TechTips

Techtips is a collection of useful ideas, techniques, and procedures designed to further EDM knowledge.

by Roger Kern

SINKER DIELECTRIC FUNDAMENTALS

The adage "The three most important things in EDM are: Flushing, Flushing, and Flushing" while somewhat diminished by today's power supplies, orbiting, and high speed jump technologies, is still fundamentally true. In this article we will explore the properties, types, selection, and maintenance of sinker EDM dielectric fluids.

— Definition of a — DIELECTRIC

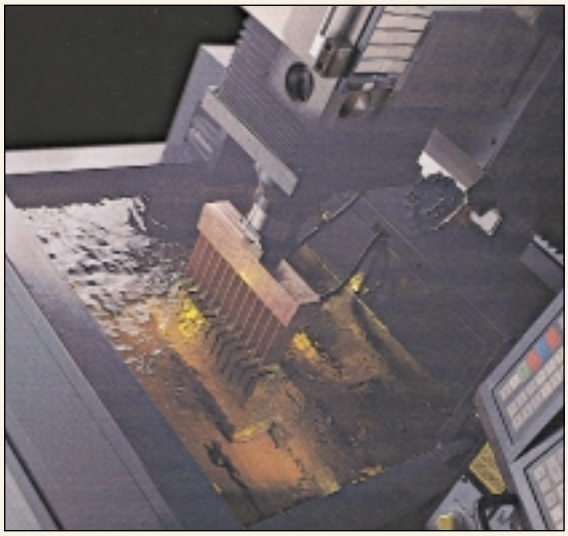
Before we delve into the specific properties of dielectric fluids and how they affect and are affected by the EDM process, let's first delve into the definition the word "dielectric".

Rest assured, that this digression into physics will be brief and painless.

"This discharge is the basis of the EDM process, which is defined as a controlled series of discharges."

As paraphrased from Wikipedia:

A **dielectric** is a non-conducting substance, i.e. an insulator. Although "dielectric" and "insulator" are generally considered synonymous, the term "dielectric" is more often used when considering the effect of alternating electric fields on the substance while "insulator" is more often used when the material is being used to withstand a high electric field.



Dielectrics... are not a narrow class of so-called insulators, but the broad expanse of nonmetals considered from the standpoint of their interaction with electric, magnetic, and electromagnetic fields. Thus, we are concerned with gases as well as with liquids and solids, and with the storage of electric and magnetic energy as well as its dissipation.

Since the use of an insulator is somewhat contra-intuitive to the EDM process which is characterized by the *conduction of electricity*, we need to explore this a little further.

Again, referring to the definition of **dielectric strength** in Wikipedia, we learn that:

For a given configuration of electrode, dielectric material, and workpiece, as the applied voltage across the gap is increased, at a certain level the resulting electric field will produce a breakdown. At breakdown, the electric field frees bound electrons in the dielectric. If the applied electric field is sufficiently high, free electrons may become accelerated to velocities that can liberate additional electrons during collisions with neutral atoms or molecules in a process called avalanche breakdown. This breakdown occurs quite abruptly (typically in nanoseconds), resulting in the formation of an electrically conductive path (known in EDM as the Discharge Channel) and a disruptive discharge through the material.

This discharge is the basis of the EDM process, which is defined as a controlled series of discharges.

Functions of a Dielectric Fluid

The sinker EDM process has primarily used oil for the dielectric fluid, and the balance of this article will focus on dielectric oils. The dielectric oil in a Sinker EDM serves a number of functions:

- The dielectric oil acts as a medium through which controlled electrical discharges occur.
- The dielectric oil acts as a quenching medium to cool and solidify the gaseous EDM debris resulting from the discharge.
- The dielectric oil acts as a medium used to carry away the solidified EDM debris from the discharge gap to the filter system.
- The dielectric oil acts as a heat transfer medium to absorb and carry away the heat generated by the discharges from both the electrode and the workpiece.

> "The flash point of a flammable liquid is the lowest temperature at which it can form an ignitable mixture in air."

