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Microconstituents in Tool Steels After Hardening

A hardened tool steel is not one structure. It is martensite, retained austenite and undissolved carbides together, and the share each one takes decides the hardness the part reaches, the toughness it keeps and how much it moves during the treatment.

Reference only. This is a reference summary of published practice and it is not a specification of ours. The volume percentages are the published figures for the four grades named, at the hardening treatment given, and a different furnace, quench medium or austenitizing temperature will move them. Final treatment parameters are set by the heat treater.

The three constituents

Martensite is the hard constituent and it supplies the as-quenched hardness.

Retained austenite is the part of that austenite which never transformed, and it is still present at room temperature.

Undissolved carbides are the alloy carbides that never went into solution during austenitizing.

The balance between the three is set by the alloy content of the grade, the austenitizing temperature and the quench.

Volume percentages after hardening

Steel	Hardening treatment	As-quenched hardness, HRC	Martensite, vol%	Retained austenite, vol%	Undissolved carbides, vol%
W1	790 °C (1450 °F), 30 min; WQ	67.0	88.5	9	2.5
L3	845 °C (1550 °F), 30 min; OQ	66.5	90	7	3.0
M2	1225 °C (2235 °F), 6 min; OQ	64	71.5	20	8.5
D2	1040 °C (1900 °F), 30 min; AC	62	45	40	15

Microconstituents in W1, L3, M2 and D2 tool steel after hardening from the recommended austenitizing temperature. WQ, water quench; OQ, oil quench; AC, air cool. Source, Table 1 of Size Distortion in Tool Steels, in ASM Handbook, Volume 4, Heat Treating.

What the numbers say

W1 is a plain carbon water-hardening grade, and it comes out of the quench as almost nothing but martensite. It measured 88.5 vol% martensite with 9 vol% retained austenite and 2.5 vol% undissolved carbides at 67.0 HRC. L3 behaves in much the same way at 66.5 HRC, with 90 vol% martensite and 7 vol% austenite left.

M2 and D2 move in the other direction. Their alloy content holds the martensite start temperature down, so a much larger share of the austenite survives the quench. The measured retained austenite is 20 vol% in M2 and 40 vol% in D2. The same alloying leaves 8.5 vol% of carbides undissolved in M2 and 15 vol% in D2.

How the retained austenite is dealt with

Tempering is the usual answer. As the tempering temperature rises through the range 120 to 260 °C (250 to 500 °F), part of the retained austenite transforms to bainite, and that transformation is accompanied by an expansion in volume.

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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, P20+Ni and 420 and 440C stainless. Forged or hot rolled, annealed or pre-hardened, cut to your sizes, with test certificates. Source, Table 1 of Size Distortion in Tool Steels, in ASM Handbook, Volume 4, Heat Treating.

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