Saw Blades & Knives

Fundamentals of D2 & M2 Tool Steel

Demands

Choosing the right tool steel for the application becomes more and more important as the demands on the tool increase. What are these demands?

- The tool must have sufficient wear resistance.
- The tool must perform reliably. It should not fail due to premature cracking.

Optimal tooling economy—the lowest possible tooling costs per part produced—can only be achieved if the correct tool steel for the application in question is used.

Performance

The performance of a cold work tool depends on many factors. These are shown in Figure 1. The performance of a tool is often monitored by examining the quality of the parts it produces. In most applications, there are special requirements on surface finish and dimensional tolerances etc., for the parts being produced. A worn or damaged tool usually results in rejection of the parts produced and the tool must be reconditioned or replaced.

Failure Mechanisms

Failure investigations on numerous worn-out tools from many different applications have shown that five main failure mechanisms are encountered in cold work tooling. These are illustrated in Figure 2 and include the following:

- wear
- chipping
- plastic deformation
- cracking/total failure
- galling.

All these mechanisms have mechanical origins. They are due to high pressures and sliding contact between the working surfaces of the tool and the work material. Wear will always occur to a greater or lesser extent in every cold work application. However, depending on the application, working conditions and work material, one or more of the above mechanisms can be present at the same time. The work material itself has a fundamental influence on the failure mechanisms.

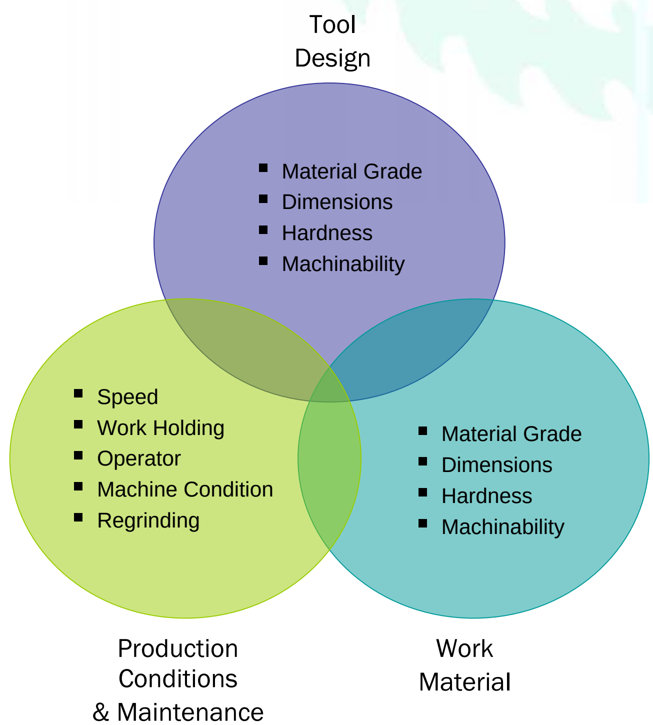

Figure 1. Factors influencing tool life in cold work applications.

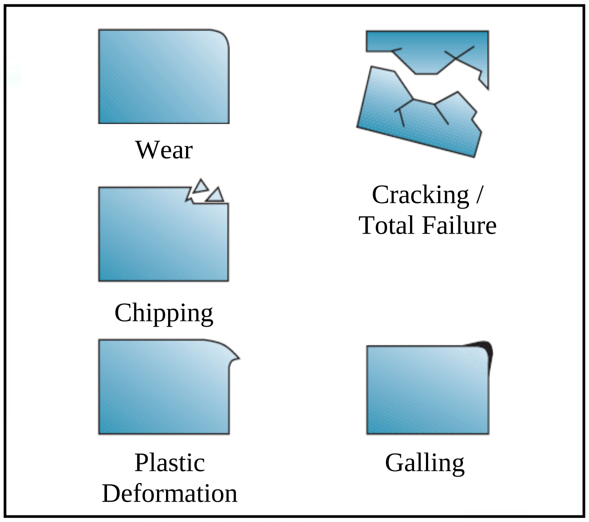

Figure 2. Common failure mechanisms of cold work tools

Wear Types and Influences

There are three primary categories of wear in cold work tool steel applications. By understanding these types, we can efficiently manage the relationship between wear, tool failure and tool design.

Abrasive Wear

This type of wear dominates when the work material is hard and/or contains hard particles such as oxides or carbides. These hard particles scour the tool surface. An example of a punch worn by abrasive wear is shown in Figure 3. Abrasive wear is dominant with such work materials as hardened steels, ceramics and wood. The tool steel properties that are important for good resistance to abrasive wear are:

- high hardness
- high volume of carbides
- high hardness of the carbides
- large carbide size.

