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Cutting Fluids Manual

Collected Knowledge on Cutting Fluids for Metalworking

The right cutting fluid – equally important as the right tool

Choosing the right cutting fluid product for metalworking is a good example of minor details making a major difference.

With the right cutting fluid you can reduce the number of unplanned stoppages, and increase the life of both the tool and the cutting fluid. This means you can increase capacity utilisation, thereby reducing the cost per produced unit. With the right cutting fluid, the right checks and the right handling, you can keep production at a consistently high level – both in terms of quality and efficiency. In certain cases you can even reduce one or more stages in the production process, saving both time and money.

So in other words, it pays to keep an eye on how cutting fluids work and how they should be handled. At FUCHS Lubricants we have cutting fluids for every kind of need, and we can help you find the optimum products for your particular field of operation.

This brochure brings together our key knowledge of cutting fluids: from composition and the role of the various additives, to how they can improve your bottom line.

/Kenneth Borin

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What are cutting fluids made of?

Metalworking fluids can be divided into water-miscible fluids (emulsions, semi-synthetics and synthetics) and neat oils.

Water-miscible cutting fluids

Emulsions are the most common type of cutting fluid today. An emulsion is made by adding a concentrate to water to form a milky product. The appearance of an emulsion varies with the type of product and the size of the oil drops. Larger oil drops give a more cream-like colour, while smaller drops give a more transparent emulsion that looks like very low-fat milk.

There are also concentrates that contain no oil; these give a transparent emulsion and are called synthetics.

Cutting fluid concentrates are comprised of base oil, esters and fatty acids, emulsifiers, rust protection, pH-regulating additives, biocides and anti-foaming agents. The properties of the emulsion can be altered and varied by changing the levels of the constituent components. The products are normally used at a concentration of 4–10%. Water-miscible cutting fluids have excellent cooling capacity. In industry, the need for products with good cooling capacity has increased. This is because new machines run at higher speeds, which generates more heat.

Water-miscible cutting fluids are cheap compared to straight cutting oils. The drawback of water-miscible cutting fluids is that they have to be checked frequently to make sure the concentration is right. If the wrong concentration is in the system the result is lower productivity, corrosion problems, and possibly also bacterial growth..

Emulsion – structure

- Base – Mineral oil, esters
- Emulsifier/tenside – Sulphonates, soaps, synthetic tensides
- Corrosion protection – Sulphonates, soaps, amines, fatty acid amides
- pH regulators – Alkylamines, boramines
- Wear protection – Mineral oil, esters, sulphur/phosphorus compounds
- Biocides – Formaldehyde donors etc.
- Anti-foaming agents – Silicon oils, wax emulsions, calcium compounds

Synthetics have the same structure as emulsions, with one exception: they do not have mineral oil as the base.

Cutting oils

This type of product is not mixed with water, but is applied directly. Neat cutting oils are primarily used when good lubricating properties are required, such as in deep-hole drilling, threading and reaming.

Cutting oils have different viscosities, base oils and additives depending on the processes and which metals are being machined. Mineral oils, synthetic oils, white oils and esters are used as base oils. 'Fatty oils' are also often added (such as vegetable oils, animal oils or esters) to protect against wear. EP additives are also sometimes used (e.g. sulphur, phosphorus or chlorine). This type of fluid has better lubricating properties than the water-miscible ones, but has less of a cooling effect. Neat oils vary from the technically simple to some highly sophisticated formulations.

One drawback of cutting oils that contain active sulphur additives is that they can discolour yellow metals.

Normally, this type of product provides excellent corrosion protection.

Lubricating additives

There are two main types of additives: anti-wear (or 'polar') additives, and extreme pressure (or EP) additives.

Anti-wear (polar) additives

- Fatty acid
- Ester
- Polyglycol

- *Extreme pressure/high-temperature (EP) additives*
- Phosphate
- Chlorine (not as widely used nowadays for environmental reasons)
- Sulphur

Anti-wear additives

When component surfaces come into light contact with each other (mixed lubrication), the wear can be limited using surfactant additives. These additives form a membrane on the surfaces that slide against one another. A typical product that has an anti-wear additive is hydraulic oil.

The process

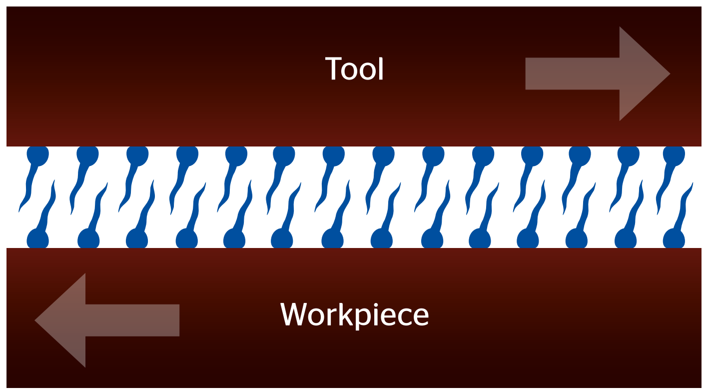
In mixed and boundary lubrication, the metal surfaces rub against each other.

