Designation: E1304 – 97 (Reapproved 2020)

Standard Test Method for
Plane-Strain (Chevron-Notch) Fracture Toughness of Metallic Materials[1]

1. Scope

1.1 This test method covers the determination of plane-strain (chevron-notch) fracture toughnesses, K_{Iv} or K_{IvM}, of metallic materials. Fracture toughness by this method is relative to a slowly advancing steady state crack initiated at a chevron-shaped notch, and propagating in a chevron-shaped ligament (Fig. 1). Some metallic materials, when tested by this method, exhibit a sporadic crack growth in which the crack front remains nearly stationary until a critical load is reached. The crack then becomes unstable and suddenly advances at high speed to the next arrest point. For these materials, this test method covers the determination of the plane-strain fracture toughness, K_{Ivj} or K_{IvM}, relative to the crack at the points of instability.

NOTE 1—One difference between this test method and Test Method E399 (which measures K_{Ic}) is that Test Method E399 centers attention on the start of crack extension from a fatigue precrack. This test method makes use of either a steady state slowly propagating crack, or a crack at the initiation of a crack jump. Although both methods are based on the principles of linear elastic fracture mechanics, this difference, plus other differences in test procedure, may cause the values from this test method to be larger than K_{Ic} values in some materials. Therefore, toughness values determined by this test method cannot be used interchangeably with K_{Ic}.

1.2 This test method uses either chevron-notched rod specimens of circular cross section, or chevron-notched bar specimens of square or rectangular cross section (Figs. 1-10). The terms "short rod" and "short bar" are used commonly for these types of chevron-notched specimens.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E4 Practices for Force Calibration and Verification of Testing Machines

E8/E8M Test Methods for Tension Testing of Metallic Materials

E399 Test Method for Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials

E1823 Terminology Relating to Fatigue and Fracture Testing

3. Terminology

3.1 *Definitions:*

3.1.1 The terms described in Terminology E1823 are applicable to this test method.

3.1.2 *stress-intensity factor, K_I* [$FL^{-3/2}$]—the magnitude of the mathematically ideal crack-tip stress field (stress-field singularity) for mode I in a homogeneous linear-elastic body.

3.1.2.1 *Discussion*—Values of K for mode I are given by the following equation:

$$K_I = \lim_{r_x \to 0} \sigma_y \left[2\pi r_x\right]^{1/2}$$

where:

r_x = distance from the crack tip to a location where the stress is calculated and

σ_y = the principal stress r_x normal to the crack plane.

3.2 *Definitions of Terms Specific to This Standard:*

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[1] This test method is under the jurisdiction of ASTM Committee E08 on Fatigue and Fracture and is the direct responsibility of Subcommittee E08.07 on Fracture Mechanics.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.
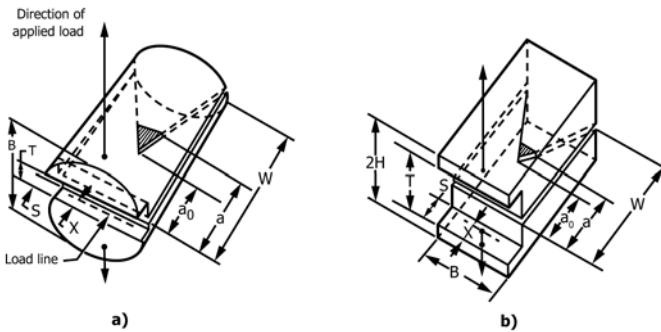
NOTE 1—The crack commences at the tip of the chevron-shaped ligament and propagates (shaded area) along the ligament, and has the length "a" shown. (Not to scale.)

FIG. 1 Schematic Diagrams of Chevron-Notched Short Rod (a) and Short Bar (b) Specimens

3.2.1 *plane-strain (chevron-notch) fracture toughness, K_{Iv} or K_{Ivj}* [FL$^{-3/2}$]—under conditions of crack-tip plane strain in a chevron-notched specimen: K_{Iv} relates to extension resistance with respect to a slowly advancing steady-state crack. K_{Ivj} relates to crack extension resistance with respect to a crack which advances sporadically.

3.2.1.1 *Discussion*—For slow rates of loading the fracture toughness, K_{Iv} or K_{Ivj}, is the value of stress-intensity factor as measured using the operational procedure (and satisfying all of the validity requirements) specified in this test method.

3.2.2 *plane-strain (chevron-notch) fracture toughness, K_{IvM}* [FL$^{-3/2}$]—determined similarly to K_{Iv} or K_{Ivj} (see 3.2.1) using the same specimen, or specimen geometries, but using a simpler analysis based on the maximum test force. The analysis is described in Annex A1. Unloading-reloading cycles as described in 3.2.6 are not required in a test to determine K_{IvM}.

