

Tool and Die Design Faults That Cause Cracking

Sharp corners, holes placed for convenience, stamp marks, heavy sections beside light ones and inserts that were never seated properly all put stress into a tool before it sees a load. The tables below give the six faults that come back most often with the correction for each, and the corner radius comparison behind the fillet rule.

Reference only. This is a reference summary of published practice and it is not a specification of ours. The design faults and the corner radius comparison are reproduced from Tool and Die Making Troubleshooter, and the source prints the comparison to demonstrate the effect of notch radius rather than to project the strength of a tool. The design decision belongs to the person responsible for the tool. Final specification is confirmed on the job.

Why the design is the first place to look

The design faults that come back most often

Design fault	What it does to the tool	The change that removes it
Sharp corners and sharp-cornered keyways	Internal and external corners and keyways act as stress intensifiers. A sharp corner is the most frequent cause of premature tool failure and can raise the local stress to ten times the average calculated stress.	Leave a well rounded radius in every corner and use generous filleting wherever the function of the tool allows it. Every drawing should be checked for sharp corners that the tool does not actually need before it is released for manufacture.
Light sections next to heavy sections	The light section cools and hardens first during the quench, while the heavy section beside it is still hot. The differential cooling and transformation stresses that build up can pass the ultimate strength of the steel and produce distortion or cracking.	Where the shape is unavoidable, choose an air hardening steel so the whole part transforms at a rate the section can take.
Badly placed holes	Blind holes, threaded holes and holes placed without thought leave thin and weak walls between the hole and the edge of the die. Those walls see the same differential cooling stresses and are difficult to quench uniformly, especially in a liquid quenched steel.	Place the holes as part of the design rather than on the drawing after it. Where the hole pattern cannot be improved, choose an air hardening steel.
Stamp marks	A stamped impression is a sharp change of section cut into the surface. Stamps concentrate both the residual stress from heat treatment and the service stress, and a stress crack often runs straight through the characters.	Use low stress stamps with rounded characters, spread the marks out, and keep the number of characters down. Engraving with an electric pencil, paint, labels or etching is the better choice.
Rough machining	Heavy machining marks are built-in notches and they become the nucleation sites for cracks that open during hardening or in service.	Finish the surfaces that will see stress. This is the fault where the machinist and the die maker have to be told what the drawing means by a finished surface.
An insert that is not seated	The die insert touches its holder at the edges only, so the load is carried on part of the area. The uneven pressure and the deflection that follows open a crack at the corner of the insert.	Machine for full contact on the seating face. Where the dimensions do not allow it, machine undersize, true the tool up, and add a shim of the thickness the seating area needs so the contact is complete.

Design faults behind premature tool failure, with the correction for each, from the tooling design chapter of Tool and Die Making Troubleshooter.

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Corner radius and the impact strength it buys

Radius at the base of the notch	Projected impact strength	What the change buys
0.002 in. (0.05 mm)	4 ft-lbf (5.4 J)	The sharp corner. The tool is at its most brittle at the notch root.
0.010 in. (0.25 mm)	7 ft-lbf (9.5 J)	A radius that a file could be said to have left. The gain over the sharp corner is already most of what a larger radius will give.
0.020 in. (0.51 mm)	16 ft-lbf (21.7 J)	A radius a machine shop would call small. Impact strength is four times the sharp corner.
0.040 in. (1.02 mm)	19 ft-lbf (25.8 J)	A radius a shop would call normal on a die corner.
0.080 in. (2.03 mm)	22 ft-lbf (29.8 J)	A generous fillet, the kind drawn where the designer has thought about the load path.
0.125 in. (3.18 mm)	24+ ft-lbf (32.5+ J)	The widest radius in the table. Beyond this the returns are small against the section the radius costs.

Approximate strength comparison of corner sections with different size radii, from Tool and Die Making Troubleshooter. The source prints this comparison to demonstrate the effect of notch radius and states that it is not to be used for strength projections. Actual impact strength also depends on the grade, the heat treatment and the surface finish.

Grain direction against the direction of draw

Seating an insert so the load is carried everywhere

When the shape cannot be changed, change the steel

How this page sits next to failure analysis

Where to go next

Aobo Steel, tool steel supplier

Aobo Steel supplies tool steel to distributors and mold, tool and die shops, including D2, D3, DC53, A2, O1, H13, H11, H10, H21, S7, M2, M42, L6, P20 and 420 and 440C stainless. Forged or hot rolled, annealed or pre-hardened, cut to your sizes, with test certificates.

Source, Tool and Die Making Troubleshooter, R. M. Leed, Society of Manufacturing Engineers, 2003.

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