Cutting Fluids

WHAT ARE THE FUNCTIONS OF A CUTTING FLUID ?

Primarily, a cutting fluid must contribute in three ways to a machining process.

1. First, it must act as a lubricant. By reducing friction, it reduces the heat generated.
2. Because frictional heating cannot be completely eliminated – and often, not even substantially reduced – the cutting fluid must also act as an effective coolant.
3. Finally, it should act as an antiweld agent to counteract the tendency of the work material to weld the tool under heat and pressure.

CUTTING FLUIDS AS LUBRICANTS

To perform satisfactorily as a lubricant, the cutting oil must maintain a strong protective film in that portion of the area between the tool face and the metal being cut where hydrodynamic conditions can exist. Such a film assists the chip in sliding readily over the tool. Besides reducing heat, proper lubrication lowers power requirements and reduces the rate of tool wear, particularly in machining tough, ductile metals.

CUTTING FLUIDS AS COOLANTS

If a cutting fluid performs its lubricating function satisfactorily the problem of heat removal from the cutting tool, chip, and work is minimised. But, cooling still remains an important function. To perform this function effectively, a cutting fluid should possess high thermal conductivity so that maximum heat will be absorbed and removed per unit of fluid volume.

WHY IS IT THAT WATER CANNOT BE USED AS A CUTTING FLUID ?

Water, which has high thermal conductivity and a high specific heat, is a very effective coolant but its lubricating property is practically nil. Moreover, water rapidly corrodes machine parts and components. It can neither lubricate the moving parts of the machine like guides and slides nor can it reduce friction in the cutting area. Also, it is not effective in absorbing heat as it cannot spread well on metallic surfaces.

WHAT ARE THE DIFFERENT TYPES OF CUTTING FLUIDS ?

- Soluble Oils
- Synthetic Oils
- Semi-Synthetic Oils
- Straight Cutting Oils

SOLUBLE OILS

WHAT ARE THE MAIN CONSTITUENTS OF SOLUBLE OILS ?

Soluble oil contains :

- Mineral Oil – Provides lubricity
- Emulsifier – Breaks oil into small globules
- Rust inhibitor – Since water can cause rusting
- Bactericide – To control the growth of anerobic bacteria which causes foul smell and renders oil useless.

WHAT IS AN "EMULSION" ?

Oil does not dissolve in water. Oil is suspended in water in the form of tiny globules. Breaking of the oils into tiny particles is done by a chemical known as "**Emulsifier**". This medium of oil in water is known as an "**Emulsion**". "**Specific heat**" (ability to absorb heat) and thermal conductivity (ability to dissipate heat) of water is much better than oil whereas "**lubricity**" (ability to reduce "**Friction**") can be provided only by oil. In a metal cutting operation using an emulsion "**oil**" provides lubricity and "**water**" does the cooling.

WHY DOES "EMULSION STRENGTH" VARY FOR DIFFERENT OPERATIONS ?

"**Oil**" provides lubricity and "**water**" ensures cooling. Operations where lubricity is equally important as cooling is, require "**Richer emulsions**" (higher oil concentration) e.g. Drilling, Milling, Turning. Operations where cooling is the primary role of the coolant permit "**higher dilutions**" e.g. Grinding.

EXPLAIN THE EFFECTS OF "HARD WATER" ON EMULSIONS ?

Emulsifier chemical used in soluble oils is "**Sodium petroleum sulphonate**". Hard water contains dissolved carbonates and sulphates of Sodium and Potassium. These salts react with the emulsifier. The emulsifier is consumed and balance left over is not sufficient enough to form a stable emulsion. "**Separation**" takes place and the emulsion is rendered useless. The pace of separation depends on the degree of hardness. "**Hard Water**" also accelerates the growth of Anerobic bacteria which renders the emulsion useless.

HOW DOES ONE OVERCOME "HARD WATER" PROBLEMS ?