3.2.3 *smooth crack growth behavior*—generally, that type of crack extension behavior in chevron-notch specimens that is characterized primarily by slow, continuously advancing crack growth, and a relatively smooth force displacement record (Fig. 4). However, any test behavior not satisfying the conditions for crack jump behavior is automatically characterized as smooth crack growth behavior.

3.2.4 *crack jump behavior*—in tests of chevron-notch specimens, that type of sporadic crack growth which is characterized primarily by periods during which the crack front is nearly stationary until a critical force is reached, whereupon the crack becomes unstable and suddenly advances at high speed to the next arrest point, where it remains nearly stationary until the force again reaches a critical value, etc. (see Fig. 5).

3.2.4.1 *Discussion*—A chevron-notch specimen is said to have a crack jump behavior when crack jumps account for more than one half of the change in unloading slope ratio (see 3.2.6) as the unloading slope ratio passes through the range from $0.8r_c$ to $1.2r_c$ (see 3.2.6 and 3.2.7, and 8.3.5.2). Only those sudden crack advances that result in more than a 5 % decrease in force during the advance are counted as crack jumps (Fig. 5).

3.2.5 *steady-state crack*—a crack that has advanced slowly until the crack-tip plastic zone size and crack-tip sharpness no

longer change with further crack extension. Although crack-tip conditions can be a function of crack velocity, the steady-state crack-tip conditions for metals have appeared to be independent of the crack velocity within the range attained by the loading rates specified in this test method.

3.2.6 *effective unloading slope ratio, r*—the ratio of an effective unloading slope to that of the initial elastic loading slope on a test record of force versus specimen mouth opening displacement.

3.2.6.1 *Discussion*—This unloading slope ratio provides a method of determining the crack length at various points on the test record and therefore allows evaluation of stress intensity coefficient Y^* (see 3.2.11). The effective unloading slope ratio is measured by performing unloading-reloading cycles during the test as indicated schematically in Fig. 4 and Fig. 5. For each unloading-reloading trace, the effective unloading slope ratio, r, is defined in terms of the tangents of two angles:

$$r = \tan\theta/\tan\theta_o$$

where:

$\tan\theta_o$ = the slope of the initial elastic line, and
$\tan\theta$ = the slope of an effective unloading line.

The effective unloading line is defined as having an origin at the high point where the displacement reverses direction on unloading (slot mouth begins to close) and joining the low point on the reloading line where the force is one half that at the high point.

3.2.6.2 *Discussion*—For a brittle material with linear elastic behavior the unloading-reloading lines of an unloading-reloading cycle would be linear and coincident. For many engineering materials, deviations from linear elastic behavior and hysteresis are commonly observed to a varying degree. These effects require an unambiguous method of obtaining an effective unloading slope from the test record (6-5).[3]

3.2.6.3 *Discussion*—Although r is measured only at those crack positions where unloading-reloading cycles are performed, r is nevertheless defined at all points during a chevron-notch specimen test. For any particular point it is the value that would be measured for r if an unloading-reloading cycle were performed at that point.

3.2.7 *critical slope ratio, r_c*—the unloading slope ratio at the critical crack length.

3.2.8 *critical crack length*—the crack length in a chevron-notch specimen at which the specimen's stress-intensity factor coefficient, Y^* (see 3.2.11 and Table 3), is a minimum, or equivalently, the crack length at which the maximum force would occur in a purely linear elastic fracture mechanics test. At the critical crack length, the width of the crack front is approximately one third the dimension B (Figs. 2 and 3).

3.2.9 *high point, High*—the point on a force-displacement plot, at the start of an unloading-reloading cycle, at which the displacement reverses direction, that is, the point at which the specimen mouth begins closing due to unloading (see points labeled High in Figs. 4 and 5).

