

## General Properties of Tool Steels

Reference table of the principal AISI tool steel grades, covering wear resistance, toughness, hot hardness, usual working hardness, depth of hardening, grain size and hardness after hardening. Reference summary of published property data, not an Aobo Steel standard.

**Reference only.** Aobo Steel supplies tool steel in round bar and plate form, in annealed condition. Hardening, quenching and tempering are performed by the customer's heat-treatment facility. Verify the values below against the applicable standard and the heat treater's own procedure.

### Properties by grade

1–9 rating relative, 1 = low, 9 = high · Depth of hardening, S = shallow, M = medium, D = deep · Grain size, Shepherd standard, at full hardness · Core hardness, 25 mm (1 in.) diameter round

| Grade                                 | Wear <sup>(b)</sup> | Toughness <sup>(c)</sup> | Hot hardness | Working hardness, HRC | Depth <sup>(d)</sup> | Grain size (Shepherd) | Surface HRC | Core HRC |
|---------------------------------------|---------------------|--------------------------|--------------|-----------------------|----------------------|-----------------------|-------------|----------|
| <b>Molybdenum high-speed steels</b>   |                     |                          |              |                       |                      |                       |             |          |
| M1                                    | 7                   | 3                        | 8            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M2                                    | 7                   | 3                        | 8            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M3, class 1                           | 8                   | 3                        | 8            | 63–66                 | D                    | 9½                    | 64–66       | 64–66    |
| M3, class 2                           | 8                   | 3                        | 8            | 63–66                 | D                    | 9½                    | 64–66       | 64–66    |
| M4                                    | 9                   | 3                        | 8            | 63–66                 | D                    | 9½                    | 65–67       | 65–67    |
| M7                                    | 8                   | 3                        | 8            | 63–66                 | D                    | 9½                    | 64–66       | 64–66    |
| M10                                   | 7                   | 3                        | 8            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M30                                   | 7                   | 2                        | 8            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M33                                   | 8                   | 1                        | 9            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M34                                   | 8                   | 1                        | 9            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M35                                   | 7                   | 2                        | 8            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M36                                   | 7                   | 1                        | 9            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| M41                                   | 8                   | 1                        | 9            | 66–70                 | D                    | 9½                    | 63–65       | 63–65    |
| M42                                   | 8                   | 1                        | 9            | 66–70                 | D                    | 9½                    | 63–65       | 63–65    |
| M43                                   | 8                   | 1                        | 9            | 66–70                 | D                    | 9½                    | 63–65       | 63–65    |
| M44                                   | 8                   | 1                        | 9            | 66–70                 | D                    | 9½                    | 63–65       | 63–65    |
| M46                                   | 8                   | 1                        | 9            | 66–69                 | D                    | 9½                    | 63–65       | 63–65    |
| M47                                   | 8                   | 1                        | 9            | 66–70                 | D                    | 9½                    | 63–65       | 63–65    |
| <b>Intermediate high-speed steels</b> |                     |                          |              |                       |                      |                       |             |          |
| M50                                   | 6                   | 3                        | 6            | 61–63                 | D                    | 8½                    | 63–65       | 63–65    |
| M52                                   | 6                   | 3                        | 6            | 62–64                 | D                    | 8½                    | 63–65       | 63–65    |
| <b>Tungsten high-speed steels</b>     |                     |                          |              |                       |                      |                       |             |          |
| T1                                    | 7                   | 3                        | 8            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| T2                                    | 8                   | 3                        | 8            | 63–66                 | D                    | 9½                    | 65–67       | 65–67    |
| T4                                    | 7                   | 2                        | 8            | 63–65                 | D                    | 9½                    | 63–66       | 63–66    |
| T5                                    | 7                   | 1                        | 9            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| T6                                    | 8                   | 1                        | 9            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| T8                                    | 8                   | 2                        | 8            | 63–65                 | D                    | 9½                    | 64–66       | 64–66    |
| T15                                   | 9                   | 1                        | 9            | 64–68                 | D                    | 9½                    | 65–68       | 65–68    |
| <b>Chromium hot-work steels</b>       |                     |                          |              |                       |                      |                       |             |          |
| H10                                   | 3                   | 9                        | 6            | 39–56                 | D                    | 8                     | 52–59       | 52–59    |
| H11                                   | 3                   | 9                        | 6            | 38–55                 | D                    | 8                     | 53–55       | 53–55    |
| H12                                   | 3                   | 9                        | 6            | 38–55                 | D                    | 8                     | 53–55       | 53–55    |
| H13                                   | 3                   | 9                        | 6            | 40–53                 | D                    | 8                     | 51–54       | 51–54    |
| H14                                   | 4                   | 6                        | 7            | 40–54                 | D                    | 8                     | 53–57       | 53–56    |
| H19                                   | 5                   | 6                        | 7            | 40–55                 | D                    | 8½                    | 48–57       | 48–57    |
| <b>Tungsten hot-work steels</b>       |                     |                          |              |                       |                      |                       |             |          |
| H21                                   | 4                   | 6                        | 8            | 40–55                 | D                    | 9                     | 45–63       | 45–63    |
| H22                                   | 5                   | 5                        | 8            | 36–54                 | D                    | 9                     | 48–56       | 48–56    |
| H23                                   | 5                   | 5                        | 8            | 38–48                 | D                    | 7                     | 34–40       | 34–40    |
| H24                                   | 5                   | 5                        | 8            | 40–55                 | D                    | 9                     | 52–56       | 52–56    |
| H25                                   | 4                   | 6                        | 8            | 35–45                 | D                    | 9                     | 33–46       | 33–46    |
| H26                                   | 6                   | 4                        | 8            | 50–58                 | D                    | 9                     | 51–59       | 51–59    |