The result

Wear, leading to a shorter life span.

The additive's function

o Forms a protective coating on the metal surfaces, thus reducing wear.



Anti-wear additives form a seaweed-like membrane on the surfaces that slide against one another, making the contact far less abrasive.

Extreme pressure (EP) additives

When component surfaces come into frequent contact with each other under heavy loads (boundary lubrication), heat is generated.

Extreme pressure additives, which have the ability to form chemical compounds in the contact surface at high temperatures, can be used to reduce harmful wear. Cutting oils for tougher machining in steel, aluminium and titanium almost always have some kind of EP additive.

The process

- The metal surfaces rub heavily against each other under heavy loads.
- The kinetic energy is converted into a dramatic rise in temperature in the contact points.
- The metals are welded together and the material gradually comes loose.

The result

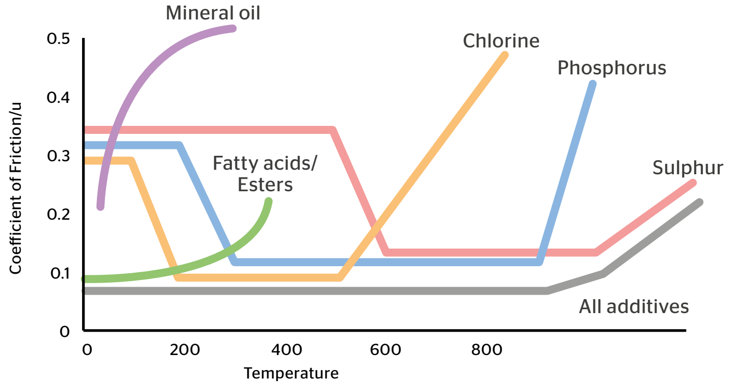
- A shortened tool life and more rejected machined parts.

The additive's function

- As the temperature rises in the contact between die and work piece, the additive is activated and provides a protective chemical film that prevents welding.

EP additive: As the temperature rises in the contact between die and work piece, the additive is activated and provides a protective chemical film that prevents welding.

Synergies between different additives



Different kinds of additive may be required depending on the operation and type of material being machined. Generally speaking, for tough machining at high temperatures you need more additives in your oil to ensure cost-effective production. Without the right additives in the oil, you may need to reduce the production rate to maintain the level of quality

A cutting fluid's main tasks

Cutting fluid is used to cool, lubricate and remove metal particles, swarf and dirt from the machine, which can otherwise increase wear on the machine and tools.

Desirable characteristics

Technical *primary* characteristics: A cutting fluid has to cool and lubricate effectively in the metalworking process. It also has to keep machines and tools clean and free of mess.

- Effective cooling and lubrication
- Good cleaning of machines and tools
- Effective removal of swarf
- Good cleaning of the grinding disc

Technical *secondary* characteristics: There are also secondary considerations with regard to technical properties. Here are some examples:

- Good corrosion/rust protection
- Low foaming tendency
- Low tendency to emulsify in leaked oil
- Must not damage machines or components
- Simple preparation
- Simple control methods
- Biostability

An optimal cutting fluid increases productivity and contributes to:

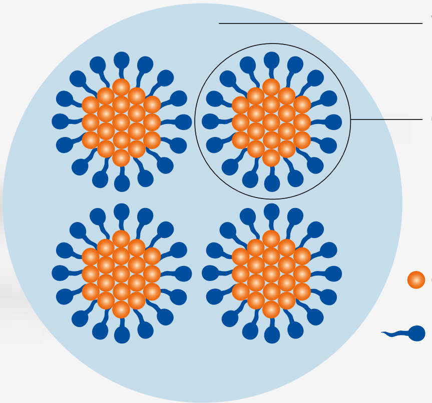
- higher cutting speeds
- fewer rejects
- longer tool life
- excellent surface finish
- better dimensional accuracy
- controlled swarf management
- lower energy consumption

Choosing a cutting fluid can be complicated, especially if you have several different processes and types of material to machine. If you need any help or advice, please contact FUCHS Lubricants.

Cutting emulsion compared to cutting oils

Cutting Emulsion – Water-Miscible Fluids

Emulsions (coarse emulsion, macroemulsion)
The most common fluids for metalworking are emulsions. An emulsion is made by mixing a concentrate into water, never the other way around. The concentrate consists of a mineral oil and possibly a synthetic ester, along with an emulsifier and other additives. When the concentrate is mixed with water, a milky-white emulsion is formed. The concentrate is mixed to different concentrations depending on the process and the metal. This type of product can vary from the technically relatively simple to a highly sophisticated formulation.



The principle for the system including oil, water and emulsifier.

Semi-synthetic (microemulsions)
It is possible to vary the size of the oil drops using different types of emulsifiers in different quantities. It is therefore possible to produce emulsions with very small oil particles. Such emulsions are clearer than normal and are called semi-synthetics or microemulsions.