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[3] The **boldface** numbers in parentheses refer to the list of references at the end of this standard.
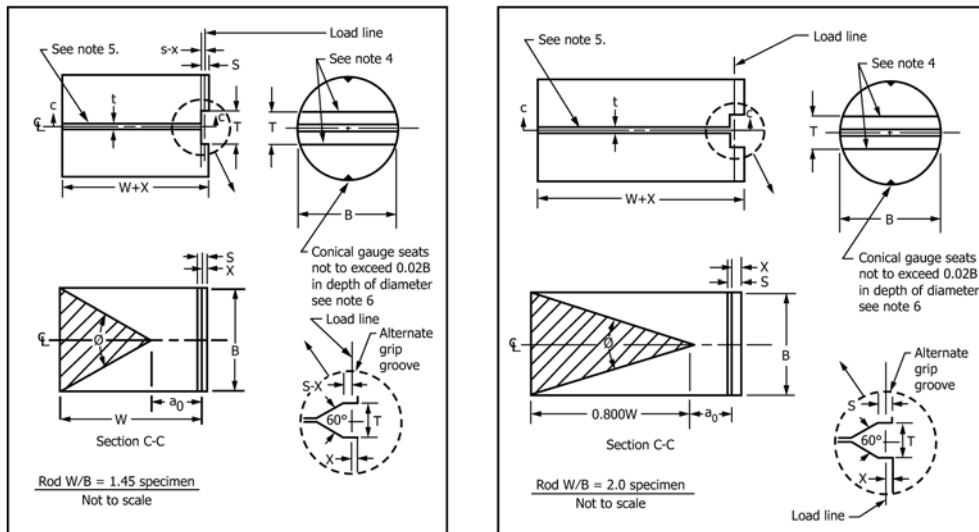
NOTE 1—See Table 1 for tolerances and other details.
FIG. 2 Rod Specimens Standard Proportions
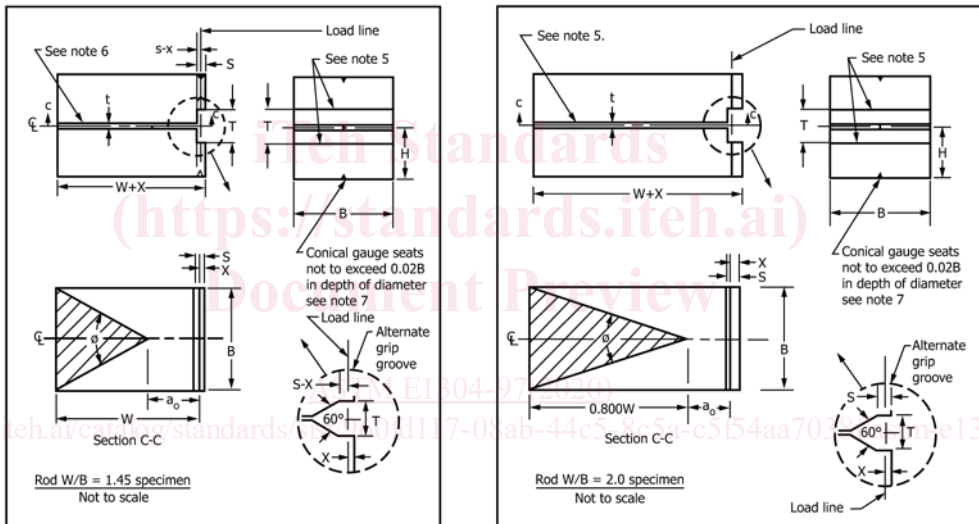
NOTE 1—See Table 2 for tolerances and other details.
FIG. 3 Bar Specimens Standard Proportions

3.2.10 *low point, Low*—the point on the reloading portion of an unloading-reloading cycle where the force is one half the high point force (see points labeled Low in Figs. 4 and 5).

3.2.11 *stress-intensity factor coefficient, Y**—a dimensionless parameter that relates the applied force and specimen geometry to the resulting crack-tip stress-intensity factor in a chevron-notch specimen test (see 9.6.3).

3.2.11.1 *Discussion*—Values of Y^* can be found from the graphs in Fig. 10, or from the tabulations in Table 4 or from the polynominal expressions in Table 5.

3.2.12 *minimum stress-intensity factor coefficient, Y^*_m*—the minimum value of Y^* (Table 3).

4. Summary of Test Method

4.1 This test method involves the application of a load to the mouth of a chevron-notched specimen to induce an opening displacement of the specimen mouth. An autographic record is made of the load versus mouth opening displacement and the slopes of periodic unloading-reloading cycles are used to calculate the crack length based on compliance techniques. These crack lengths are expressed indirectly as slope ratios. The characteristics of the force versus mouth opening displacement trace depend on the geometry of the specimen, the specimen plasticity during the test, any residual stresses in the specimen, and the crack growth characteristics of the material being tested. In general, two types of force versus displacement traces are recognized, namely, smooth behavior (see 3.2.3) and crack jump behavior (see 3.2.4).

