

Heat-treatment for steel materials

Name	Vickers hardness (HV)	Quenching depth (mm)	Strain	Applicable material	Typical materials	Remarks
Through hardening	Max.750	Full depth	Varies according to material.	High C-steel C>0.45%	SKS3 SKS21 SUJ2 SKH51 SKS93 SK4 S45C	• Not applicable to long or precision parts such as spindles, etc.
Carburizing and quenching	Max.750	Standard : 0.5 Max. : 2	Moderate	Low-C steel C<0.3%	SCM415 SNCM220	• Quenchable parts. • Quenching depth specified on drawings. • Applicable to precision parts.
High frequency quenching	Max.500	1~2	High	Medium-C steel C0.3~0.5%	S45C	• Quenchable parts. • Expensive in small volume lot. • Good strain resistance.
Nitriding	900~1000	0.003~0.008	Low	Nitriding steel	SACM645	• Obtains highest hardness of all quenching techniques. • Applicable to precision parts. • Applicable to spindles for radial bearing.
Tuftriding	Carbon steel : 500 SUS : 1000	0.01~0.02	Low	Steel materials	S45C SCM415 SK3 Stainless	• Good fatigue resistance and wear resistance. • Same corrosion resistance as zinc plating. • Not applicable to precision parts because it cannot be polished after heat-treatment. • Applicable to dry bearings.
Bluing				Wire rod	SWP—B	• Low-temperature annealing. • Removes internal stress in forming to enhance elasticity.

Hardness tests and applicable parts

Test method	Principle	Applicable heat-treated parts	Features	Remarks
1.Brinnell hardness	• A (steel or superhard alloy) ball indenter is used to indent the test surface. Hardness is given as a quotient minus the surface area of the indent, computed from the diameter.	• Annealed parts • Normalized parts • Anchored materials	①Applicable to uneven materials and forged products because indent is large. ②Not applicable to small or thin specimens.	JISZ2243
2.Rockwell hardness	• The standard or test load is applied via a diamond or ball indenter. Hardness is read on a tester.	• Quenched—tempered parts • Carburized surfaces • Nitrided surfaces • Thin sheets like copper, brass, bronze, etc. ※ Rockwell C scale (HRC) is not suitable for fine pins and thin plates-	①Hardness value obtained quickly. ②Applicable as intermediate test to actual products. ③Care must be taken as there are many types. ※There are many types of scale of Rockwell Hardness meter, such as the A scale (HRA), B scale (HRB), C scale (HRC), and D scale (HRD)	JISZ2245
3.Shore hardness	• The specimen is set on a table. A hammer is dropped from a uniform height. Hardness is based on how high the hammer bounces.	• Quenched—tempered parts • Nitrided parts • Large carburized parts, etc.	①Extremely easy to operate. Data obtained quickly. ②Applicable to large parts. ③Indent is kept shallow, therefore is applicable to actual products. ④Compact and light-weight. Portable.	JISZ2246
4.Vickers hardness	• Uses a diamond 136° square pyramid indenter. Hardness value is obtained as the surface area of the indent, computed from the length of the diagonal lines of the indent.	• Thin parts hardened by high frequency quenching, carburizing, nitriding, electrolytic plating, ceramic coating, etc. • Hardened layer depth in carburized and nitrided parts	①Applicable to small and thin specimens. ②Applicable to all materials because of diamond indenter.	JISZ2244

Conversion table for approximate values for steel according to Rockwell hardness C scale<sup>(1)</sup>