Synthetic fluids (solutions)
Synthetic fluids do not contain mineral oil but are often based on glycols. There are also synthetic fluids that do not contain any lubricating components. These are used as grinding fluids. Unlike emulsions, such liquids are entirely soluble in water, and the resultant solution is normally very clear and transparent.

Cutting oils – neat oils

Cutting neat oils are particularly stable. No further maintenance is generally needed other than filtering and centrifuging the fluid to remove swarf and impurities.

A straight cutting oil rarely has to be changed as it is normally used in the process as it follows the machined parts and swarf, so it constantly needs refilling. The exception is if the oil starts to oxidise, or if the levels of metal particles or sediment give rise to problems.

There is also an application method known as minimum lubrication, whereby a small amount of oil is sprayed into the air and then applied to the machining area under high pressure. The benefits are very low oil consumption and a reduced cleaning requirement. The drawbacks are swarf management and inadequate cooling. Consequently, minimum lubrication can only be used for certain processes and metals

How to choose the right cutting fluid?

One can generally base one's choice of lubricant on norms, specifications and quality labels from machine manufacturers. However, norms and quality labels very rarely appear on cutting fluids. The choice of cutting fluid depends on the material being machined and the types of machine being used. Most machines work fine with both water-miscible cutting fluids and cutting oils, while others are more adapted to a type of product.

To choose the right cutting fluid, you must consider:

- The types of material being machined
- The type of machining
- The premises, environmental and health & safety aspects

Material

Cast iron and copper alloys are the easiest materials to machine. Cast iron contains graphite and copper which lubricate well by themselves, so very little extra lubrication is needed. Compare this to high alloy steel and aluminium alloys, which are harder to machine and need more advanced high lubricating products.

The material's effect on the fluid

However, when we look at the material's effect on the cutting fluid, cast iron and copper alloys form small metal particles during machining which can easily get stuck in nooks and crannies and make the machine dirty. There are therefore higher demands on the fluid's cleaning properties when machining these materials.

COMMON MATERIALS

THE MATERIALS EFFECT ON THE FLUID

Advantages and drawbacks of different types of cutting fluids

Slow operation = high demands on lubrication = **Cutting oil**
Fast operation = high demands on cooling = **Cutting emulsion**

Cutting oil
Demands:
– High demands on lubrication
– High demands on surface finish
– Hard-to-machine materials
– "Maintenance free"

Examples:
– Grinding hard metals
– Deep-hole drilling
– Threading difficult materials
– Gear cutting
– Rotary table machines

Drawbacks:
– Worse cooling
– Mess in and around machines
– Fire risk

Cutting Emulsion – Water-Miscible Cutting Fluid
Demands:
– High demands on cooling
– High cutting speeds
– Most materials can be machined

Examples:
– Turning
– Milling
– Drilling
– Grinding

Drawbacks:
– Requires care/maintenance
– Systems need replacing
– Greater risk of allergies etc.

Properties	Cutting oil	Emulsion	Synthetic
Lubrication	++	+	–
Cooling	–	+	++
Cleaning	–	+	++
Removal of swarf	++	+	–
Corrosion protection	++	+	–
Antibacterial	++	–	+
Mould/fungi	++	+	–

Comparison between cutting oil, emulsions and synthetics, where + means the product type is better suited to that particular property.
- Cutting oils provide the best lubrication and rust protection.
- Emulsions provide better lubrication and rust protection than synthetics.
- Synthetics have the best cooling and cleaning properties.

Optimisation of cutting fluids when circumstances change

It's not always easy to find an optimum cutting fluid that works perfectly in several different types of operation and with widely varying materials. To make life easier for our customers, at FUCHS we have produced different additives to change the properties of our cutting fluids and adapt them to the customer's specific production. One example is our lubricating additives, which increase the lubrication of the products should the customer change to a new material that is harder to machine. When the system is topped up with a lubricating additive, it becomes a more lubricating product without having to stop the machine and halt production.

Filling of cutting fluids

Filling the chosen cutting fluid

Once you have chosen a cutting fluid it is easy to fill a machine with the new product if the machine is new, but if it is not new and another cutting fluid is already in it, there are various options available.

Changing cutting oils

If there is cutting oil in the system and it is in good condition, the new cutting oil can be dilution-fed into the old one. Before adding the new cutting oil, a miscibility test between the new product and the old one should be carried out in the laboratory, to make sure there are no foaming problems or precipitation when the two are mixed.

The mixing proportions between the products to be tested should be 10/90, 50/50 and 90/10. This simulates the beginning of the dilution when there is 10% new product and 90% old product in the system, 50% of each in the middle of the changing process and 90% of the new and 10% of the old once the fluid change is almost complete. If problems do arise, this generally happens at the 10/90 or 90/10 stage. If the lab test results are good, changing the oil normally proceeds quite smoothly.

hanging water-miscible cutting fluids (emulsions)

1. Changing the whole system

If you are changing the entire cutting fluid system, it is always best to begin with a system cleaner before emptying the system (see the chapter on Handling and maintenance).