4.1.1 In metals that exhibit smooth crack behavior (3.2.3), the crack initiates at a low force at the tip of a sufficiently sharp chevron, and each incremental increase in its length corresponds to an increase in crack front width and requires further
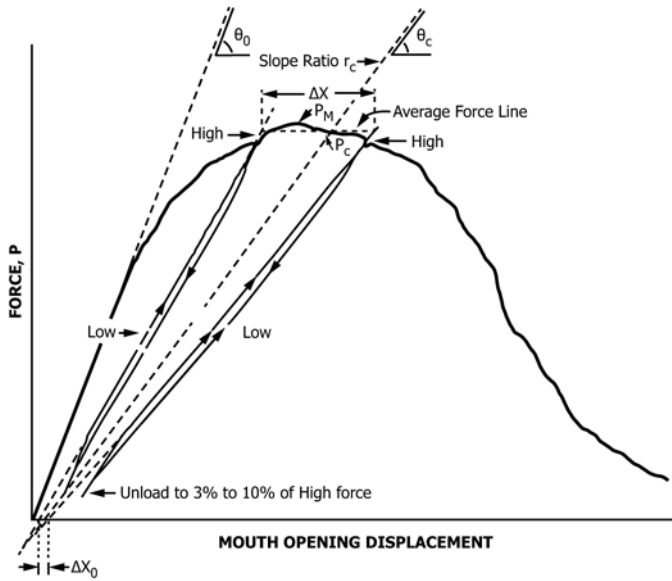
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FIG. 4 Schematic of a Load-Displacement Test Record for Smooth Crack Growth Behavior, with Unloading/Reloading Cycles, Data Reduction Constructions, and Definitions of Terms
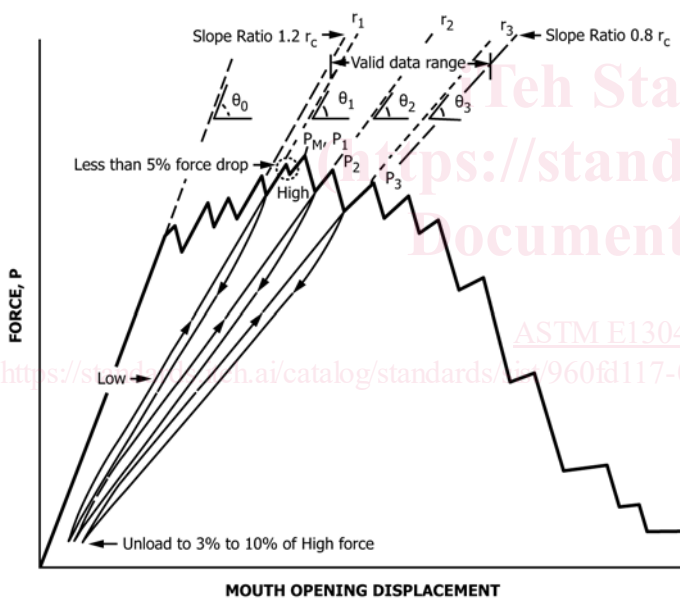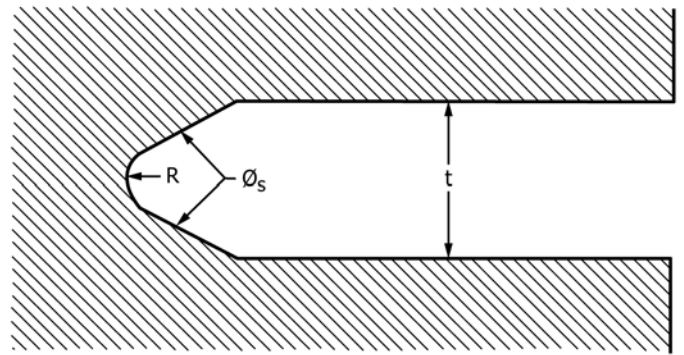

FIG. 5 Schematic of a Load-Displacement Test Record for Crack Jump Behavior, with Unloading/Reloading Cycles, Data Reduction Constructions, and Definitions of Terms

$R \leq 0.010B$
$\varphi_s \leq 60°$
$t \leq 0.03B$

NOTE 1—These requirements are satisfied by slots with a round bottom whenever $t \leq 0.020B$.

FIG. 6 Slot Bottom Configuration
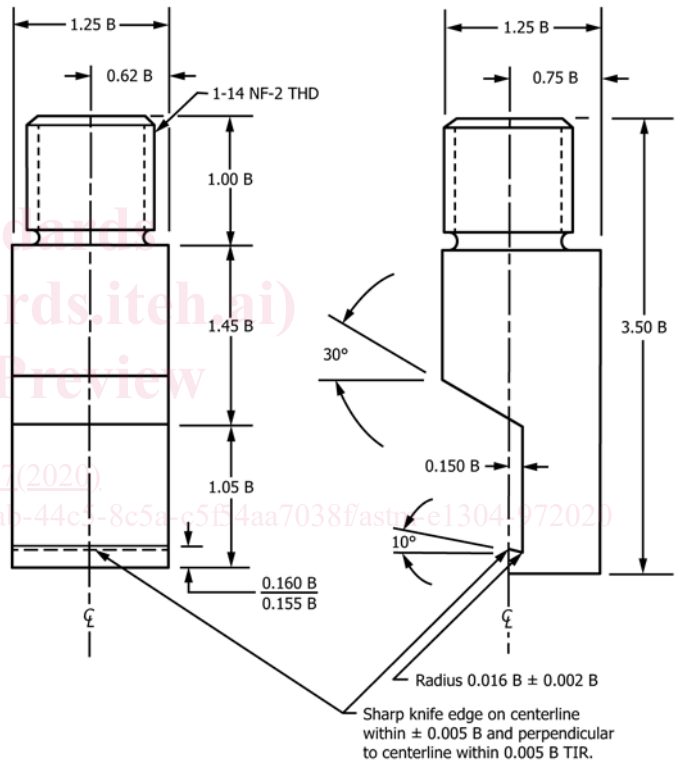
NOTE 1—Machine finish all over equal to or better than 64 μin.
NOTE 2—Unless otherwise specified, dimensions ±0.010B; angles ±2°.
NOTE 3—Grip hardness should be RC = 45 or greater.

