## Heat Treatment for Steel Materials

| Name | Vickers hardness (HV) | Hardening depth (mm) | Strain | Applicable materials | Typical materials | Remarks |
|---|---|---|---|---|---|---|
| Through hardening | Max. 750 | All | Varies according to the material. | High-C steel C＞0.45% | SKS3 (JIS)<br>SKS21 (JIS)<br>52100<br>M2<br>SKS93 (JIS)<br>W1-9<br>1045 | • Should not be used for long parts such as spindles or for precision parts. |
| Carburizing | Max. 750 | Standard 0.5<br>Max. 2 | Medium | Low-C steel C＜0.3% | SCM415 (JIS)<br>8620 | • Localized hardening is possible.<br>• Hardening depth must be specified on drawings.<br>• Suitable for precision parts |
| Induction hardening | Max. 500 | 1～2 | Large | Medium-C steel<br>C 0.3～0.5% | 1045 | • Localized hardening is possible.<br>• Expensive in small volumes<br>• Good fatigue resistance |
| Nitriding | 900～1000 | 0.003～0.008 | Small | Nitriding steel | SACM645 | • Highest hardening hardness<br>• Suitable for precision parts<br>• Suitable for sliding bearing spindles |
| Tufftride® | Carbon steel 500<br>SUS 1000 | 0.01～0.02 | Small | Steel materials | 1045<br>SCM415 (JIS)<br>W1-10<br>Stainless steel | • Good fatigue resistance and wear resistance<br>• Same corrosion resistance as zinc plating<br>• Not suitable for precision parts because polishing following the heat treatment is not possible.<br>• Suitable for oil-free lubrication |
| Bluing | | | | Wire rod | SWP—B | • Low temperature annealing<br>• Enhances elasticity by removing internal stress during forming |

## Hardness Test Methods and Applicable Parts

| Test method | Principle | Applicable heat-treated parts | Characteristics | Remarks |
|---|---|---|---|---|
| 1. Brinell hardness | • A ball indenter (steel or carbide alloy) is used to indent the test surface. Hardness is given by dividing the test load by the surface area, which was found from the diameter of the indentation. | • Annealed parts<br>• Normalized parts<br>• Anchored materials | ①Suitable for uneven materials and forged products because the indent is large.<br>②Not suitable for small or thin specimens | JIS Z 2243 |
| 2. Rockwell hardness | • The standard or test load is applied via a diamond or ball indenter, and the hardness value is read from the tester. | • Hardened parts and tempered parts<br>• Carburized surfaces<br>• Nitrided surfaces<br>• Thin sheets of copper, brass, bronze, or similar materials<br>※Rockwell C scale (HRC) is not suitable for materials such as narrow pins and thin sheets. | ① Hardness value can be obtained quickly.<br>② Suitable as an intermediate test of actual products<br>③ Caution is required because there are many types.<br>※ There are many types of Rockwell hardness testers, including the A scale (HRA), B scale (HRB), C scale (HRC), and D scale (HRD). | JIS Z 2245 |
| 3. Shore hardness | • The specimen is set on a table and a hammer is dropped from a set height. Hardness is determined based on how high the hammer bounces. | • Hardened parts and tempered parts<br>• Nitrided parts<br>• Large parts treated by carburizing or similar process | ① Extremely easy to operate. Data can be obtained quickly.<br>② Suitable for large parts<br>③ Because indent is small and not noticeable, this test is suitable for actual products.<br>④ Compact and light-weight. Portable. | JIS Z 2246 |
| 4. Vickers hardness | • A diamond square pyramid indenter with a vertex angle of 136 degrees is used to create an indentation in the test surface. The hardness value is found from the test load and the surface area of the indent, computed from the length of the diagonal lines of the indent. (Conversion is performed automatically.) | • Materials with a thin hardened layer created by induction hardening, carburizing, nitriding, electroplating, ceramic coating, etc.<br>• Hardened layer depth in carburized and nitrided parts | ① Suitable for small and thin specimens<br>② Because the indenter is diamond, this test can be used with materials of any hardness. | JIS Z 2244 |





## Approximate Conversion Values for Rockwell C Hardness Values of Steel (1)

| (HRC) Rockwell C scale hardness | (HV) Vickers hardness | Brinell hardness (HB) 10 mm ball Load 3000 kgf | | Rockwell Hardness(3) | | | Rockwell superficial hardness Diamond conical indenter | | | (Hs) | Tensile strength (approximate value) | Rockwell C scale hardness (3) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Standard ball | Tungsten carbide ball | (HRA) A scale Load 60kgf Diamond conical indenter | (HRB) B scale Load 100kgf Dia. 1.6mm (1/16 in.) ball | (HRD) D scale Load 100kgf Diamond conical indenter | 15—N scale Load 15kgf | 30—N scale Load 30kgf | 45—N scale Load 45kgf | Shore hardness | MPa (kgf/mm²) (2) | |
| 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 | 58.6 | 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) |

Note (1) : Figures in blue are based on ASTM E 140, Table 1 (Jointly prepared by SAE, ASM and ASTM.)

(2) : The units and figures shown in parentheses ( ) following the listed value are the results of conversion from PSI figures by reference to JIS Z 8413 and Z8438 conversion tables.
1MPa = 1N/mm²

(3) : The figures in parentheses ( ) are in ranges not frequently used. They are given as reference data.