Then remove the couplings and pressure-wash the pipes, along with mechanical cleaning of nooks and crannies. If you don't clean the pipes and tank properly, there is a high risk of dirt and cutting fluid residue getting into the new fluid during filling – especially if the new fluid washes better, which can result in clogged filters and possibly overflowing.

Any problems tend to subside after the system has been running a while. There is a greater risk of foaming initially when the entire system is changed and started up with a new product in soft water.

2. Part-draining the system

In this process, a certain amount of the old fluid is removed and replaced with the new one, after which the new fluid is dilution-fed into the system.

There is a risk that some of the old deposits could come loose, but it is far less than with option 1 if you have not also cleaned all the tanks and pipes properly.

3. Dilution-feeding the new product

Dilution-feeding may gradually increase the cleaning properties, and the filters will have no problem dealing with a bit of dirt coming loose slowly compared to a complete fluid change. With this option there is a gentler transition to the new product, with fewer operational disruptions. It is important to check the miscibility.

Handling and maintenance of cutting fluids/systems

Clean the cutting oil system regularly

During Christmas or summer stoppages, pump the oil off and remove swarf and any other residues at the bottom of the tank. Clean the conveyor, tank and machine, and then filter the oil back into the system. You generally only need to fill with a small amount of new oil.

Clean the emulsion system with an effective system cleaner (e.g. CoolWay System Cleaner 1).
The system cleaner is normally added 1-2 days before the fluid is to be changed. However, you can also use a higher concentration of cleaner over a shorter period of about 6-8 hours, as long as there are no operators working inside the machine. The approach you choose depends on the circumstances in production when the fluid is due for a change.

Next the system is emptied (including swarf and other impurities) and rinsed with water. Use a system cleaner only in conjunction with an emulsion change.

Disposing of used cutting fluid
Use a disposal method that has as low an impact on the environment as possible. Used emulsion can either be evaporated or splitted using acid. The emulsion should be evaporated to approximately 10% before being sent for disposal. When emulsion is splitted using acid, the oil phase is sent for disposal. The water phase is cleaned up and reused, or neutralised and sent to a treatment works if this is approved by the local authorities.

Mixing emulsion
The best results are always achieved using a mixer. To ensure a stable emulsion, concentrate must always be added into the water, rather than the other way around. This ensures the emulsification process is successful and the resulting emulsion is stable. If you add water into the concentrate there is a risk that the emulsion becomes inverted, which means there are water drops in oil rather than oil drops in water, and the emulsion will not work as intended.

Checking cutting fluids and system

Checking the concentration of the emulsion

The concentration of the emulsion must be kept at the right level if the emulsion is to work optimally.
- If the concentration is too high it will produce more mess, increase the risk of skin problems and also increase cutting fluid consumption.
- Too low a concentration results in bacteria, fungal infestations, corrosion, poor lubrication, and a reduced life span on the tools and system.

It is therefore important to regularly measure the concentration, ideally daily but at least once or twice a week.

How to measure the concentration

The concentration is measured either using a refractometer, which is easiest, or by titration.

Refractometer: Reset the refractometer before use, with the same water used to dilute the cutting fluid.

The reading on the refractometer needs to be multiplied by a factor (Refractometer Index) which applies to the water-miscible cutting fluid being used. The factor is given in the product data sheet or a label on the packaging.

The refractometer measures the total oil content of the fluid, i.e. the reading on the refractometer will also include any oil that has leaked into the system. If it is hard to read the refractometer reading, this indicates that a fair amount of oil has leaked into the system.

Titration: Unlike the refractometer, titration does not measure the oil content, but components in the cutting fluid. A fair amount of equipment is required, such as a burette, a conical flask, a weak hydrochloric acid solution (0.5 M HCl) and methyl orange as the indicator.

Concentration = Volume ml hydrochloric acid (HCl) used in titration x Factor for the specific cutting fluid.

Measuring the tramp oil:

The tramp oil content can be measured as follows:
Concentration (refractometer) – Concentration (titration) = Tramp oil content
Tramp oil is most easily removed using a skimmer or an oil separator.

Adjust the concentration as required after measurement. A weaker concentration of approximately 1–2% should normally be used for topping up the system.