FIG. 7 Suggested Loading Grip Design

increase in force. This force increase continues until a point is reached where further increases in force provide energy in excess of that required to advance the crack. This maximum force point corresponds to a width of crack front approximately one third the specimen diameter or thickness. If the loading system is sufficiently stiff, the crack can be made to continue its smooth crack growth under decreasing force. Two unloading-reloading cycles are performed to determine the location of the crack, the force used to calculate K_{Iv}, and to provide validity checks on the test. The fracture toughness is calculated from the force required to advance the crack when the crack is at the critical crack length (see 3.2.8). The plane-strain fracture

toughness determined by this procedure is termed K_{Iv}. An alternative procedure, described in Annex A1, omits the unloading cycles and uses the maximum test force to calculate a plane-strain fracture toughness K_{IvM}, where M signifies the use of the maximum force. Values of K_{Iv} versus K_{IvM} are discussed in Annex A1.

4.1.2 A modified procedure is used to determine K_{Ivj} when crack jump behavior is encountered. In this procedure, unloading-reloading cycles are used to determine the crack

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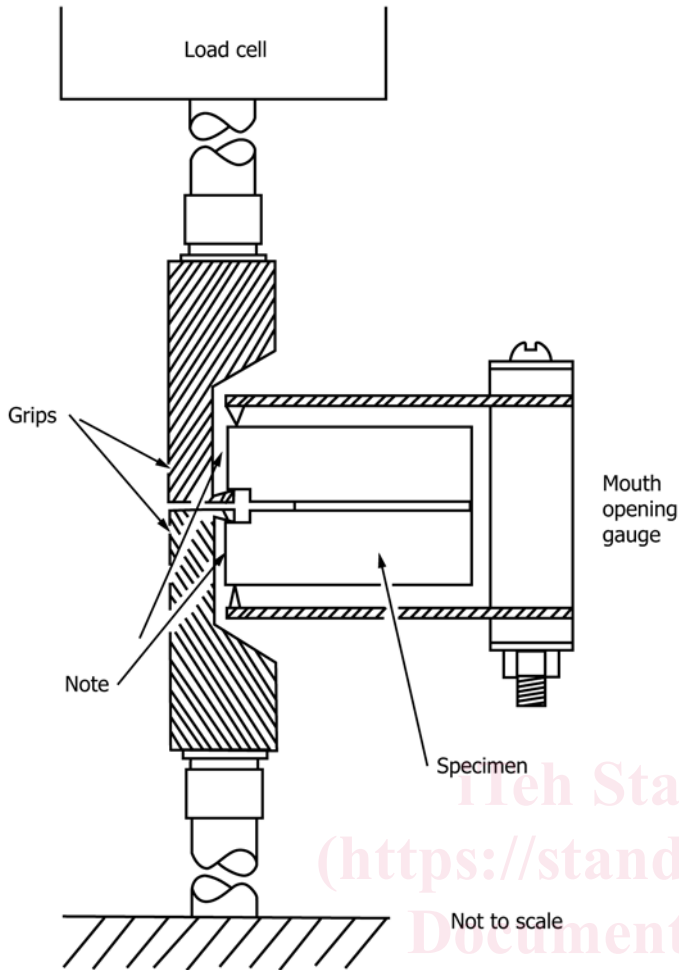
NOTE 1—To assist alignment, shims may be placed at these locations and removed before the load is applied, as described in 8.3.2.

FIG. 8 Recommended Tensile Test Machine Test Configuration

FIG. 9 Suggested Design for the Specimen Mouth Opening Gage

NOTE 1—Compiled from Refs (**1**), (**2**), (**3**), and (**4**).

FIG. 10 Normalized Stress-Intensity Factor Coefficients as a Function of Slope Ratio (*r*) for Chevron-Notch Specimens

TABLE 1 Rod Dimensions

NOTE 1—All surfaces to be 64-μin. finish or better.

NOTE 2—Side grooves may be made with a plunge cut with a circular blade, such that the sides of the chevron ligament have curved profiles, provided that the blade diameter exceeds 5.0*B*. In this case, φ is the angle between the chords spanning the plunge cut arcs, and it is necessary to use different values of φ and a_o (**5**), so that the crack front has the same width as with straight cuts, at the critical crack length.

NOTE 3—The dimension a_o must be achieved when forming the side grooves. A separate cut that blunts the apex of the chevron ligament is not permissible.

NOTE 4—Grip groove surfaces are to be flat and parallel to chevron notch within± 2°.

