

Tool Steel Fracture Toughness Chart (K1c)

Fracture toughness in MPa root metre for eight common tool steel grades, measured on bend bars taken from three forging reductions and tempered at three temperatures, with the hardness each specimen was tested at.

Reference only. Values are reproduced from the source named under each table and are a reference summary of published practice rather than a specification of ours. Fracture toughness is sensitive to specimen orientation, section size and heat treatment, so treat the tables as a comparison between grades rather than as a design value for a particular part.

Fracture toughness of the oil-hardening grades (L6 and O2)

Grade	Forging reduction	Section size	Temper temperature	K1c (MPa√m)	Average K1c	HRC
L6	99%	38 mm Sq.	149 °C, 1h	20.86, 18.50	19.7	60.0
L6	95%	89 mm Sq.	149 °C, 1h	23.19, 22.14	22.7	59.5
L6	88%	171 mm Rd.	149 °C, 1h	26.11, 25.39	25.7	58.5
L6	99%	38 mm Sq.	204 °C, 1h	24.76, 24.79	24.8	57.0
L6	95%	89 mm Sq.	204 °C, 1h	26.04, 24.86	25.5	57.0
L6	88%	171 mm Rd.	204 °C, 1h	28.53, 28.11	28.3	56.5
L6	99%	38 mm Sq.	288 °C, 1h	27.15, 26.03	26.6	54.5
L6	95%	89 mm Sq.	288 °C, 1h	25.71, 27.42	26.6	54.5
L6	88%	171 mm Rd.	288 °C, 1h	29.12, 30.32	29.7	53.5
O2	99%	38 mm Sq.	149 °C, 1h	18.37, 17.50	17.9	62.0
O2	95%	89 mm Sq.	149 °C, 1h	19.31, 19.45	19.4	62.0
O2	88%	159 mm Rd.	149 °C, 1h	19.80, 19.84	19.8	62.0
O2	99%	38 mm Sq.	204 °C, 1h	19.82, 18.94	19.4	59.5
O2	95%	89 mm Sq.	204 °C, 1h	21.23, 20.72	21.0	59.0
O2	88%	159 mm Rd.	204 °C, 1h	21.62, 21.49	21.6	59.0
O2	99%	38 mm Sq.	288 °C, 1h	18.66, 18.37	18.5	56.5
O2	95%	89 mm Sq.	288 °C, 1h	18.77, 19.11	18.9	56.5
O2	88%	159 mm Rd.	288 °C, 1h	20.31, 20.32	20.3	56.0

Source, Table II, Results of Fracture Toughness Testing of AISI L6 and O2, printed page 69 of Tool Materials for Molds and Dies (G. Krauss and H. Nordberg, eds.), PDF page 76 of the copy consulted. Figures were read from the page image rather than from the scanned text layer.

Forging reduction is the total reduction from the 432 mm ingot. L6 was austenitized in salt at 830 °C for 5 minutes and oil quenched, O2 in salt at 802 °C for 5 minutes and oil quenched. Both values in each row are individual test results on separate specimens and the average column is the arithmetic mean of them.

Fracture toughness of D3 and A6

Grade	Forging reduction	Section size	Temper temperature	K1c (MPa√m)	Average K1c	HRC
D3	99%	38 mm Sq.	204 °C, 1h	33.54, 33.67	33.7	58.0
D3	99%	38 mm Sq.	371 °C, 1h	32.76	32.8	55.5
A6	99%	38 mm Sq.	149 °C, 1h	21.81, 21.53	21.7	59.5
A6	95%	89 mm Sq.	149 °C, 1h	24.63, 21.80	23.2	61.0
A6	88%	173 mm Rd.	149 °C, 1h	24.34, 25.80	25.1	59.5
A6	99%	38 mm Sq.	371 °C, 1h	21.95, 20.25	21.1	53.0
A6	95%	89 mm Sq.	371 °C, 1h	21.63, 21.77	21.7	54.0
A6	88%	173 mm Rd.	371 °C, 1h	22.95, 23.17	23.1	52.5
A6	99%	38 mm Sq.	496 °C, 1h	28.41, 27.09	27.7	49.0
A6	95%	89 mm Sq.	496 °C, 1h	29.60, 29.46	29.5	49.5
A6	88%	173 mm Rd.	496 °C, 1h	30.06, 29.05	29.6	48.0

Source, Table III, Results of Fracture Toughness Testing of AISI D3 and A6, printed page 70 of Tool Materials for Molds and Dies, PDF page 77 of the copy consulted. Figures were read from the page image rather than from the scanned text layer.

D3 cracked during precracking at seven of the nine conditions tested, so only the two conditions in the table produced a valid value and the source gives no figure for the others. D3 was austenitized in salt at 968 °C for 25 minutes and oil quenched, A6 in salt at 843 °C for 25 minutes and air cooled.

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At normal working hardness the grades separate into the three groups the tool trade already works with. The oil-hardening L6 is the toughest of the eight, running from 19.7 MPa root metre at 60 HRC up to 29.7 at 53.5 HRC, with O2 below it at 17.9 to 20.3. The wear-resisting chrome grades come next, D3 at 32.8 to 33.7 and D2 from 25.2 to 45.2 against A2 holding 20.9 to 22.3 across the whole range. The hot work and shock grades top the set, S7 reaching 34.5 at 57 HRC and H13 running from 27.4 to 88.0 as it is tempered down from 53.5 to 40.0 HRC.