Adhesive Wear

The origin of adhesive wear is the occurrence of local micro-welding between the surface of the tool and the work material. The relative motion between the tool and work material will cause the micro-welds to be torn apart again and small fragments of tool material may be pulled out of the tool surface. Such a loss of tool material can result in significant wear of the tool surface. However, the torn off fragments can also stick to the work material and cause abrasive wear on the tool surface. Adhesive wear may also be the origin of chipping. A fatigue mechanism gradually takes over from the adhesive wear dominant in the early stages. Micro-cracks are initiated and these will start to deepen and widen. The cracks can then cause a large scale spalling (chipping) or even lead to a catastrophic failure. An example of a punch worn by adhesive wear is shown in Figure 4. Fatigue cracks can be clearly seen. Adhesive wear will occur with soft, adhesive metallic work materials such as aluminum, copper, stainless steel and low carbon steels. The adhesive type of wear can be decreased by making the micro-welding and/or tearing off mechanisms more difficult. The tool steel properties that are critical for good resistance to adhesive wear are:

- high hardness,
- low coefficient of friction between the tool and work material
- high ductility.

Mixed Wear

It should be noted that not all metallic work materials cause purely abrasive or purely adhesive wear. Some will cause partly adhesive and partly abrasive wear. This type of wear is designated as "mixed wear"

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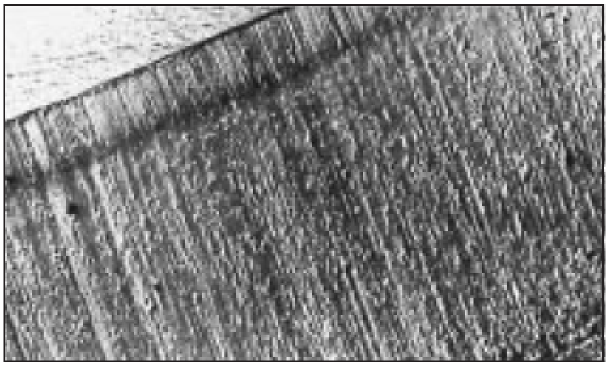

Figure 3. Photograph of D2 worn by abrasive wear.

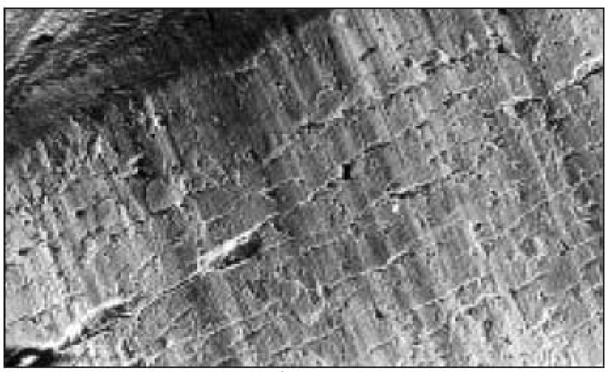

Figure 4. Photograph of D2 worn by adhesive wear.

Chipping

Chipping often occurs after the tool has been in service for a relatively short time. This failure mechanism is one of low cycle fatigue. Small cracks are initiated in the working surface of the tool and further growth finally results in pieces chipping out. To obtain good resistance to chipping it is important to make crack initiation and growth more difficult. One tool steel property that gives a good resistance to chipping is high ductility.

Plastic Deformation

Plastic deformation occurs when the yield strength of the tool steel has been exceeded. Plastic deformation causes damage to or shape changes on the working surfaces of the tool. The tool steel property that is important for a good resistance to plastic deformation is high hardness.
Note: Appropriate consideration of toughness and ductility must be made when selecting the hardness level to be used.

Cracking

Cracking is a failure mechanism which tends to occur spontaneously and usually means that the tool has to be replaced. Unstable crack propagation is the mechanism causing this type of failure. The formation of cracks is often caused by the presence of stress concentrators, e.g. grinding and machining marks or design features such as sharp corners or radii. EDM remelted layers on the tool surface are also a frequent cause. The tool steel properties that give a good resistance to cracking are:

- low hardness
- high microstructural toughness.

Note: Low hardness will have a detrimental effect on the resistance to the other failure mechanisms. Thus working with a low hardness is normally not a good solution. It is better to use a steel with a good microstructural toughness.

Galling

Galling is a problem associated with soft, adhesive metallic work materials. It normally appears as a gradual build up of small fragments of the work material which are torn off and adhere to the working surfaces of the tool. A low coefficient of friction between the tool surface and the work material will help to prevent galling.

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Side by Side Comparison

The resistance of cold work steels to the various tool failure mechanisms is shown on a relative scale in the following table. Additionally, you will note the cost relationship between the two materials.

				Resistance to Cracking		
		Wear Resistance		Initiation Stage	Propagation Stage	
Tool Steel Grade	Hardness/Plastic Deformation	Abrasive	Adhesive	Ductility/ Resistance to Chipping	Toughness/ Resistance to Gross Cracking	Cost
D2						
M2						

Chemical analyses of D2 and M2 tool steels. Note: D2 has considerably more chrome, whereas M2 has considerably more Molybdenum.

	Analyses, %						
Grade	C	Si	Mn	Cr	Mo	W	V
D2	1.55	0.3	0.4	***11.8***	0.8	-	0.8
M2	0.82	0.35	0.25	4.2	5	***6.2***	2

Summary

Choosing the correct type of tool steel for the cutting application is as important as choosing the correct parameters under which the tool should be run. We give very careful consideration to the hardening, quenching and annealing processes. Additionally, all grinding processes are performed on CNC equipment under high pressure flood coolant to prevent heat and ensure consistency from blade to blade and batch to batch. Quality and innovation in every manufacturing step are the rule not the exception.

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