Rockwell hardness C scale (HRC)	Vickers hardness (HV)	Brinnell hardness (HB) Ball : 10mm in diameter/Load : 3000kgf		Rockwell hardness <sup>(3)</sup>			Rockwell superficial hardness Diamond conical penetrator			Shore hardness (Hs)	Tensile strength (Approximate value) MPa (kgf/mm <sup>2</sup> ) <sup>(2)</sup>	Rockwell hardness C scale <sup>(3)</sup>
		Standard ball	Tungsten carbide ball	A scale (HRA) Load : 60kgf Diamond conical penetrator	B scale (HRB) Load : 100kgf Ball of 1.6mm (1/16") dia.	D scale (HRD) Load : 100kgf Diamond conical penetrator	15-N Scale Load : 15kgf	30-N Scale Load : 30kgf	45-N Scale Load : 45kgf			
68	940	—	—	85.6	—	76.9	93.2	84.4	75.4	97	—	68
67	900	—	—	85.0	—	76.1	92.9	83.6	74.2	95	—	67
66	865	—	—	84.5	—	75.4	92.5	82.8	73.3	92	—	66
65	832	—	(739)	83.9	—	74.5	92.2	81.9	72.0	91	—	65
64	800	—	(722)	83.4	—	73.8	91.8	81.1	71.0	88	—	64
63	772	—	(705)	82.8	—	73.0	91.4	80.1	69.9	87	—	63
62	746	—	(688)	82.3	—	72.2	91.1	79.3	68.8	85	—	62
61	720	—	(670)	81.8	—	71.5	90.7	78.4	67.7	83	—	61
60	697	—	(654)	81.2	—	70.7	90.2	77.5	66.6	81	—	60
59	674	—	(634)	80.7	—	69.9	89.8	76.6	65.5	80	—	59
58	653	—	615	80.1	—	69.2	89.3	75.7	64.3	78	—	58
57	633	—	595	79.6	—	68.5	88.9	74.8	63.2	76	—	57
56	613	—	577	79.0	—	67.7	88.3	73.9	62.0	75	—	56
55	595	—	560	78.5	—	66.9	87.9	73.0	60.9	74	2075 (212)	55
54	577	—	543	78.0	—	66.1	87.4	72.0	59.8	72	2015 (205)	54
53	560	—	525	77.4	—	65.4	86.9	71.2	58.5	71	1950 (199)	53
52	544	(500)	512	76.8	—	64.6	86.4	70.2	57.4	69	1880 (192)	52
51	528	(487)	496	76.3	—	63.8	85.9	69.4	56.1	68	1820 (186)	51
50	513	(475)	481	75.9	—	63.1	85.5	68.5	55.0	67	1760 (179)	50
49	498	(464)	469	75.2	—	62.1	85.0	67.6	53.8	66	1695 (173)	49
48	484	451	455	74.7	—	61.4	84.5	66.7	52.5	64	1635 (167)	48
47	471	442	443	74.1	—	60.8	83.9	65.8	51.4	63	1580 (161)	47
46	458	432	432	73.6	—	60.0	83.5	64.8	50.3	62	1530 (156)	46
45	446	421	421	73.1	—	59.2	83.0	64.0	49.0	60	1480 (151)	45
44	434	409	409	72.5	—	58.5	82.5	63.1	47.8	58	1435 (146)	44
43	423	400	400	72.0	—	57.7	82.0	62.2	46.7	57	1385 (141)	43
42	412	390	390	71.5	—	56.9	81.5	61.3	45.5	56	1340 (136)	42
41	402	381	381	70.9	—	56.2	80.9	60.4	44.3	55	1295 (132)	41
40	392	371	371	70.4	—	55.4	80.4	59.5	43.1	54	1250 (127)	40
39	382	362	362	69.9	—	54.6	79.9	58.6	41.9	52	1215 (124)	39
38	372	353	353	69.4	—	53.8	79.4	57.7	40.8	51	1180 (120)	38
37	363	344	344	68.9	—	53.1	78.8	56.8	39.6	50	1160 (118)	37
36	354	336	336	68.4	(109.0)	52.3	78.3	55.9	38.4	49	1115 (114)	36
35	345	327	327	67.9	(108.5)	51.5	77.7	55.0	37.2	48	1080 (110)	35
34	336	319	319	67.4	(108.0)	50.8	77.2	54.2	36.1	47	1055 (108)	34
33	327	311	311	66.8	(107.5)	50.0	76.6	53.3	34.9	46	1025 (105)	33
32	318	301	301	66.3	(107.0)	49.2	76.1	52.1	33.7	44	1000 (102)	32
31	310	294	294	65.8	(106.0)	48.4	75.6	51.3	32.7	43	980 (100)	31
30	302	286	286	65.3	(105.5)	47.7	75.0	50.4	31.3	42	950 ( 97 )	30
29	294	279	279	64.7	(104.5)	47.0	74.5	49.5	30.1	41	930 ( 95 )	29
28	286	271	271	64.3	(104.0)	46.1	73.9	48.6	28.9	41	910 ( 93 )	28
27	279	264	264	63.8	(103.0)	45.2	73.3	47.7	27.8	40	880 ( 90 )	27
26	272	258	258	63.3	(102.5)	44.6	72.8	46.8	26.7	38	860 ( 88 )	26
25	266	253	253	62.8	(101.5)	43.8	72.2	45.9	25.5	38	840 ( 86 )	25
24	260	247	247	62.4	(101.0)	43.1	71.6	45.0	24.3	37	825 ( 84 )	24
23	254	243	243	62.0	100.0	42.1	71.0	44.0	23.1	36	805 ( 82 )	23
22	248	237	237	61.5	99.0	41.6	70.5	43.2	22.0	35	785 ( 80 )	22
21	243	231	231	61.0	98.5	40.9	69.9	42.3	20.7	35	770 ( 79 )	21
20	238	226	226	60.5	97.8	40.1	69.4	41.5	19.6	34	760 ( 77 )	20
(18)	230	219	219	—	96.7	—	—	—	—	33	730 ( 75 )	(18)
(16)	222	212	212	—	95.5	—	—	—	—	32	705 ( 72 )	(16)
(14)	213	203	203	—	93.9	—	—	—	—	31	675 ( 69 )	(14)
(12)	204	194	194	—	92.3	—	—	—	—	29	650 ( 66 )	(12)
(10)	196	187	187	—	90.7	—	—	—	—	28	620 ( 63 )	(10)
( 8 )	188	179	179	—	89.5	—	—	—	—	27	600 ( 61 )	( 8 )
( 6 )	180	171	171	—	87.1	—	—	—	—	26	580 ( 59 )	( 6 )
( 4 )	173	165	165	—	85.5	—	—	—	—	25	550 ( 56 )	( 4 )
( 2 )	166	158	158	—	83.5	—	—	—	—	24	530 ( 54 )	( 2 )
( 0 )	160	152	152	—	81.7	—	—	—	—	24	515 ( 53 )	( 0 )

Notes : <sup>(1)</sup> The figures in blue are based on Table 1 of ASTM E 140 (adjusted by SAE, ASM and ASTM in collaboration).  
<sup>(2)</sup> The values and units in parentheses have been converted from psi based on conversion tables of JIS Z 8413 and Z 8438.  
1MPa=1N/mm<sup>2</sup>  
<sup>(3)</sup> The figures in parentheses are less frequently used values and are for reference only.