Properties & Characteristics of Dielectric Oils

Let's examine the more significant EDM dielectric oil properties and characteristics as they relate to the functions of the dielectric oil in the EDM process:

Viscosity

Viscosity is the property that describes a fluids resistance to flow. Viscosity is commonly measured by two different units:

- Centistokes (cST)
- Saybolt Universal Seconds (SUS)

This often causes a great deal of confusion, as dielectric manufacturers often do not use the same units to specify viscosity, making comparison difficult.

Another point of confusion results from the fact that a viscosity specification is always associated with the temperature at which the test was performed, again rendering comparisons meaningless unless both fluids were tested at the same reference temperature.

Regardless of the system used, a lower number means a thinner (less viscous) fluid.

Generally, a thinner fluid will flush better than a thicker fluid, and for most oils, the oil will get thinner as the oil temperature increases.

Flash Point

Again from Wikipedia ***"The flash point of a flammable liquid is the lowest temperature at which it can form an ignitable mixture in air."***

The Flash Point is usually reported in units of ºF and is often measured by the Cleveland Open Cup (COC) procedure. "The sample is contained in an open cup (hence the name) which is heated, and at intervals a flame is brought over the surface." The oil temperature at which ignition of the resulting vapor occurs is the Flash Point.

Flash points for common liquids are listed below:

- Gasoline -40º F
- Ethanol 55º F
- Kerosene 120º F
- Diesel 143º F
- Vegetable Oil 620º F

The flash point for commonly used EDM dielectric oils ranges from 160º F to 255º F.

Obviously for reasons of safety, the higher the flash point the better.

Dielectric Strength

Paraphrasing from Wikipedia, dielectric strength has the following meaning:

For a given configuration of dielectric material and electrodes, the dielectric strength is the minimum electrical field that produces breakdown.

The dielectric strength is commonly measured in units of either MV/m, or V/mil.

Unfortunately, reported values of dielectric strength are highly dependent upon test conditions, and therefore are subject to a great deal of variability. It has been my experience that in actual practice, the reported values for this parameter in commonly used dielectric oils doesn't seem to have much effect upon EDM performance.

Pour Point

The pour point of an oil is the temperature below which the oil no longer pours freely. This is also sometimes called the gel point, since at temperatures below the gel point the oil begins to gel. The pour point is usually stated in units of ºF.

Since EDM oil is normally used at or above room temperature, one might surmise that this property is not worthy of consideration. However, if your drums of dielectric fluid are stored in an unheated area in the winter, and that fluid has a relatively high pour point, the dielectric will gel and cannot be pumped from the drum until it is warmed to room temperature.

> "Having greater oxidation stability means that the dielectric fluid will resist degradation longer, retaining its clarity, initial viscosity, and give longer service life."

Some EDMers believe that, all other properties being equal, a dielectric fluid with low pour point is preferable to a dielectric fluid with a high pour point because is has less dissolved paraffin wax or long chain molecules.

Volatility

Volatility is a measure of the tendency of a dielectric fluid to vaporize. While most all dielectric fluids will exhibit some degree of evaporation, the more volatile dielectric fluids will evaporate significantly more rapidly than their less volatile cousins. Volatility in dielectric oils is generally related to flash point.

Volatility is often not listed in the specifications for a dielectric oil, however an oil with low volatility is clearly more desirable.

Oxidation Stability

Oxidation stability is a measure of the dielectric fluids tendency to react with oxygen. Having greater oxidation stability means that the dielectric fluid will resist degradation longer, retaining its clarity, initial viscosity, and give longer service life.

Oxidation stability is often not listed in the specifications for a dielectric oil, however an oil with high oxidation stability is clearly more desirable.

Acid Number

The acid number is used to quantify the amount of acid present in a sample of dielectric oil. Excessive levels of acid in a dielectric oil could lead to corrosion in the dielectric system.

The acid number is expressed in units of mg KOH/g, or the amount of Sodium Hydroxide necessary to neutralize the acid present in an oil sample.

Color

The color of a dielectric oil can be classified by an ASTM test.

