Innovation in Metalworking Fluids

Straight Oils for Cutting & Grinding

Optimum Performance
Where Lubrication & Extreme Pressure Properties are Required

E-LEARNING GUIDE

KOOLRite™

CUTTING & GRINDING OILS

REDUCE FRICTION • LONGER TOOL LIFE
IMPROVED SURFACE FINISH

Oil based metalworking fluids, otherwise known as straight oils, are meant to be used in tough operations where lubrication and extreme pressure properties are necessary.

They are not meant to replace or compete with their water-based counterparts; rather, they provide an option for those applications where lubrication is more essential than cooling. Straight oils provide significant improvements in cutting and grinding operations by reducing friction resulting in improved surface finishes and longer tool life, especially with grinding wheels and other abrasive tools.

Premium cutting and grinding straight oils are specially designed to provide optimum performance across a variety of different operational levels and viscosities. They have distinct advantages such as:

- Excellent lubricity
- Exceptional rust control
- Long or continuous service life of fluids
- Less fluid and sump maintenance

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Oil based metalworking fluids can range from low to high viscosity and in performance from light to heavy duty machining, each feature dialed into the specific applications in which it will be used.

Some examples of these oils are:

- Low viscosity light duty oils are designed to provide excellent wetting properties and are ideal in higher speed operations and Swiss machines.
- ISO 32 medium duty oils offer excellent performance in light to moderate duty cutting applications and are often used as dual or tri-purpose oils. These types of oils are ideal for screw machines or any operation where there is a high probability of leakage.
- Straight oils for medium to heavy duty performance at higher viscosities that are fortified with lubricity and extreme pressure additives provide excellent performance in gear hobbing, gear shaping, threading, and tapping applications.
- Extreme duty oils that are heavily fortified with lubricity and extreme pressure additives provide protection during the most difficult machining operations including, but not limited to; pipe threading, tapping, reaming and internal broaching.

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Although these oils can be the best choice in many of the applications mentioned here, there can be some challenges to consider when formulating and choosing the right straight oil for your process.

- Oils can incur excess heat and are better suited for slower operations that produce less heat.
- Because of their thicker viscosity, oils are known to mist which can be very messy as well as a health and safety issue for the operators.
- Petroleum oils can be a safety hazard due to their aspiration hazard classification as well as the oily film that can be left throughout the shop floor.
- During use they can cause unpleasant odors, especially if they smoke during the operation.
- Oils are subject to oxidation which can affect their tribological performance, or their ability to get to the tool/workpiece interface and provide lubrication to the process.

Some, if not all, of these challenges can be overcome with the correct combination of additives; misting can be reduced with anti-mist additives, oxidation can be controlled with antioxidants, friction can be reduced with the use of lubricity additives, and welding and tool failure can be prevented with the use of extreme pressure additives.

Newer Oil Based Metalworking Fluids:

Better Formulations ● Specialty Additives ● Highly Fortified

Traditional straight oils were made up of only oil or a combination of oil and lard and did not last very long in-process. Today's formulators have access to a broad selection of performance additives to help prolong the life of the fluid, provide the best surface finish on the part and increase the tool-life of the machine tool.

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Specialty lubricity additives for oil based fluids help reduce friction and surface tension, while improving surface finish. Lubricity performance is provided by several different methods:

- By absorbing onto the surface providing protection in metal removal and protecting fluids
- By providing physical separation in metal forming fluids
- By increasing the viscosity index of the straight oil with specialty esters which will allow for less change in viscosity with fluctuations in temperature as well as increase the film strength of the oil

Extreme pressure (EP) additives form a sacrificial film that fills asperities on metal surfaces to:

- Help prevent metal to metal contact
- Reduce friction allowing for low shear strength
- Eliminate surface wear and welding

Other Additives

Because straight oils run hotter and are traditionally a combination of mineral oils, oxidation is a big concern for fluid life. Naphthenic or even Group I oils, which are less oxidatively stable, require an antioxidant be added to help extend the functional life of the oil. Some additive chemistry can stain the metal being machined. Active sulfur is a commonly used extreme pressure additive that will stain yellow metals. Fortunately, stain inhibitors have been developed to help protect the metal surface. Misting was once a big health and safety concern because as mist was introduced into the shop air, operators were subjected to breathing in these droplets of oil. With antimist additives, misting is reduced or even eliminated from the shop air.