Our soluble oil is capable of forming stable emulsions upto a hardness of 400 ppm. If the water is harder beyond this, "**separation**" would take place. Use of soda ash at the rate of 5 gms. per litre of water used would soften the water to some extent. If the salt content in the water is carbonate of Potassium or magnesium, this would be neutralised by soda and water would be "**softened**". However, if water contains mostly sulphates (permanent hardness) addition of soda would make no difference. Addition of larger quantities of soda would not only have no effect on the water but would result in a very alkaline emulsion. Highly alkaline emulsion would cause skin-etching, rusting of components, weakening of bonding of resin-bonded grinding wheels.

In view of the above, permanent solution for hard water problem is to use soft water or demineralised water.

SYNTHETIC AND SEMI-SYNTHETIC OILS

WHAT ARE SYNTHETIC OILS ? WHAT ARE ITS MAIN ADVANTAGES AND LIMITATIONS?

Synthetic oils do not contain mineral oil. Instead they contain some synthetic chemicals as substitutes.

Its main advantages are :

- They are not affected by bacterial growth. "Life" of synthetic coolants is very high.
- They are capable of forming emulsions in hard water.

Limitations of Synthetic Oils are :

- They provide very poor lubricity.
- pH value is much higher around 9.5.
- They are used in dilutions around 1:60. Arbitrary topping of emulsion and increase in this dilution can result in "component rusting".
- Synthetic coolants peel of poor quality epoxy paints on the machines.
- Synthetic coolants have a very high detergency property. This results in collection of large quantities of muck and dirt in the coolant pump. Unless the filtering mechanism is very good, this property can lead to a lot of undersirable machining conditions.
- Synthetic coolants have a tendency to foam. If the rate of coolant flow for a particular requirement is very high, excessive foaming can be caused. This would result in poor surface finish and reduced tool life.

WHAT ARE THE IDEAL APPLICATIONS FOR SYNTHETIC COOLANT USAGE ?

- Carbide grinding with diamond wheel.
- Very sophisticated CNC machines with low stock removal and no operator contact with coolant.

- Ordinary commercial grinding where finish is not very critical.

WHAT ARE SEMI-SYNTHETIC COOLANTS?

Semi-Synthetic coolants contain partially mineral oil and synthetic chemicals. They combine the advantages of synthetic coolants and at the same time the disadvantages are not as in the case of hundred percent synthetics. Ideal applications for semi-synthetic coolants are :

- General purpose cylindrical and centreless grinding where very high surface finishes are not required.

STRAIGHT CUTTING OILS OR NEAT OILS

WHAT ARE STRAIGHT CUTTING (NEAT) OILS ?

Straight Cutting Oils or Neat Oils are pertroleum based mineral oils reinforced with "Extreme pressure" additives (EP additives). For applications where the speed of the tool is very low, depth of cut taken is high, cutting pressures are high, the primary role of coolant is to provide:

- Adequate lubricity so that friction is reduced.
- Prevent chip welding of the tool of edge build up.
- Wash away the chips from the cutting zone.

Lubricity is provided by the mineral oil. Commonly used EP additives are chlorine and sulphur. These additives form a low shear strength chloride or sulphide coating over the tool rake preventing chip welding. Choice of one or both of these additives is governed by the nature of the application and the material that is being machined.

WHAT ARE THE IMPORTANT PROPERTIES OF NEAT OILS TO BE BORNE IN MIND WHILE SELECTING THEM FOR A GIVEN APPLICATION ?

- **Viscosity :** The correct viscosity is very important to give adequate lubricity and wash away the chips from the cutting zone.
- **Flash Point :** Neat oil application generates enormous amount of friction and cutting pressures. If the quantity of coolant and the viscosity is not optimum, the friction reduced would not be sufficient. This would lead to excessive heat being generated and risk of fire. Therefore, the flash point should be high enough to provide adequate factor of safety against chances of fire.
- **The EP package :** Depending on the material that is being machined and the severity of the operation, this has to be decided.
- **Wetting agents :** To provide adequate lubricity in the cutting zone.

WHAT ARE DIFFERENT TYPES OF NEAT CUTTING OILS ?