Data source, ASM Handbook, Volume 1, Table 13, General properties of tool steels.

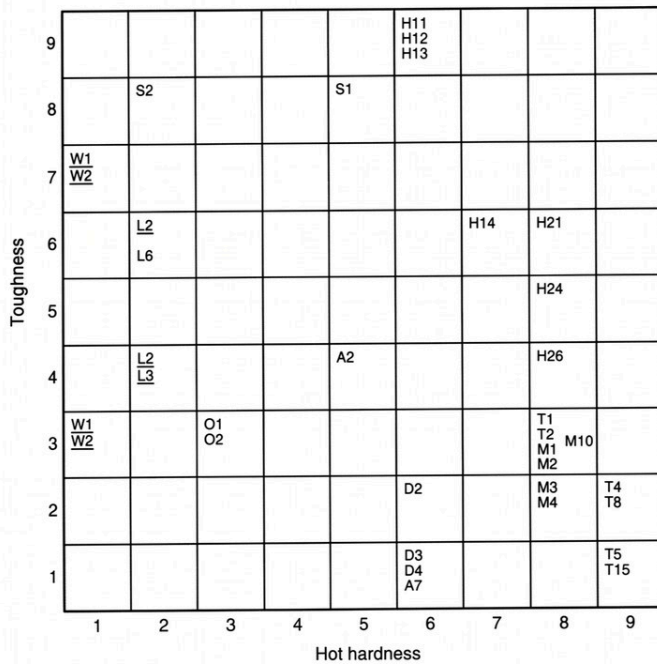
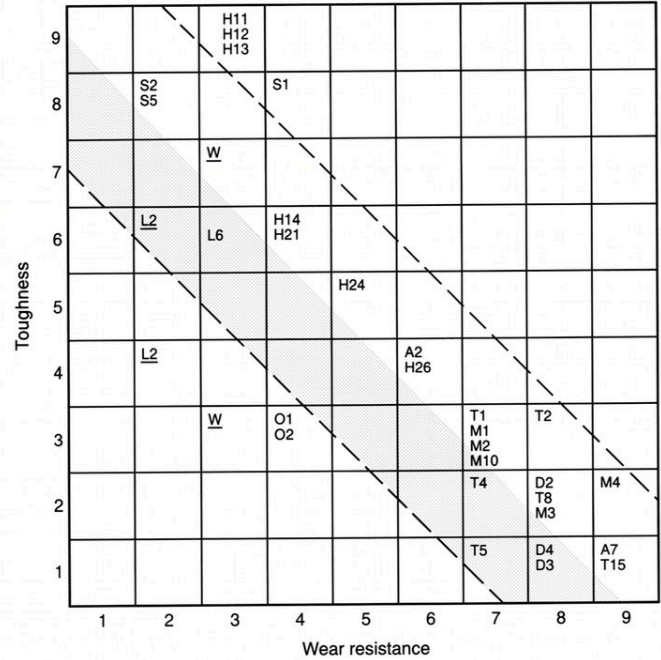
## Properties by grade, continued

