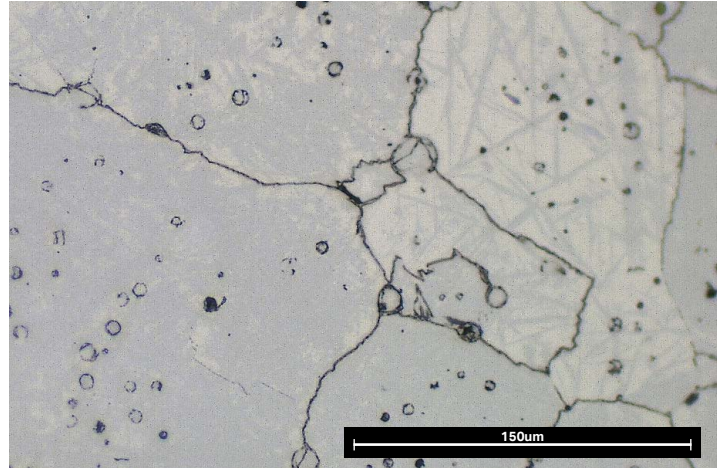


A2 Tool Steel

Other Designations: UNS T30102, DIN 1.2363 , X100CrMoV5, SKD12, BA2

A2 tool steel is a highly versatile air-hardening tool steel often regarded as a “universal” cold work steel. It offers a combination of good wear resistance (between O1 and D2) and toughness. Considered relatively easy to machine in the annealed condition, it has a high compression strength and good dimensional stability during hardening and tempering. It’s used for a wide variety of cold-work tools, from forming and cutting equipment to high wear parts.

Composition	Amount
Chromium	4.75-5.5%
Molybdenum	0.9-1.4%
Carbon	0.95-1.05%
Manganese	0.4-1%
Phosphorus	0.3% max
Vanadium	0.15-0.5%
Silicon	0.1-0.5%
Iron	bal



Typical Mechanical Properties	Standard	Markforged As-Sintered ³	Markforged Heat-Treated ¹	Wrought Heat Treated
0.2% Compressive Yield Strength	ASTM E9	up to 900 MPa	1170 MPa	—
Elastic Modulus	ASTM E9	180 GPa	160 GPa	190 GPa
Hardness	ASTM E18	up to 50 HRC	50 HRC	63 HRC
Relative Density ⁴	ASTM B923	94.5%	94.5%	100%

Heat Treatment

A2 tool steel can be heat-treated to increase hardness and durability. Markforged recommends heat-treating A2 tool steel to optimize material properties, though it can be used as-sintered.

1. Heat A2 Tool Steel part in a standard (non vacuum) furnace to 970°C (1780°F) . Hold part at temperature for 30-45 minutes.
2. Air quench part to below 65°C (150 °F).
3. Double temper A2 Tool Steel part in a standard furnace. For each temper, heat part to 150-550°C² (302-1022°F) and temper for 2 hours, or 1 hour per inch of thickness. If double tempering, let part cool to room temperature between tempers.

1. Markforged heat-treated A2 tool steel was heated to 970°C (1780°F) and single tempered at 200°C (392°F) for 30 minutes.

2. Tempering temperature has a significant effect on final material properties. For higher hardness, temper at low temperatures. For higher toughness, temper at higher temperatures.

3. As-sintered hardness can vary significantly based on furnace loading and ambient environment. Markforged recommends post-sinter heat treatment for maximum hardness and compression strength.