Fracture toughness of the air-hardening cold work grades (A2 and D2)

Grade	Forging reduction	Section size	Temper temperature	K1c (MPa√m)	Average K1c	HRC
A2	99%	38 mm Sq.	149 °C, 1h	21.05, 20.69	20.9	63.0
A2	95%	89 mm Sq.	149 °C, 1h	21.58, 20.78	21.2	63.5
A2	88%	159 mm Rd.	149 °C, 1h	20.80, 20.90	20.9	63.0
A2	99%	38 mm Sq.	204 °C, 1h	22.08, 22.50	22.3	61.0
A2	95%	89 mm Sq.	204 °C, 1h	22.58, 21.46	22.0	61.0
A2	88%	159 mm Rd.	204 °C, 1h	21.40, 21.52	21.5	61.0
A2	99%	38 mm Sq.	371 °C, 1h	22.31, 22.30	22.3	58.0
A2	95%	89 mm Sq.	371 °C, 1h	21.41, 21.96	21.7	57.5
A2	88%	159 mm Rd.	371 °C, 1h	21.74, 22.09	21.9	57.5
D2	99%	38 mm Sq.	204 °C, 1h	28.84, 28.35	28.6	60.0
D2	95%	89 mm Sq.	204 °C, 1h	36.77, 36.58	36.6	59.5
D2	88%	167 mm Rd.	204 °C, 1h	45.35, 40.08, 41.00	42.1	59.0
D2	88%	167 mm Rd., transverse	204 °C, 1h	25.00	25.0	60.0
D2	99%	38 mm Sq.	371 °C, 1h	30.07, 30.62	30.4	56.5
D2	95%	89 mm Sq.	371 °C, 1h	38.63, 38.83	38.7	57.0
D2	88%	167 mm Rd.	371 °C, 1h	44.18, 46.32	45.2	57.0
D2	99%	38 mm Sq.	538 °C, 1h	24.85, 25.48	25.2	54.5
D2	95%	89 mm Sq.	538 °C, 1h	27.71, 29.87	28.8	57.5
D2	88%	167 mm Rd.	538 °C, 1h	33.12, 32.62	32.9	58.5

Source, Table IV, Results of Fracture Toughness Testing of AISI A2 and D2, printed page 71 of Tool Materials for Molds and Dies, PDF page 78 of the copy consulted. Figures were read from the page image rather than from the scanned text layer.

A2 was austenitized in salt at 954 °C for 25 minutes and air cooled, D2 in salt at 1010 °C for 25 minutes and air cooled. The 88 per cent row tempered at 204 °C marked transverse is a single specimen cut across the 167 mm round bar rather than along it, and it is listed separately because it is the only transverse reading in the table.

Fracture toughness of the hot work and shock-resisting grades (H13 and S7)

Grade	Forging reduction	Section size	Temper temperature	K1c (MPa√m)	Average K1c	HRC
H13	99%	38 mm Sq.	538 °C, 2h + 2h	29.76, 29.89, 29.21	29.6	53.5
H13	95%	89 mm Sq.	538 °C, 2h + 2h	28.19, 27.92, 28.18	28.1	53.5
H13	88%	154 mm Rd.	538 °C, 2h + 2h	27.63, 26.98, 27.54	27.4	53.5
H13	99%	38 mm Sq.	593 °C, 2h + 2h	41.25, 37.50, 38.71	39.2	48.0
H13	95%	89 mm Sq.	593 °C, 2h + 2h	34.42, 32.74, 31.98	33.0	47.5
H13	88%	154 mm Rd.	593 °C, 2h + 2h	35.90, 38.24	37.1	47.5
H13	99%	38 mm Sq.	621 °C, 2h + 2h	87.84, 88.85, 87.74	88.0	40.0
H13	95%	89 mm Sq.	621 °C, 2h + 2h	55.02, 80.62, 77.20	71.0	40.0
H13	88%	154 mm Rd.	621 °C, 2h + 2h	59.96, 60.61	60.3	40.5
S7	99%	38 mm Sq.	204 °C, 1h	34.67, 34.41	34.5	57.0
S7	95%	89 mm Sq.	204 °C, 1h	35.02, 35.97	35.5	56.5
S7	88%	154 mm Rd.	204 °C, 1h	32.99, 33.11	33.0	56.0
S7	99%	38 mm Sq.	496 °C, 1h	38.90, 38.41	38.6	53.0
S7	95%	89 mm Sq.	496 °C, 1h	39.48, 39.27	39.4	52.0
S7	88%	154 mm Rd.	496 °C, 1h	34.28, 35.13	34.7	51.5
S7	99%	38 mm Sq.	538 °C, 1h	40.48, 40.25	40.4	51.5
S7	95%	89 mm Sq.	538 °C, 1h	40.39, 42.93	41.7	51.0
S7	88%	154 mm Rd.	538 °C, 1h	32.21, 33.10	32.7	50.5

Source, Table V, Results of Fracture Toughness Testing of AISI H13 and S7, printed page 72 of Tool Materials for Molds and Dies, PDF page 79 of the copy consulted. Figures were read from the page image rather than from the scanned text layer.

H13 was austenitized in salt at 1024 °C for 25 minutes and air cooled, S7 in salt at 941 °C for 25 minutes and air cooled. The H13 rows were tempered twice at each temperature, two hours each time, which is the practice its data sheets call for because of its secondary hardening peak.

Aobo Steel, tool steel supplier

Aobo Steel supplies tool steel to distributors and mold, tool and die shops, including D2, D3, O1, O2, A2, S7, H13, H11, H10, H21, M2, M42, L6, P20 and 420 and 440C stainless. Forged or hot rolled, annealed or pre-hardened, cut to your sizes, with test certificates.

Compiled from Tool Materials for Molds and Dies, Application and Performance (G. Krauss and H. Nordberg, eds.), the paper Impact and Fracture Toughness Testing of Common Grades of Tool Steels by R. M. Hemphill and D. E. Wert of Carpenter Technology Corporation, Tables II to V on printed pages 69 to 72.

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