Understanding How to Extend Tool Life with Lubricants: An Overview

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Two important competitive advantages:

- Cut it faster
- Cut it cheaper

These factors are primarily governed by:

- Material
- Cutting tools
- Equipment or machines

And these factors once optimized are the same everywhere in the world.
So where and how do you break out of the box and surpass the competition?

Where could you look to get out of the box.
Test economical improvements.
Analyze cost verses savings.

Tool work piece interface is where the economy of the cut begins.
Improve your process with outside the box ideas!

Better fixtures and process combining;
   Combine operations.
   Remove operator error.
   Reduce non-cutting time.

Cutting time tends to stay the same without improving physical limitations;
   Improve the way you use the tooling by applying and controlling proper lubrication.
   Tooling speeds and feeds can be better optimized to reduce cut time.
   Extends tool life, reducing overall tooling budget and machine down time.
Some of the parameters to look at when optimizing the lubricant.

Proper flow, laminar verses turbulent:

- Is the lubricant doing anything in the cut?
- Is the lubricant optimizing chip formation and length?
- Is the lubricant transforming at the cut?

Without the correct flow your lubricant can not perform to optimum;

Proper direction and flow:

- Through the tool or fixed direction.
- Nozzle shape and direction.
- Overhead coolant.

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Laminar flow high pressure

Excellent flow!

Good direction!

Through the tool provides better performance.
Even with low pressure the lubricant can perform better with the correct flow.
Turbulent flow

Coolant is getting on the part but not doing much for the cutter.

Given the right circumstances the cutter will not receive any lubricant.
This is the most expensive way to use your lube.

Technical term “puddle flow”. Ok for EDM’s but not for CNC machining.
Cooling verses lubrication.

– What is happening during a cut?
  • Heat removal verses friction reduction?
– Chemical reactions, the composition of the lubricant.
  • Does the lubricant provide a good environment that promotes the best cutting action?

The heat coefficient of mineral oil $0.329613 \times 10^{-5}$
The heat coefficient of water / coolant $0.1409215 \times 10^{-4}$
Approximately $4.2$ *’s difference in heat absorption.

If it’s all about heat removal than why can oil improve tool life so dramatically?
The heat generated in the cut creates a chemical reaction within the heat effected zone. Think of the welding process and how gas is used to protect the heated zone from contamination. In welding the reverse happens but the chemical process parallels the metal removal process as it enhances the environment allowing process optimization and repeatability.

The same happens when a lubricant atomizes in the heat of the cutting zone.

Chlorine, Sulfur, Phosphorus, Various Fats, Synthetic Oil, Vegetable, Mineral

To name a few common additives, go through a chemical reaction in the heat zone and that’s when they work.
Water reducible coolants.
Cutting oils.
Stable clean and well engineered.
Safe for people and the machine.

As with all chemicals, they should be used as directed and proven safe.
Bad Chemistry

May be interesting to watch but not in your shop.
The aluminum panel is destroyed. If your coolant supplier says no to aluminum it’s for a good reason. These are standard test panels for the ASTM corrosion test. Aluminum and copper can be reactive with the wrong chemistry.
Extreme Pressure/Load Carrying

Cutting Additive/Active Sulfur

Antiwear / Lubricity Improver

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When choosing the proper lubricant technology, chemical compatibility is first then the correct balance of lubricity and heat removal.

Examples:

**Plastics and epoxy works well with water soluble oils and straight oils.**

Lubricity and cooling to prevent melting at the tool tip to produce a good chip.

Check the chips,

Check for melting on the leading edge of the chip.
Check for fracturing on the work piece. Heat not being removed with the chip.
On some plastics the chips work hardened.
This is a sign that the heat is being carried way.
Aluminum works well with oil based coolants and straight oils.

The lubricant should have high lubricity and preserve surface finish.

Check the part finish, chips and cutting edge,
Check the part finish for over cutting and tearing.
The chips should have a smooth front surface and a ridged back surface.