Check the pH value

It's important to keep an eye on the pH value in the system. If the pH decreases, you either have too low a concentration or a bacterial problem. In most cutting fluids, the pH should be at least 9.0.

pH can either be checked using a pH meter or a pH stick.

pH-scale

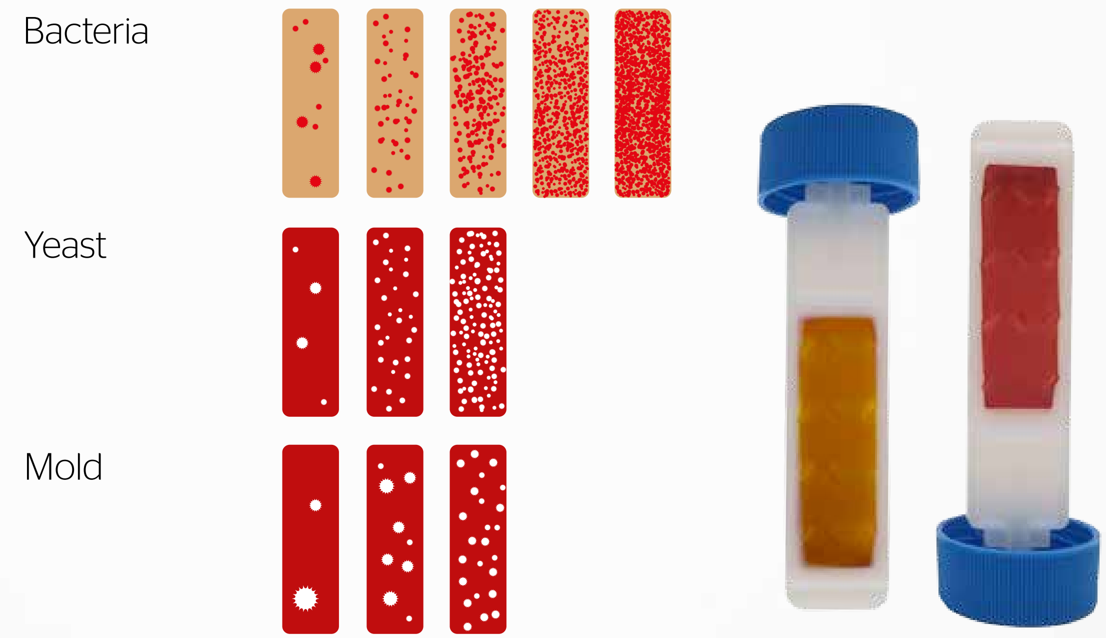
Most cutting fluids have a pH of 9–9.6 but there are also products that have a lower pH during use.

Measure the bacteria content in the emulsion

The problem with bacteria is that they eat the cutting fluid's components and secrete acidic substances, which leads to a drop in pH and then to corrosion problems and bad odours. Bacteria breed quickly if they are able to infect the system, so it is important to measure the bacteria levels once a week.

Bacteria is most easily measured using a dip slide. Bear in mind the results could take up to two days for bacteria, and up to four days for mould and fungi. More advanced equipment can be used to also measure the amount of bactericide in the system.

Measureing of bacterial and fungal content with dip-slides. The more dots, the more bioactivity.



Contact FUCHS Lubricants or follow the standard maintenance procedure if the pH falls below the recommended value, or if the bacteria content cannot be kept below 10^6 per ml.

Tips and advice

1. Appoint someone to be in charge of emulsion
- This person will check that there is the right concentration in the systems.
- They will also keep a logbook of concentration and pH values.
- Take corrective action to maintain the fluid's optimum properties.

2. Label the machines. If you use different cutting fluids for different kinds of machining, label each machine with the type of cutting fluid used in that machine. This will avoid mixing fluids, which may compromise the properties in the cutting fluid.

3. Try to minimise the number of 'dead' spaces in the system, where the cutting fluid stands still.

4. Check that the concentration is correct.

5. Even topping up of concentrate/water.

6. Check that the pH is correct. If applicable use a pH booster, preservative – see Figure 1 below.

7. Keep the fluid as clean as possible.

8. Minimise leaked oil using skimmers and separators.

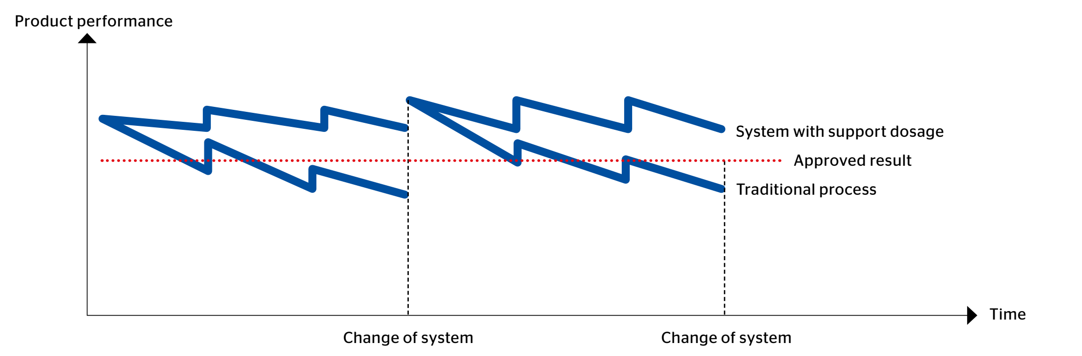
9. Continuous removal of swarf.