NOTE 5—Notch on centerline within ±0.005*B* and perpendicular or parallel to surfaces as applicable within 0.005*B* (TIR).

NOTE 6—The imaginary line joining the conical gage seats must be perpendicular (±2°) to the plane of the specimen slot.

Sym-bol	Name	Value		Tolerance
		W/B = 1.45	*W/B* = 2.0	
B	Diameter	*B*	*B*	...
W	Length	1.450*B*	2.000*B*	±0.010*B*
a_o	Distance to chevron tip	0.481*B*	0.400*B*	±0.005*B*
S	Grip groove depth	0.150*B*	0.150*B*	±0.010*B*
	alternate groove	0.130*B*	0.130*B*	±0.010*B*
X	Distance to load line	0.100*B*	0.100*B*	±0.003*B*
	alternate groove	0.050*B*	0.050*B*	±0.003*B*
T	Grip groove width	0.350*B*	0.350*B*	±0.005*B*
	alternate groove	0.313*B*	0.313*B*	±0.005*B*
t	Slot thickness	≤0.030*B*[A]	≤0.030*B*[A]	...
φ	Slot angle	54.6°	34.7°	±0.5°

[A] See Fig. 6.

location at which the next jump will begin. The K_{Ivj} values are calculated from the forces that produce crack jumps when the crack front is in a defined region near the center of the specimen. The K_{Ivj} values so determined have the same significance as K_{Iv}.

4.1.3 The equations for calculating the toughness have been established on the basis of elastic stress analyses of the specimen types described in this test method.

TABLE 2 Bar Dimensions

Note 1—All surfaces to be 64-μin. finish or better.

Note 2—Side grooves may be made with a plunge cut with a circular blade, such that the sides of the chevron ligament have curved profiles, provided that the blade diameter exceeds 5.0B. In this case, φ is the angle between the chords spanning the plunge cut arcs, and it is necessary to use different values of φ and a_o (5), so that the crack front has the same width as with straight cuts, at the critical crack length.

Note 3—The dimension a_o must be achieved when forming the side grooves. A separate cut that blunts the apex of the chevron ligament is not permissible.

Note 4—Grip groove surfaces are to be flat and parallel to chevron notch within± 2°.

Note 5—Notch on centerline within ±0.005B and perpendicular or parallel to surfaces as applicable within 0.005B (TIR).

Note 6—The imaginary line joining the conical gage seats must be perpendicular (±2°) to the plane of the specimen slot.

Sym-bol	Name	Value		Tolerance
		$W/B = 1.45$	$W/B = 2.0$	
B	Thickness	B	B	...
W	Length	1.450B	2.000B	±0.010B
a_o	Distance to chevron tip	0.481B	0.400B	±0.005B
S	Grip groove depth	0.150B	0.150B	±0.010B
	alternate groove	0.130B	0.130B	±0.010B
X	Distance to load line	0.100B	0.100B	±0.003B
	alternate groove	0.050B	0.050B	±0.003B
T	Grip groove width	0.350B	0.350B	±0.005B
	alternate groove	0.313B	0.313B	±0.005B
t	Slot thickness	≤0.030B^A	≤0.030B^A	...
φ	Slot angle	54.6°	34.7°	±0.5°
H	Half-height			
	(square specimen)	0.500B	0.500B	±0.005B
	(rectangular specimen)	0.435B	B	±0.005B

^{A} See Fig. 6.
^{B} See Note 1.

TABLE 3 Minimum Stress-Intensity Factor Coefficients and Critical Slope Ratios for Chevron-Notch Specimens

Note 1—The values in this table are derived from the polynomials in Table 5, and are selected from the values in Table 4.

Specimen	W/B	a_o/W	H/B	Y^*_m	r_c
Rectangular Bar	1.45	0.332	0.435	28.22	0.52
Square Bar	1.45	0.332	0.50	25.11	0.62
Square Bar	2	0.2	0.5	29.90	0.30
Rod	1.45	0.332	0.5	29.21	0.52
Rod	2	0.2	0.5	36.25	0.28

TABLE 4 Stress-Intensity Factor Coefficients as a Function of Slope Ratio (r) for Chevron-Notch Specimen^A

