surface direction** The relation between the test piece notch direction, the main manufacturing direction of the material and the test force direction is expressed with the letter code shown in Fig. 3, and the first letter indicates the direction perpendicular to the crack surface, and the following letter indicates the expected crack extension direction.



a) Crack surface direction to board material



b) Crack surface direction to inclined direction



c) Crack surface direction to round rod and hollow cylinder

Fig. 3 Crack surface directions

6.2 Classification of test pieces The classification of test pieces shall be as follows:

- a) **Standard test piece** The standard test piece shall be compact test piece of thickness $B = 25$ mm, width $W = 50$ mm and dimension of each part is in proportion to W shown in Fig. 4 a). Besides, either test piece without side groove [Fig. 4 a)] or test piece with side groove [Fig. 4 b)] may be used. In the case of the test piece with side groove, the net thickness of the test piece (B_N) is the interval of the bottom of the side groove, and the effective test piece thickness (B_e) is given by the formula (1).