10. Minimise stoppages in the systems. When stoppages occur, raise the pH by 0.2–0.3 units. If there is a longer period of down time, such as during the summer shutdown, a bactericide may also be needed. Circulate the system regularly, or air the system. A small aquarium pump is adequate for small systems.

11. Planned fluid changes. Keeping a good eye on your systems helps you avoid costly unplanned fluid changes.

12. Always use a system cleaner when changing the fluid.

Figure 1. Support dosage *(which we refer to in the above text, point 6)*



Support products

Support products are used to maintain the performance of the cutting fluids and to rectify various kinds of problems.

System cleaners

A system cleaner is a water-soluble cleaner and dispersant for emulsions and solutions. System cleaners are only used in connection with a change of emulsion, rather than for regular emulsion maintenance. System cleaners kill bacterial and fungal growth, and also loosen microbiological slime and sludge..

Biocides

Biocides are used to prevent uncontrolled bacterial and fungal growth.

Anti-foaming agents (antifoams)

Metalworking fluids do not normally produce any problems with foam. If foam does form, it is either due to a mechanical problem (e.g. the pump is sucking in air), or because the metalworking fluid has been contaminated with another liquid. Causes of foam problems could be soft water, too high an emulsion pressure, incorrect nozzles or system tanks that are too small.

Anti-foaming agents can be added to the cutting fluid in small amounts as a temporary measure, but it is important to identify and remedy the underlying cause of the foam. Otherwise the problem will soon reoccur..

pH-adjusters

Used to raise the pH of an emulsion. The pH should always be adjusted in connection with a production stoppage, and before using biocides.

Health, safety and the environment

Cutting oils

To optimise the working environment when using cutting oils, we have developed a complete product programme based on synthetic base oils and esters. Using synthetic base oils and esters, which have a high flash point and low volatility, minimises the formation of oil mist. In addition to low volatility, these base fluids are extremely clean and have minimal levels of harmful substances.

Water-miscible cutting fluids

When choosing a coolant/lubricant, it is vital to consider the product's environmental properties, primarily regarding the working environment, as well as its technical performance. It is no good nowadays having a technically perfect product if it contains large amounts of components that are harmful to health or the environment.

To optimise the working environment, the cutting fluid can be both formulated and handled in different ways. It is generally best to strive for a long life span for the fluid as this reduces disposal volumes and the use of support chemicals.

Bacterial and fungal infestations must be avoided if the technical performance of the fluid is to be maintained. There are different strategies for minimising bacterial and fungal infestations.

- You could choose a product that contains biocide, or add biocide on site as required.
- The latter is often slightly more complicated, but it is also possible to choose a technical solution to minimise the occurrence of fungi and bacteria, for instance using UV light or ozone.
- By meticulously checking the system you may be able to avoid biocides in certain cases, but it depends on the material being machined and how the systems are designed.

Advantages and drawbacks of biocides

Biocides are added to kill fungi and bacteria. This has a positive impact, but incorrect handling could lead to side effects, usually in the form of allergic reactions in operators and service engineers. The risk increases if you add biocides on site and fail to dose or handle the chemicals in exactly the right way. Choosing a cutting fluid that contains biocide from the start and following the product's handling instructions properly minimises the risk of side effects.

Here at FUCHS, we have developed different types of water-miscible cutting fluid for minimising the risk of side effects, bacterial and fungal problems in different ways.