Specimen Type	Rectangular Bar	Square Bar	Square Bar	Rod	Rod
W/B	1.45	1.45	2	1.45	2
a_o/W	0.332	0.332	0.2	0.332	0.2
r	Y^*			Y^*	
0.16	...	...	33.14	...	38.20
0.18	...	...	32.04	...	37.44
0.20	...	42.24	31.24	45.10	36.90
0.22	...	39.39	30.68	42.16	36.55
0.24	...	37.00	30.30	39.71	36.34
0.26	...	35.00	30.07	37.68	36.25
0.28	...	33.32	29.95	35.98	36.25^B
0.30	33.22	31.90	29.90^B	34.57	36.32
0.32	32.09	30.70	29.91	33.39	36.43
0.34	31.16	29.68	29.96	32.42	36.57
0.36	30.40	28.82	30.02	31.62	36.74
0.38	29.79	28.10	30.10	30.97	36.91
0.40	29.31	27.49	30.18	30.45	37.08
0.42	28.93	26.97	30.25	30.04	37.25
0.44	28.65	26.54	30.33	29.72	37.42
0.46	28.45	26.19	30.41	29.49	37.59
0.48	28.31	25.89	30.50	29.33	37.77
0.50	28.24	25.66	30.62	29.24	37.96
0.52	28.22^B	25.47	30.78	29.21^B	38.19
0.54	28.25	25.32	31.02	29.22	38.46
0.56	28.31	25.22	31.34	29.28	38.81
0.58	28.42	25.15	31.80	29.39	39.25
0.60	28.56	25.11	32.43	29.53	39.81
0.62	28.73	25.11^B	...	29.70	...
0.64	28.93	25.14	...	29.91	...
0.66	29.16	25.21	...	30.16	...
0.68	29.42	25.31	...	30.43	...
0.70	29.72	25.45	...	30.74	...
0.72	30.05	25.63	...	31.09	...
0.74	30.42	25.86	...	31.48	...
0.76	30.84	26.15	...	31.91	...
0.78	31.32	26.49	...	32.38	...
0.80	31.85	26.90	...	32.91	...
0.82	32.46	27.40	...	33.51	...
0.84	33.15	27.98	...	34.17	...

^{A} Compiled from Refs (1), (2), (3), and (4), and using the polynomials in Table 5.
^{B} Minimum value of Y^*.

4.2 The specimen size required for testing purposes increases as the square of the ratio of fracture toughness to yield strength of the material (see 6.1), therefore proportional specimen configurations are provided.

5. Significance and Use

5.1 The fracture toughness determined by this test method characterizes the resistance of a material to fracture by a slowly advancing steady-state crack (see 3.2.5) in a neutral environment under severe tensile constraint. The state of stress near the crack front approaches plane strain, and the crack-tip plastic region is small compared with the crack size and specimen dimensions in the constraint direction. A K_{Iv} or K_{Ivj} value may be used to estimate the relation between failure stress and defect size when the conditions described above would be expected, although the relationship may differ from that obtained from a K_{Ic} value (see Note 1). Background information concerning the basis for development of this test method in terms of linear elastic fracture mechanics may be found in Refs (6-15).

5.1.1 The K_{Iv}, K_{Ivj}, or K_{IvM} value of a given material can be a function of testing speed (strain rate) and temperature. Furthermore, cyclic forces can cause crack extension at K_I values less than K_{Iv}, and crack extension can be increased by the presence of an aggressive environment. Therefore, application of K_{Iv} in the design of service components should be made with an awareness of differences that may exist between the laboratory tests and field conditions.

5.1.2 Plane-strain fracture toughness testing is unusual in that there can be no advance assurance that a valid K_{Iv}, K_{Ivj}, or K_{IvM} will be determined in a particular test. Therefore, it is essential that all the criteria concerning the validity of results be carefully considered as described herein.

5.2 This test method can serve the following purposes:

TABLE 5 Closed Form Expressions for Stress Intensity Factor Coefficients for Chevron-Notched Specimens of Several Configurations[A,B]

Specimen	W/B	a_o/W	H/B	C_0	C_1	C_2	C_3	C_4
Rectangular Bar[C]	1.45	0.332	0.435	5.112	−10.36	22.46	−21.88	8.46
Square Bar[D]	1.45	0.332	0.500	5.010	−9.65	20.31	−20.27	8.257
Square Bar[E]	2.00	0.200	0.500	4.300	−9.238	34.77	−57.24	35.25
Rod[D]	1.45	0.332	0.500	5.052	−9.488	19.78	−18.48	6.921
Rod[E]	2.00	0.200	0.500	4.163	−6.104	23.32	−37.97	23.07

[A] Compiled from Refs (1), (2), (3), and (4).
[B] $Y^* = \exp[C_0 + C_1 r + C_2 r^2 + C_3 r^3 + C_4 r^4]$, accuracy ±0.5 %.
[C] Estimated from finite element analysis (3), and extrapolated equation from Ref (4). Accuracy for $0.3 \leq r \leq 0.85$ is ±0.5 %.
[D] Extrapolated from equations in Ref (4). Accuracy estimated to be ±0.5 % for $0.2 \leq r \leq 0.85$.
[E] Equation from Ref (4). Accuracy estimated to be± 0.5 % for $0.15 \leq r \leq 0.6$.

TABLE 6 Mean Values and Sample Standard Deviations of K_{IvM} and K_{Iv} for Five Materials Tested in an Interlaboratory Test Program

NOTE 1—Specimens of grade 250 maraging steel were heat-treated by individual participants, and some contribution to the scatter may have been made by heat-treatment variations.