- **Fatty-Mineral Oils** (Oils containing Mineral Oil + Fatty Oils)

  Under this classification are included combinations of one or more fatty oils blended into straight mineral oils. Of the fatty oils, lard oil is most frequently used for this purpose. The percentage of fatty oils in the blend may very upto 40% depending upon depth of cut, cutting speed, feed, and type of chip in the particular machining operation.

- **Sulfurised-Mineral Oils** (Oils containing Mineral Oil + Sulphur (EP) additive)

  Sulphur added to mineral oils increase their cooling and lubricating qualities and helps prevent welding of chip and tool. Such oils are useful for general and severe machining operations on tough metals of high ductility. Not to be used on yellow metals since Sulphur causes "staining".

- **Chlorinated-Mineral Oils** (Oils containing Mineral Oil + Chlorine (EP) additive)

  Chlorine gives mineral oil excellent anti-weld characteristics.

- **Sulfurised-Fatty-Mineral Oils** (Oils containing Mineral Oil + Fatty Oils + Sulphur (EP) additive)

Oils of this type have excellent lubricity and stain less than sulfurised-mineral oil.

- **Sulfo-Chlorinated-Mineral Oils** (Oils containing Mineral Oils + Sulphur + Chlorine additives)

  Oils of this type give anti-weld properties over a wide range of temperatures.

TROUBLE SHOOTING

COMMON PROBLEMS AND LIKELY CAUSES

1. **Rusting of components**

   Soluble oils :

   Normal topping up required on a daily basis is around 10 to 15 percent. The recommended practice for this topping up is by making a separate emulsion of the desired strength and mixing up with the existing emulsion. However, in most shopfloors the topping up is done by adding of water and oil directly into the emulsion tank. Over a period of time this arbitrary practice results in altering of emulsion strength to well beyond the maximum limit of 1:40. The rust inhibitive property of any soluble oil emulsion beyond 1:40 is weakened and components would begin to rust.

   Solution : Care should be taken to ensure that emulsion dilutions do not exceed 1:40.

   Chlorinated Neat Oils :

   Chlorinated neat oils have to be stored in air tight condition. If atmospheric moisture seeps into the drums it reacts with the highly volatile chlorine and forms hydrochloric acid. This acid is a very corrosive medium and oils thus "contaminated" can cause rusting of components.

2. **Emulsion Separation :**

   If soluble oil forms a proper emulsion at the time of mixing, any subsequent separation is caused only due to water hardness. Extent of the hardness would determine the pace of separation. Common complaints would be separation in 3 days to separation within a day in some cases.

   Soluble oil if stored vertically in the drums for a long time would result in emulsifier settling down at the bottom of the barrel. The oil pump which draws oil would be pumping out oils at the bottom which is "rich in emulsifier content". As the oil gets consumed and the level in the barrel goes down the "oil" that is now being drawn is poor in emulsifier content and therefore, it is not capable of forming a stable emulsion. Oil barrels should, therefore, be stored horizontally with the two caps in 3 O'clock and 9 O'clock positions. If, however, oil is drawn from a vertically stored barrel care should be taken to stir the oil in the drum before using the same.

3. **Foul Smell :**

   Any residual oils smudges in the coolant tank even after cleaning with water would be areas for bacterial growth and cause smell even though the emulsion is new. Care should be taken to use a disinfectant like phenyl in the water that is circulated to clean the coolant tank. This would make the tank bacteria free and life of new emulsion would be relatively better.

   Leaking of hydraulic oils and other machine oils into the emulsion sump can cause rapid growth of bacteria and this would also result in severe smell problem.

4. **Skin itching caused by soluble oils :**

   Soluble oil emulsions have a pH of 8.5. Human skin is acidic and pH value is around 5.5. Continuous contact of skin with soluble oil emulsions results in drying of the skin due to neutralisation reaction. Dry skin is prone to injuries. Cotton waste used commonly in shopfloor contain metallic chips. When rubbed against the dry skin, minute scratches are caused resulting in injury. Over a period of time, these injuries get infected and result in "itching". Use of very corrosive and cheap soaps can also cause dry skin which can get further aggravated by exposure to soluble oils.