New types of products – Trends

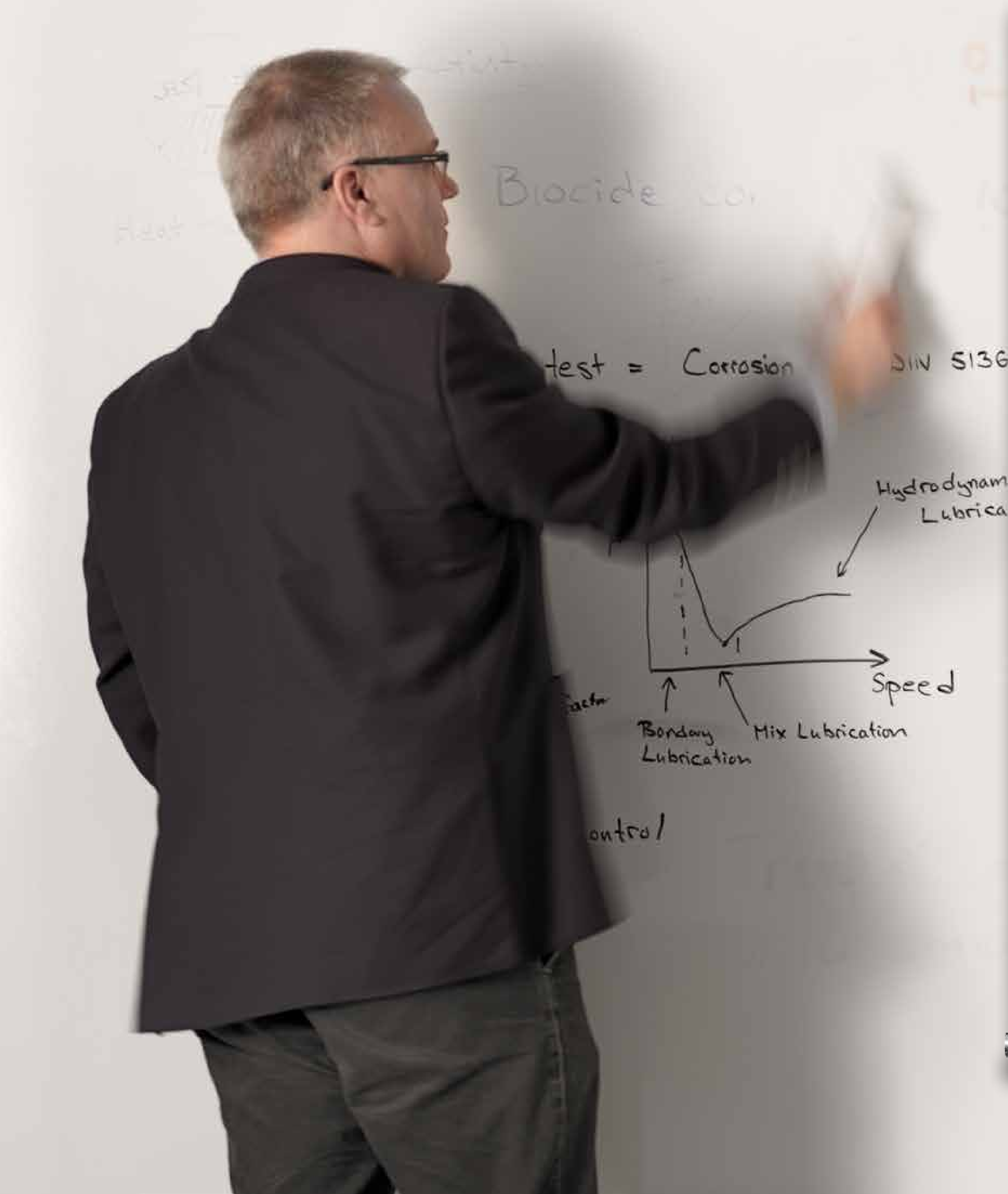
REACH (1907/2006) is the EU-wide legislation for chemicals occurring on the EU's internal market. Major changes are under way within REACH, with certain chemicals being phased out and many substances being reclassified, which means there is increasing demand for new types of cutting fluids.

When it comes to cutting oils, the viscosity limit for what is deemed to have a low impact on inhalation has been altered from the previous >7 cSt to >21.5 cSt. Consequently, demand for products with a viscosity above 21.5 cSt will increase as they are not classified.

We can expect higher demand for ester-based products since they are not as volatile as oil-based products, and they are not classified even though their viscosity is below 21.5 cSt.

For water-miscible cutting fluids, a change in the evaluation and classification of chemicals will mean an increase in demand for products that are free of boron and formaldehyde bactericides. More control and a new approach to maintaining cutting fluid systems will also be required. The alternative is to return to old technology based on allergenic biocides that do not emit formaldehyde. This in turn will lead to a greater need for knowledge about chemicals and more control over water-miscible cutting fluids.

Efforts to limit the use of certain chemicals will drive the development of new types of cutting fluids.


Biocide
test = Corrosion
DIN 5136
Hydrodynam
Lubrica
Speed
Bondary
Lubrication
Mix Lubrication
ontrol

Notes

Glossary

Extreme Pressure (EP) additive: Extreme pressure (EP) additives have the ability to form chemical compounds in the contact surface at high temperatures, and can therefore be used to reduce harmful wear. Cutting oils for tougher machining in steel, aluminium and titanium almost always have some kind of EP additive.

Examples of EP additives are sulphur, phosphorus and chlorine.

Anti-wear (AW/polar) additives: These additives form a membrane on the surfaces that slide against one another. Examples of anti-wear additives are fatty acids, esters and polyglycol.

Base oils: Cutting oils consist of one or more base oils which are either mineral oils, synthetic oils, white oils or esters.

Biocides: Biocides are divided into two main groups: bactericides (bacteria killers) and fungicides (fungus killers). There are two types of bactericides: formaldehyde-emitting and non formaldehyde-emitting.

Bacterial and fungal content: Measured using a dip slide, results are ready within 24-48 hours. The bacterial content should normally be below 105 per ml (depending on product), and the fungal content should be lower than 'low content'. If the bacterial content is 106 per ml or higher or if the fungal content is 'medium', the fluid must be treated with biocides to reduce the bacterial content. In the event of a fungal/mould infestation, the fluid must be treated with fungicides, or the system must be completely replaced and the machine cleaned.

Boron additives: Boron additives act as emulsifiers, inhibit corrosion and bacterial growth, and provide buffer capacity for maintaining the right pH level. Boric acid is classed as toxic to human reproduction. In water-miscible cutting fluids, the boric acid has reacted with amines to produce boramines, which means that boric acid only occurs at extremely low levels.