Material	Specimen Orientation	Yield Strength, ksi (MPa)	K_{IvM} ksi $\sqrt{in.}$ (MPa $\sqrt{m}$)	Sample Standard Deviation of K_{IvM}	Number of Valid Tests	K_{Iv} K_{Ivj} ksi $\sqrt{in.}$ (MPa $\sqrt{m}$)	Sample Standard Deviation of K_{Iv} or K_{Ivj}	Number of Valid Tests
2024-T351	L-T	52.4 (361)	50.8 (55.9)	8.0 (8.8)	3	45.2 (49.7)	2.1 (2.3)	4
Aluminum	S-L	42.7 (294)	35.3 (38.8)	2.8 (3.1)	10	36.5 (40.2)	2.8 (3.1)	4
7075-T651	L-T	78.7 (543)	31.3 (34.4)	1.7 (1.9)	36	29.9 (32.9)	1.9 (2.1)	20
Aluminum	S-L	67.8 (468)	20.7 (22.8)	1.0 (1.1)	26	20.1 (22.1)	1.3 (1.4)	15
Grade 250	L-T	230.8 (1592)	90.6 (99.7)	12.0 (13.2)	29	92.5 (101.8)	6.6 (7.3)	4
Maraging Steel	S-L	229.6 (1583)	79.1 (87.0)	9.0 (9.9)	21	83.2 (91.5)	12.0 (13.2)	11
Grade 300	L-T	274.0 (1890)	49.0 (53.9)	4.0 (4.4)	15	51.9 (57.1)	2.1 (2.3)	5
Maraging Steel	S-L	288.0 (1986)	47.3 (52.0)	4.0 (4.4)	9	48.3 (53.1)	2.6 (2.9)	5
6A1-4V	L-T	131.5 (907)	103.9 (114.3)	4.7 (5.2)	19	104.2 (114.6)	5.5 (6.1)	3
Titanium	S-L	122.8 (847)	95.2 (104.7)	2.7 (3.0)	14	92.2 (101.4)	1.1 (1.2)	3

5.2.1 To establish the effects of metallurgical variables such as composition or heat treatment, or of fabricating operations such as welding or forming, on the fracture toughness of new or existing materials.

5.2.2 For specifications of acceptance and manufacturing quality control, but only when there is a sound basis for specification of minimum K_{Iv}, K_{Ivj}, or K_{IvM} values, and then only if the dimensions of the product are sufficient to provide specimens of the size required for valid K_{Iv} determination (9). The specification of K_{Iv} values in relation to a particular application should signify that a fracture control study has been conducted on the component in relation to the expected history of loading and environment, and in relation to the sensitivity and reliability of the crack detection procedures that are to be applied prior to service and subsequently during the anticipated life.

5.2.3 To provide high spatial resolution in measuring plane strain fracture toughness variations in parent pieces of material (14).

NOTE 2—The high spatial resolution is possible because of the small allowable specimen size criterion, $B \geq 1.25 (K_{Iv}/\sigma_{YS})^2$ (9), and because the toughness is measured at approximately the midline of the specimen, and only in the material covered by the crack's lateral extent, which is about one third of the specimen's lateral dimension, B.

6. Specimen, Size, Configuration, Dimensions, and Preparation

6.1 *Specimen Size*—In order for a test result to be considered valid in accordance with this test method, it is required that the specimen's lateral dimension, B, equals or exceeds $1.25 (K_{Iv}/\sigma_{YS})^2$, $1.25 (K_{Ivj}/\sigma_{YS})^2$, or $1.25 (K_{IvM}/\sigma_{YS})^2$, where σ_{YS} is the 0.2 % offset yield strength of the material in the direction of loading in the test, and for the temperature of the test as determined by Test Methods E8/E8M.

6.2 *Specimen Configuration and Dimensions*—Both the rod specimen of the circular cross section and the rectangular bar specimen are equally acceptable. The rod dimensions for which compliance calibrations are provided are given in Fig. 2, and for the bar in Fig. 3. Fig. 6 shows an enlarged cross section of the slot that forms the chevron-shaped ligament.

6.3 *Specimen Preparation*—The dimensional tolerances and surface finishes shown on the specimen drawings shall be followed in specimen preparation.

7. Apparatus

7.1 Specimens should be tested in a machine that can record applied force versus specimen mouth opening displacement either digitally for processing by computer or autographically with an x-y plotter.

7.2 *Grips and Fixtures for Tensile Test Machine Loading*—Fig. 7 shows the suggested grip design. Grips should have a hardness of 45 Rockwell C or greater, and the loading system should be capable of maintaining the specimen to the grip alignment specified in 8.3.2. The grip knife edges are inserted into the grip slot in the specimen, and the specimen is loaded as the test machine arms apply an opening displacement to the grips as shown in Fig. 8. A transducer for measuring the specimen mouth opening displacement during the test and a