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All of these additives work together to provide features and benefits to the end user.

Features	Benefits
Minimizes misting, smoke, and odor	Providing a healthier, safer, and more pleasant work environment for machine shop operators
Improved finish due to lubricity and extreme pressure additives	Less scrapped parts
Provides solvency	Giving better penetration of the oil to the tool/workpiece interface where lubrication is essential
Viscosity optimization: a product that is not too thick and not too thin	Providing a balance dialed into specific applications which will allow for the best tool-life and part finish

Choosing the Best Formulation

When selecting the best formulation of oil based metalworking fluid the following conditions are important to consider:

Machining conditions
- Feed
- Speed
- Depth of Cut

Metal types
- Compatibility of the fluid with the metal, some additives will react and stain the metal
- Workability of each individual metal

Machining operations
- Light duty
- Medium duty
- Heavy duty

Downstream operations
- Surface finish requirements
- Ensure selection of cutting oils will be compatible with the production environment

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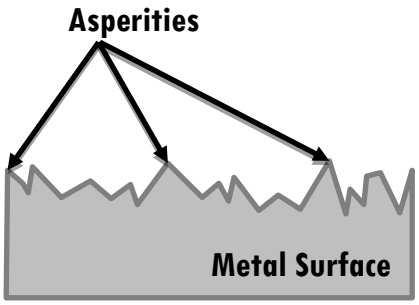
Always refer to the fluid manufacturer's guidelines to ensure the proper match of oil and chemistry with the application.

Keep in mind that oil based metalworking fluids are utilized in operations where lubrication and extreme pressure protection are the two most essential characteristics of the fluid. In metal cutting operations, the metal surface of the tool will always come into contact with the metal surface of the workpiece. It is at this point where the type of fluid film is critical.

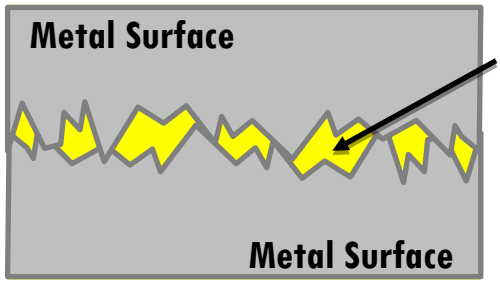
Lubrication Regimes

There are four different lubrication regimes, the way in which a lubricant interacts with two pieces of metal that are coming into contact. The two main focuses for metal cutting are boundary lubrication and mixed film lubrication which are explained here. Also, in order to understand how the specialty additives work to protect the metal surfaces of both the tool and workpiece, it is important to understand that a metal surface, although appearing to be smooth to the naked eye, is not. The surface actually contains asperities as seen the in this picture.