| Grade                                                | Wear <sup>(b)</sup> | Toughness <sup>(c)</sup> | Hot hardness | Working hardness, HRC | Depth <sup>(d)</sup> | Grain size (Shepherd) | Surface HRC | Core HRC |
|------------------------------------------------------|---------------------|--------------------------|--------------|-----------------------|----------------------|-----------------------|-------------|----------|
| <b>Molybdenum hot-work steels</b>                    |                     |                          |              |                       |                      |                       |             |          |
| H42                                                  | 6                   | 4                        | 7            | 45–62                 | D                    | 8½                    | 54–62       | 54–62    |
| <b>Air-hardening, medium-alloy, cold-work steels</b> |                     |                          |              |                       |                      |                       |             |          |
| A2                                                   | 6                   | 4                        | 5            | 57–62                 | D                    | 8½                    | 63–65       | 63–65    |
| A3                                                   | 7                   | 3                        | 5            | 58–63                 | D                    | 8½                    | 63–65       | 63–65    |
| A4                                                   | 5                   | 4                        | 4            | 54–62                 | D                    | 8½                    | 61–63       | 61–63    |
| A5                                                   | 5                   | 4                        | 4            | 54–60                 | D                    | 8½                    | 60–62       | 60–62    |
| A6                                                   | 4                   | 5                        | 4            | 54–60                 | D                    | 8½                    | 60–62       | 60–62    |
| A7                                                   | 9                   | 1                        | 6            | 58–66                 | D                    | 8½                    | 64–66       | 64–66    |
| A8                                                   | 4                   | 8                        | 6            | 48–57                 | D                    | 8                     | 60–62       | 60–62    |
| A9                                                   | 4                   | 8                        | 6            | 40–56                 | D                    | 8                     | 55–57       | 55–57    |
| A10                                                  | 3                   | 3                        | 3            | 55–62                 | D                    | 8                     | 60–63       | 60–63    |
| <b>High-carbon, high-chromium, cold-work steels</b>  |                     |                          |              |                       |                      |                       |             |          |
| D2                                                   | 8                   | 2                        | 6            | 58–64                 | D                    | 7½                    | 61–64       | 61–64    |
| D3                                                   | 8                   | 1                        | 6            | 58–64                 | D                    | 7½                    | 64–66       | 64–66    |
| D4                                                   | 8                   | 1                        | 6            | 58–64                 | D                    | 7½                    | 64–66       | 64–66    |
| D5                                                   | 8                   | 2                        | 7            | 58–63                 | D                    | 7½                    | 61–64       | 61–64    |
| D7                                                   | 9                   | 1                        | 6            | 58–66                 | D                    | 7½                    | 64–68       | 64–68    |
| <b>Oil-hardening cold-work steels</b>                |                     |                          |              |                       |                      |                       |             |          |
| O1                                                   | 4                   | 3                        | 3            | 57–62                 | M                    | 9                     | 61–64       | 59–61    |
| O2                                                   | 4                   | 3                        | 3            | 57–62                 | M                    | 9                     | 61–64       | 59–61    |
| O6                                                   | 3                   | 3                        | 2            | 58–63                 | M                    | 9                     | 65–67       | 50–55    |
| O7                                                   | 5                   | 3                        | 3            | 58–64                 | M                    | 9                     | 61–64       | 59–61    |
| <b>Shock-resisting steels</b>                        |                     |                          |              |                       |                      |                       |             |          |
| S1                                                   | 4                   | 8                        | 5            | 50–58                 | M                    | 8                     | 55–58       | 55–58    |
| S2                                                   | 2                   | 8                        | 2            | 50–60                 | M                    | 8                     | 61–63       | 56–60    |
| S5                                                   | 2                   | 8                        | 3            | 50–60                 | M                    | 9                     | 61–63       | 58–62    |
| S6                                                   | 2                   | 8                        | 3            | 50–56                 | M                    | 8                     | 56–58       | 56–58    |
| S7                                                   | 3                   | 8                        | 5            | 47–57                 | D                    | 8                     | 59–61       | 59–61    |
| <b>Low-alloy special-purpose steels</b>              |                     |                          |              |                       |                      |                       |             |          |
| L2                                                   | 1                   | 7                        | 2            | 45–62                 | M                    | 8½                    | 56–62       | 54–58    |
| L6                                                   | 3                   | 6                        | 2            | 45–62                 | M                    | 8                     | 58–63       | 58–62    |
| <b>Low-carbon mold steels</b>                        |                     |                          |              |                       |                      |                       |             |          |
| <b>For hubbed and/or carburized cavities</b>         |                     |                          |              |                       |                      |                       |             |          |
| P2 (e)                                               | 1(e)                | 9                        | 2(e)         | 58–64 (e)             | S                    | ...                   | 62–65 (a)   | 15–21    |
| P3 (e)                                               | 1(e)                | 9                        | 2(e)         | 58–64 (e)             | S                    | ...                   | 62–64 (a)   | 15–21    |
| P4 (e)                                               | 1(e)                | 9                        | 4(e)         | 58–64 (e)             | M                    | ...                   | 62–65 (a)   | 33–35    |
| P5 (e)                                               | 1(e)                | 9                        | 2(e)         | 50–64 (e)             | S                    | ...                   | 62–65 (a)   | 20–25    |
| P6 (e)                                               | 1(e)                | 9                        | 3(e)         | 58–61 (e)             | M                    | ...                   | 60–62 (a)   | 35–37    |
| <b>For machined cavities</b>                         |                     |                          |              |                       |                      |                       |             |          |
| P20 (e)                                              | 1(e)                | 8                        | 2(e)         | 30–50                 | M                    | 7½                    | 52–54       | 45–50    |
| P21                                                  | 1                   | 8                        | 4            | 36–39 (e)             | D                    | ...                   | 22–26       | 22–26    |
| <b>Water-hardening tool steels</b>                   |                     |                          |              |                       |                      |                       |             |          |
| W1                                                   | 2–4                 | 3–7                      | 1            | 58–65                 | S                    | 9                     | 65–67       | 38–43    |
| W2                                                   | 2–4                 | 3–7                      | 1            | 58–65                 | S                    | 9                     | 65–67       | 38–43    |
| W5                                                   | 3–4                 | 3–7                      | 1            | 58–65                 | S                    | 9                     | 65–67       | 38–43    |