Check the cutting edge for buildup.
If so get the lube to the cut and with more lubricity.
Aluminum Chips
Carbon Steels work well with semi or low oil content to no oil content coolants and straight oil

Mostly cooling, carbon steel can generate a lot of heat and weld to the cutting edge causing fractures of the cutting edge.

Check the part finish, chips and cutting edge.
Check the part finish for over cutting and tearing.
The chips should have a smooth front surface and a ridge back surface.
Check the cutting edge for buildup.
If so get the lube to the cut and with more lubricity.
Steel Chips
Stainless Steel works well with water soluble oils and straight oil.

The lubricant should have lubricity to prevent work hardening and good chip formation and prevent welding on the cutting edge.

Check the part finish, chips and cutting edge,
Check the part finish for over cutting and tearing mostly on martensitic stainless.
The chips should have a smooth front surface and a ridge back surface.
Check the cutting edge for buildup.
If so get the lube to the cut and with more lubricity.
Stainless Steel Chips
Hard Steels work well with synthetic coolants.

Good heat removal. Heat must be generated to plasticize the material in front of the cut and prevent over cutting and tearing of the material. The heat must be limited to allow for good chip formation.

Check the part finish, chips and cutting edge. Check the part finish for over cutting and tearing. The chips should have a smooth front surface and a ridge back surface. The chips should look tawny or blue if you are generating enough heat. Check the cutting edge for buildup. If so get the lube to the cut and with more lubricity.
Hard Steel
The lube manufacturer show heat verse pressure charts for different additives. These are the reactive temperatures needed to be effective. These reactions can reduce or enhance tool performance.

For example:

CBN or Diamond Tooling
Mineral oils are carbon based and can act as a solvent given enough temperature in a cut using diamond/carbon tooling. They’re too much alike.

Carbide Coated and Non-Coated
The wrong type or too much free chlorine in a lubricant with enough heat can generate HCl. Phosphorus / Phosphoric acid, Sulfur / Sulfuric acid.

Each of these are sometimes called sacrificial additives, in the correct form and amount can extend tool life to the extreme.
What to look for if you are using the lube and tooling to the full extent:

What type of chemical reaction will the cutting operation create verses the chemistry of both the cutting tool and the lubricant?

Aluminum could create soaps to aid in reducing friction and keep the chips from melting to the cutting tool.

Copper and brass.
Using the correct chemistry for the type of tooling in use. Use dissimilar chemistry carbon verses non-carbon. Copper can oxidize low grade oils reducing the lubricity.

For example; If the drill’s margins start to grip or rub, wipe the drill margins with a clean rag.

There should be a dark grease protecting the edge.
This is the bridge lubricant acting as a sacrificial additive.
Steels Carbon and Alloy.
The maximized lubricant chemistry has a low lubricity and polymers that burn in the cut, preventing welding to the insert and removing heat from the cut. The lubricity comes under high tool work piece pressure. The lube residue is evident on the tooling only where the tooling is under pressure and may be clear. Some new polymers will actually go back to liquid after turning to solid under pressure.

Stainless Steels, Austenitic and Martensitic.
Austenitic stainless reacts well with a high lube product. Sometimes semi’s work but a water soluble coolant provides the bridge and high pressure lubricant required. You can see the residue on the tooling in areas that are under pressure. Martensitic stainless will react closer to steel producing higher cutting temperatures that allow for smooth chip formation. Good cooling is required to prevent martensite and a little less lubricity is required compared to austenitics.
Hard Alloy Steels.

The chemistry required needs to reduce heat but allow enough to plasticize or soften the material in front of the cut. The cutting edges should show signs of burned lubricant.

This is a simplified explanation of a very complicated chemical reaction going on inside the cut as well as on the bearing surfaces of the tools, such as drill margins.

I have learned a lot looking at bearing failure charts explaining lubrication and alignment failures. There are many resources well documented that pertain to tooling and cutting lubricant failure.