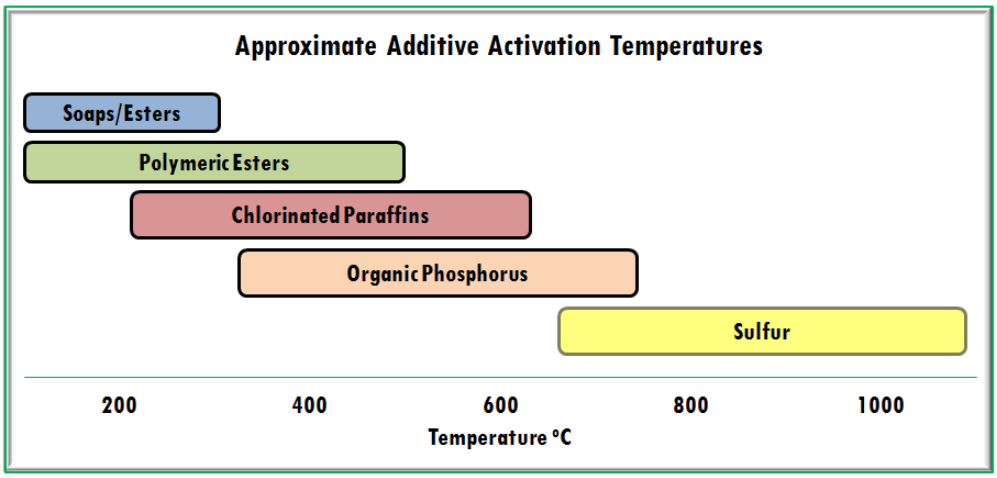
Boundary Lubrication

During the metal cutting process, the metal tool will come into direct contact with the metal workpiece. When two metal surfaces that are not smooth come into close contact with each other, their asperities will also be in close constant contact, as demonstrated in the picture below.



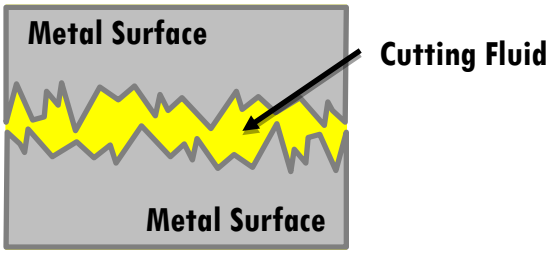
The local temperature at the point of cut can reach ~1,000 °C, causing welding of the two surfaces together. This is where extreme pressure additives are "activated," reacting with the surface of each metal to create a low sheer strength film which will prevent welding from happening.

Although the local temperature of the point of cut can reach 1,000 °C, the surface of the metal has to be protected even before it reaches the maximum temperature. Each extreme pressure additive has a different activation temperature. The best and most balanced formulations will utilize several different types of chemistries to ensure that the surface is protected along the range of temperatures it will be subjected to from process start to finish.

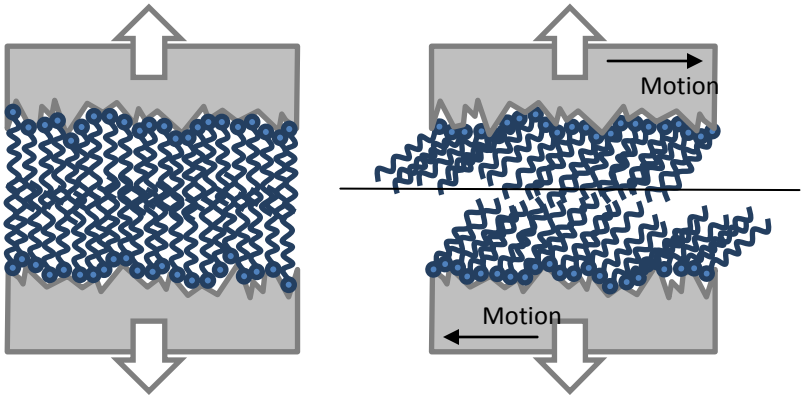


Mixed Film Lubrication

Mixed film lubrication is just how it sounds, a combination of two different lubrication regimes: boundary and hydrodynamic. Hydrodynamic is when the lubricant provides a barrier, preventing the two surfaces to come into close contact with each other. Their asperities never touch and there's no need for extreme pressure additives. In mixed film, some asperities will come into contact but not to the extent as boundary, as shown in this picture.



While boundary lubrication happens *at* the point of cut, mixed film is found *around* the point of cut: as the tool drags across the freshly machined surface and as the chip produced drags across the face of the tool. Lubricity additives are very important for protection in this lubrication regime. They are attracted to the metal surface with a polar head group while the bulky organic tail situates itself away from the surface providing a cushion between the two surfaces by filling in around the asperities. Then as the two pieces of metal slide past each other and the tails move from side to side, the negative charged head groups will provide repulsive forces to aid separation of the fluid. This is demonstrated in the pictures below.