Safety Data Sheet (SDS): Also known as a Material Safety Data Sheet (MSDS) or Product Safety Data Sheet (PSDS). The supplier has an obligation to provide a Safety Data Sheet for all products that are classified (e.g. as environmentally hazardous or allergenic). Employers who use classified products are obliged to formulate working procedures suited to local conditions, based on the SDS.

Concentration: Concentration is normally measured using a refractometer. Too high a concentration can lead to mess in machines and materials, smoke formation, foaming, and in the worst cases skin irritation on the hands of the people handling the cutting fluid. Too low a concentration can lead to a poor surface finish on the machined material and a higher risk of bacterial and fungal infestations, which can contribute to a shorter life span of the cutting fluid. Materials and tools will have poorer rust protection. The right concentration is shown in the product description.

Tramp oil content: The tramp oil content can be measured as follows:
Concentration (refractometer) – Concentration (titration) = Tramp oil content
Tramp oil is most easily removed using a skimmer or an oil separator. It is also possible to roughly estimate the tramp oil content by measuring the free oil (visible oil level above the emulsion), although this method cannot measure tramp oil that has already emulsified. Tramp oil is a general name for any oil that contaminates the emulsion. Tramp oil could be slide oil, corrosion inhibitor fluid from materials, hydraulic oil or gear oil. Bacteria thrive in the boundary layer between the leaked oil and the emulsion, which is why tramp oil should be removed daily. Use some kind of skimmer or separator. No emulsion can cope with being covered by tramp oil for any longer period of time.

pH-value: Measure using a litmus paper or pH meter. The pH is product specific and is normally between 9.0 and 9.6 in a new emulsion. When the pH starts to decrease (should be measured at least once a week), this is a sign that the emulsion is starting to break down and that maintenance is due. Attacks of rust and bacteria in materials and tools are some examples of what a decreasing pH can lead to. It is unusual for the pH to rise, but this could happen if alkaline liquid gets into the system, e.g. from degreasing.

Product Data Sheets: These should always be present in the workplace. They describe the areas of use of individual products, mixing ratios, the refractometer index, the pH of the emulsion and so on.

Foam: Cutting fluids do not normally cause any problems with foam. Foam may form initially after a system change, but it generally settles after one to two days. If foam does form in the system, it is either due to a mechanical problem (e.g. the pump is sucking in air or the pressure has increased), or because the cutting fluid has been contaminated with another liquid. The contaminated fluid is usually an alkaline degreaser or an anti-rust product that has been applied to the material. Sometimes small amounts of anti-foaming agent are added to the cutting fluid to avoid this problem.

Temperature: The best temperature for emulsions is below 25 C. Therefore, the tank should be relatively large. In practice two-thirds of the electrical energy used by a machine is transferred to the emulsion in the form of heat when the material is being machined. In excessively high temperatures the growth conditions for bacteria are more favourable and there is more water evaporation from the emulsion; consequently, larger amounts of emulsion with a lower concentration must be added.

NB: Do not just add water, instead add a low-concentration emulsion. Water alone has no protective or lubricating properties, which means tool wear and the risk of bacterial infestation increases..

Impurities: Particles are removed by filtration. Particles might for example be small metal cuttings or graphite. Impurities could also be cigarette butts, cigarette ash, coffee or chewing gum. All impurities reduce the life of the emulsion as they improve the growing conditions for bacteria and fungi..¬

Water quality: Water quality is measured using indicator strips. Water hardness is measured as ppm $CaCO_3$ or German degrees of hardness (°dH). In certain locations chlorine has been added to the mains water for reasons of hygiene, particularly during the summer when more surface water is used since it contains more bacteria and algae. A higher chlorine content may cause corrosion. If the water is very hard, the emulsion may become unstable and its life span may be reduced. Moreover, lime soap and sludge may form.

Soft water: Water with a low mineral content. Occurs naturally in certain areas depending on the nature of the bedrock.

Demineralised water: Also called desalinated or deionised water. A desalination plant includes a mixture of cation and anion exchangers. When water passes through the system, the dissolved salts in the water are replaced by hydrogen and hydroxyl ions. The result is high-quality salt-free water. Demineralised water is often used for emulsions in areas with naturally hard water.

Water from reverse osmosis: Natural osmosis occurs when two liquids with different salt concentrations are separated by an osmotic membrane (a membrane in the form of a thin polyamide film). Water molecules from the low-salt liquid pass through the membrane until the salt content is the same on both sides of the membrane. This physical process is used in reverse osmosis. The high-salt liquid is put under pressure so that the water molecules flow in the opposite direction, and demineralised water is forced through the membrane. Water from reverse osmosis is particularly suitable for emulsions, since the process simultaneously cleans the water of bacteria, algae and other impurities.

Distilled water: Formed by condensing water vapour. This could be clinically clean water, depending on the production temperature. Distilled water is particularly suitable for emulsions but is expensive due to the production method.

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