4. Relative density for A2 assumes a density of 7.86 g/cm³.

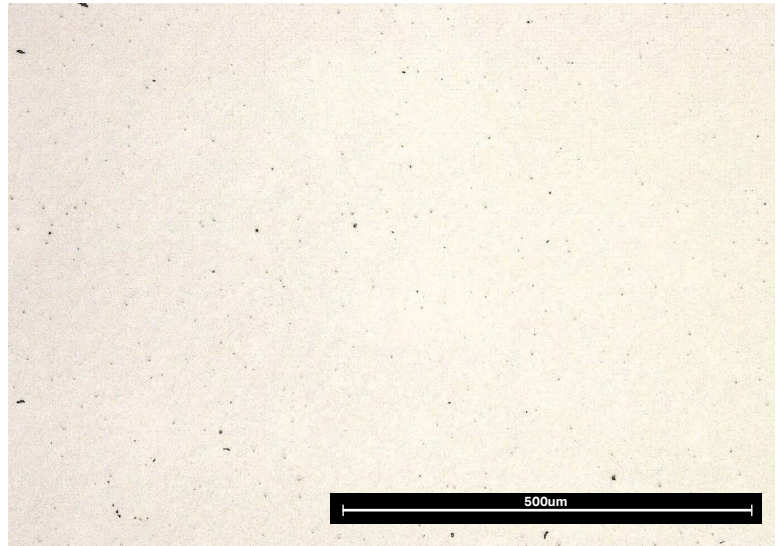
These data represent typical values for Markforged A2 Tool Steel as-sintered. Markforged samples were printed with solid fill. Relative density and as-sintered hardness was tested in house. All other data were tested and confirmed by outside sources. These representative data were tested, measured, or calculated using standard methods and are subject to change without notice. Markforged makes no warranties of any kind, express or implied.

D2 Tool Steel

Other Designations: DIN 12379, ASTM A681, UNS T30402, BD 2

D2 tool steel is a high carbon, high chromium air-hardening tool steel that can be heat treated to high hardness and compressive strength. D2 offers excellent wear resistance and is widely used in cold work applications that require sharp edges, abrasion resistance, and compressive strength. Markforged D2 meets chemical requirements of ASTM A681.

Composition	Amount
Chromium	11-13%
Carbon	1.4-1.6%
Molybdenum	0.7-1.2%
Vanadium	0.5-1.1%
Nickel + Copper	0.75% max
Manganese	0.1-0.6%
Silicon	0.1-0.6%
Phosphorus	0.03% max
Sulfur	0.03% max
Iron	bal



Typical Mechanical Properties	Standard	Markforged As-Sintered	Markforged Heat-Treated ¹	Wrought Heat Treated ²
0.2% Compressive Yield Strength	ASTM E9	830 MPa	1690 MPa	2200 MPa
Elastic Modulus	ASTM E9	170 GPa	187 GPa	210 GPa
Hardness ³	ASTM E18	54 HRC	60 HRC	62 HRC
Relative Density ⁴	ASTM B923	97%	97%	100%

Heat Treatment

D2 tool steel can be heat-treated to increase hardness and durability after an optional annealing step and machining work. Markforged recommends heat-treating D2 tool steel to optimize material properties, though it can be used as-sintered.

1. Heat D2 Tool Steel part in a standard (non-vacuum) furnace to 1000°C (1830°F). Hold part at temperature for 30-45 minutes.
2. Air quench part to below 65°C (150 °F).
3. Temper D2 Tool Steel part in a standard furnace. For each temper, heat part to 200°C⁵ (392°F) and temper for 30 minutes. If double tempering, let part cool to room temperature between tempers.

1. Markforged heat-treated D2 tool steel was heated to 970°C (1780°F) and single tempered at 200°C (392°F) for 30 minutes.

2. Wrought heat treatment data from Bohler-Uddeholm: http://cdna.terasrenki.com/ds/1.2379_X153CrMoV12_AISI-D2_SS-2310_Datasheet_2.pdf

3. Markforged hardness was measured on a sample coupon that was printed at 100% infill and has a 25 mm diameter and 10 mm height.

4. Relative density for D2 assumes a density of 7.7 g/cm³.

5. Tempering temperature has a significant effect on final material properties. For higher hardness, temper at low temperatures. For higher toughness, temper at higher temperatures.

These data represent typical values for Markforged D2 Tool Steel as-sintered. Markforged samples were printed as fully dense parts with 100% infill. Hardness and density data were tested in house, and all other data were tested and confirmed by outside sources. These representative data were tested, measured, or calculated using standard methods and are subject to change without notice. Markforged makes no warranties of any kind, express or implied.