

Grinding Cracks and Grinding Burn in Hardened Tool Steel

Grinding is a heat treatment applied to the surface of a hardened tool. Where the surface passes the tempering temperature it softens, and where it passes the hardening temperature it is rehardened into a brittle white layer that carries microcracks. The tables below give the three zones grinding heat produces, the surface signs that give each one away, the risk by grade group, and the three remedies.

Reference only. This is a reference summary of published practice and it is not a specification of ours. The mechanism and the figures are reproduced from the source, which describes one class of damage on hardened tool steels. Final judgement is made on the job.

The white layer and the zone under it

Layer	Microstructure	Hardness against the core	What it does in service
Rehardened white layer	Untempered martensite with tempered martensite and retained austenite	Higher than the core, about 65 HRC in the high carbon grades	Very brittle. The usual origin of a grinding crack.
Overtempered zone	Tempered martensite, tempered beyond the specified treatment	Lower than the core	A soft band under a hard skin. The tool wears through it quickly.
Unaffected core	The structure produced by the specified hardening and tempering	The specified working hardness	The properties the tool was ordered for.

The three zones produced when a hardened tool is ground too hot. The white layer and the overtempered band under it are often present in the same tool, which is why a hardness reading taken on the surface can look acceptable while the tool fails from the zone below it.

Why grinding cracks form and why they are hard to see

Sign on the ground surface	What it indicates	What to do
Discoloration, a burn mark	The surface reached the tempering temperature or above	Inspect before use. Expect a soft surface or a rehardened layer.
A white layer under the microscope after etching	The surface was rehardened into untempered martensite	Assume microcracks are present. Remove the layer or re-temper the part.
No visible mark at all	No proof that the surface is sound	Magnetic particle inspection is the check that finds grinding cracks.

The three conditions a ground surface can be in. A clean appearance does not clear the part, because the cracks that end tool life are usually below the resolution of the unaided eye.

Which grades carry the most risk

Group	Typical carbon, %	Risk of grinding damage	Why
Cold work, D group	1.5 to 2.25	High	High carbon with coarse primary carbides. The rehardened layer is very hard and very brittle.
Cold work, A and O groups	0.9 to 1.0	High	Air and oil hardening grades work at 60 HRC or more, where toughness is low.
High speed, M and T groups	0.8 to 1.3	High	The highest working hardness in the family, carried on a high carbide content.
Hot work, H group	0.32 to 0.56	Moderate	Lower carbon and lower working hardness, so the rehardened layer is less brittle.
Shock resisting, S group	0.45 to 0.55	Lower	The grade is built for toughness, and the lower carbon limits the hardness of the layer.

Grinding damage risk across the tool steel groups. Carbon content is taken from the typical compositions listed by the source, and the sensitivity it reports for the cold work and high speed families sets the upper band. The lower carbon groups are the ones the source does not single out as sensitive.

Three ways to reduce grinding damage

Remedy	How it is applied	What it does	Where it stops working
Control the heat	Good cooling, and correctly dressed wheels that cut instead of rubbing	Keeps the surface below the tempering temperature of the steel	Nothing is added once the pass has been taken
Stress relief after grinding	Temper at about 30 °C below the previous tempering temperature	Relieves grinding stress and tempers fresh martensite without losing hardness	It does not heal a crack that has already opened
Tumble or blast	Mechanical treatment of the ground surface	Lowers the residual stress at the surface	It cannot reach into a cavity or a bore

The three remedies given by the source, with the condition under which each one stops being effective.

Aobo Steel, tool steel supplier

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Source, Failure Analysis of Heat Treated Steel Components (L. C. F. Canale, R. A. Mesquita and G. E. Totten), ASM International, 2008.

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