When gear cutting tools are reground using oil based fluids, the surface finish on the cutting edge is significantly improved and tool-life is extended by preventing premature cratering. Cratering is the result of contact with chips that erode the tool-face. It's the lubricity additives in the oil-based fluid that are providing protection against cratering.

Conclusion

Straight oils are best for applications where lubrication power is necessary in severe machining operations such as gear cutting and broaching. They are also beneficial for applications where surface finish and extended tool-life are essential.

To enhance results, specialty additives are added to improve cutting performance, corrosion protection, and extend oil and tool-life.

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Primary additives include:

- **Lubricity –** include oil, natural fats and specialty esters that are attracted to the metal surface. They lower friction and surface tension by filling in around asperities in the metal providing a cushion between the two metal surfaces of the tool and the workpiece.
- **Extreme Pressure –** include chlorinate paraffins, sulfur and phosphorus compounds that react with the metal surface at different temperatures to provide a sacrificial film to protect the two metal surfaces of the tool and workpiece.

Secondary additives include:

- **Antimist** - which consist of long chain polymers that increase the size of the oil drops produced by rotating tools and workpieces. Increasing the size of the particle will decrease the chance it will become aerosolized (i.e. converted into a spray).
- **Copper corrosion inhibitors** - prevent adverse surface reactions for yellow metals. This passive layer made of a composite between benzotriazole and copper is formed as copper is immersed in the benzotriazole solution.
- **Antioxidant** - reduces the aging process of straight oils. As an oil ages it will become more acidic, have an increase in viscosity and become sticky.

Straight oils are best used in low speed applications when machining harder metals such as stainless steel and gummy metals such as aluminum. They are also superior in severe operations such as:

- Honing
- Deep Hole Drilling
- Tapping
- Pipe Threading
- Reaming
- Gear Hobbing & Cutting
- Grinding
- Internal Broaching

There are many advantages of using straight cutting oils due to their superior lubricity, good corrosion protection and stability of the work surface. These neat cutting oils provide significant lubrication that helps to reduce frictional heat as the cutting tool penetrates the metal or drags against the freshly machined surface and newly generated chips. They also decrease energy consumption by reducing cutting forces. Oil based cutting and grinding fluids perform best in critical grinding operations, heavy duty machining operations and where lubricity is extremely important.

About the Author

JTM Products has been manufacturing quality industrial lubricants for more than one hundred years. Founded in 1890 as the Phoenix Oil Company, it produced the axle greases, belt dressings, and lubricants that helped the Industrial Revolution run smoothly. The company was on the leading edge in the early 1900s, when it introduced the first water-soluble cutting oil for machine tools. In the 1920s, Murphy Oil Soap was born. Now a household word, Murphy Oil Soap has remained a favorite cleaning product with homemakers, industrial, and commercial maintenance people ever since. As a pioneer in the field of industrial chemicals, JTM's mission has been to provide products which meet the changing needs of customers. All of the formulations have played key roles in emerging technologies.

In the mid-2000s, JTM Products introduced **KOOLRite™** Long Life Fluids and in 2018 SynMAX™ Ultimate Coolants; both product lines offering unique and innovative solutions to metal working industry challenges. We have a dedicated team focused on the metal working industry. Within the team we have a Certified Metalworking Specialist, a Certified Lubrication Specialist, and years of expertise with our chemists, sales and technical service staff. In addition to the KOOLRite and SynMAX Coolants, JTM offers a broad portfolio of metal working fluids including Swiss Cutting, Sawing and Grinding Fluids, Forming Lubricants, Rust Preventatives, Cleaners and many others.

Our goal remains the same as it was over 100 years ago….to provide quality, innovative products that meet the current and future demands of our customers and the industrial markets that we service.