5. **Skin etchig and Dermatitis caused by Straight Cutting Oils :**

   Contact of the skin by cutting fluids may cause dermatitis in one of two ways. Cutting fluids - like dirt, grease, and other matter - tend to plug hair follicles and pores of the skin, causing blackheads to form. These block the flow of the skin's natural oils and cause them to build up under the blackheads along with bacteria normally present on the skin. Eventually, accumulation of skin oils and growth of bacrteria result in irritation and pimples.

   Cutting fluids that contain solvent oils remove the skin's natural oils. This causes dryness and loss of pliability that can result in redness, cracking, soreness, and a high degree of susceptibility to infections.

6. **Fuming and strong smell :**

   This is a problem associated with neat oils. If the viscosity of the oil chosen for an application is less, the quatity of oil available at the cutting zone in the job and tool interface is low. This results in inadequate lubricity and high heat generation. The heat so produced would burn the oil, the chip produced is very hot and the tool also gets heated up. All of this results in fuming and strong smell.

7. **Poor Surface Finish :**

   The probable cause of this is lack of lubrication or chip interference. To overcome the problem of lack of lubrication select a fluid with better lubricating qualities and check for dilution of fluid. To correct the problem of chip interference, improve the volume pressure and direction to move chips out of cut area. You may also try to improve filtration to remove particles.

STORAGE OF CUTTING FLUIDS

- Care of cutting oils begins with storage. Contamination with water, grit, dirt, or any impurities should be avoided. Best results are obtained by storing cutting fluids in a separate enclosure within the shop. The insides of tanks and receptacles should be kept clean.
- Contamination with water can be most harmful. Large users of cutting oils buy bulk quantities and employ underground storage. Condensation of moisture within the tank or seepage from the outside can easily become quite a problem. To avoid water contamination, tanks and their contents should be inspected regularly. Extraneous water can be detected by taking samples of the fluid at the bottom of the tank.
- Mixing of soluble oils supplied by different manufacturers should also be avoided. While each oil may perform satisfactorily by itself, some ingredients may be incompatible when mixed.
- Contamination of cutting oils with any other types of oils might also produce adverse effects.
- Avoid excessive temperatures.
- In a cutting fluid, the balance of the oil and the water may be upset by excessive heating. Overheating might promote acidity changes and further impair the stability of the emulsion.
- Cutting fluids are generally not over-sensitive to low temperatures. However, intermittent freezing and thawing may unbalance the components. In soluble oils, it may result in unstable emulsion. It is best to arrange storage of cutting oils so that they will not be subjected to any extended periods of freezing or overheating. Repeated extreme temperature changes will eventually impair the oils and cause separation of the ingredients which contribute to better machining.

Cutting Fluid Characteristics

	Chemical Solutions				
	True Solutions	Surface Active	Semi-Chemical	Emulsions	Neat Oils
Lubricity	Poor	Excellent	Fair to Good	Fair to Good	Good to Excellent
Cooling	Best	Good	Fair to Good	Poor to Fair	Worst
Wetting	Poor	Excellent	Fair to Good	Poor to Fair	Good
Residue	Worst	Poor to Good	Fair to Good	Best	Best
Foam	None to Low	Medium to High	Low to High	Low to Medium	Medium to High
Corrosion Inhibition					
- Ferrous	Fair to Good	Good	Good	Fair to Good	Good to Excellent
- Non-Ferrous	Poor to Fair	Fair to Good	Fair to Good	Best	Fair
- Cast Iron	Poor to Good	Good	Fair to Good	Poor	Good to Excellent
Tram Oil Rejection	Best	Worst	Fair	Poor to Fair	Good
Disposability	Poor	Poor	Poor	Best	Poor
Recyclability	Poor to Good	Fair to Good	Fair to Good	Poor to Good	Excellent
Maintenance	Good	Good	Fair	Worst	Excellent
Environmental	Excellent	Excellent	Good	Fair	Worst
Cost	Lowest	Lowest	Low	Medium	High
Wheel Life	Worst	Worst	OK	Good	Best