Data source, ASM Handbook, Volume 1, Table 13, General properties of tool steels.

## Notes & References

- **(a)** Rating range from 1 (low) to 9 (high).
- **(b)** Wear resistance increases with increasing carbon content.
- **(c)** Toughness decreases with increasing carbon content and depth of hardening.
- **(d)** S, shallow; M, medium; and D, deep.
- **(e)** After carburizing.



Toughness plotted against (a) hot hardness and (b) wear resistance for tool steels. Types underlined indicate shallow-hardened tool steels. The area between the dashed lines in (b) represents average values.

### Elastic modulus of tool steels

For all practical purposes, the modulus of elasticity of all tool steels in all conditions is about **210 GPa (30 × 10<sup>6</sup> psi)** at room temperature. It decreases uniformly to about **185 GPa (27 × 10<sup>6</sup> psi)** at 260 °C (500 °F) and about **150 GPa (22 × 10<sup>6</sup> psi)** at 540 °C (1000 °F).

### Wear resistance

Wear resistance increases with carbon content. At a given hardness, however, it may vary widely depending on the wear mechanism and heat treatment used. Steels with similar hardness can behave very differently under identical wear conditions.

### Toughness & testing

At maximum hardness, most tool steels are brittle, so tensile testing rarely gives reliable strength values. Compression, bending and torsion tests are more useful; torsion impact testing gives reproducible data on the effect of composition and heat treatment, particularly for drills and tools loaded in torsion.

## Aobo Steel, tool steel supplier

Aobo Steel supplies forged tool steel from Huangshi, Hubei, China, where the local supply chain covers ESR melting, vacuum degassing and LF refining, forging, hot rolling, turned and peeled bar, heat treatment and third party inspection. We have worked in tool steel since 2003 and supply to order in cold work grades such as D2, D3 and O1, hot work grades such as H10 and H13, and stainless grades 420, 440C and 4Cr13. Mill test certificates to EN 10204 3.1 travel with every shipment.

Reference data compiled from ASM Handbook, Volume 1, Table 13, General properties of tool steels, and from the Aobo Steel tool steel properties chart.

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