Ideally, a dielectric fluid should be water white for maximum visibility of the workpiece. There are some dielectric oils on the market that are intentionally colored with dye. I have seen both green and blue. These colors have no effect upon the properties and performance of a dielectric oil. The color is often filtered out over a period of time, especially by a low micron filter system.

Odor

The odor of a dielectric fluid is an important property, especially for those that work with or near the dielectric fluid.

Quite frankly, no one wants to work in a smelly environment, and no one wants to go home smelling like an EDM machine.

Thus, odor is an important consideration in maintaining a decent work environment for the employees.

Unfortunately, there is no standard measure or specification of dielectric odor.

Effects on the Skin

EDM dielectric oils can adversely affect the skin of EDM operators in a number of ways:

- EDM dielectric oils often have solvent properties which result in the removal the natural oils and fat from the skin. (With certain dielectric oils, if you dip your hand in a drum of fresh oil, the skin on your hand will turn white when you remove your hand and dry it off) Repeated exposure to the solvent action of the dielectric oil will often lead to cracking of the skin and dermatitis.
- EDM dielectric fluids can infiltrate the pores of the skin and cause all kinds of nasty skin reactions.

Since the EDM operator is in almost constant contact with the dielectric oil due to the handling of parts and electrodes, the effects of the dielectric oil on the operator's skin should be a very important consideration in dielectric selection. Unfortunately, more often than not, the person who specifies

> "It is important to carefully choose replacement components that are compatible with the dielectric oil."

or purchases the dielectric oil is not the person who has his hands in it every day.

Compatibility

Another important consideration when selecting a dielectric fluid is the compatibility of the fluid with the workpiece and associated fixtures; machine components such as hoses, gaskets, o-rings, and seals; and filter systems.

One might question how a dielectric oil could possibly be incompatible with a metallic workpiece. A good example is that in the aerospace industry, workpieces destined for the EDM are filled with wax for the purpose of supporting delicate areas subject to deflection in subsequent machining operations. The solvent properties of many common dielectric oils will dissolve this wax during the EDM process.

This same solvent action can also destroy machine components made of certain plastics or rubber. Thus, it is important to carefully choose replacement components that are compatible with the dielectric oil. Otherwise, those components may soon fail in service when they either harden and crack or soften and turn to mush. Replacing a failed flushing line with automotive heater hose can be catastrophic.

The following list of materials has proven to be compatible with the most common dielectric oils:

- Teflon
- Neoprene
- Buna-N
- Viton
- MCP

Finally, if your machine is equipped with a Transor, Ona, or similar high performance filter system, it is very important that you determine if the dielectric oil you intend to purchase is compatible with your system. Using a non-approved dielectric can result in poor performance, reduced media life, and the voiding of your filter system warranty.

Dielectric Fluid Types

Mineral Oils

According to Wikipedia "Mineral oil or liquid petroleum is a by-product in the distillation of petroleum."

Kerosene

Kerosene was one of the first popular dielectric oils. Its primary benefit is that it has very low viscosity and flushes very well. Unfortunately, it has many drawbacks:

- Low flash point
- High volatility
- Odor
- Skin reactions

In the "*old days*", there were numerous EDM fires and explosions attributed to the use of kerosene. It is no longer used as a dielectric, except in Third World countries.

Mineral Seal

Mineral seal oil takes its name from the fact that it originally replaced oil derived from seal blubber for use in signal lamps and lighthouses. Mineral seal is a petroleum based product that has many industrial applications, and was adopted by a number of aerospace companies as a dielectric fluid in the early days of EDM. In fact, it is still listed as an approved aerospace dielectric oil today. Unfortunately, it has been identified as having some potentially carcinogenic components, and thus its use is no longer recommended.

Transformer Oil

Transformer oil is another mineral oil based product that was adapted for use in EDMs due to its dielectric properties. Earlier generations of transformer oil were compounded with PCBs. Transformer oil has no current application in EDM.

> "There are currently numerous choices of mineral oils formulated specifically for EDM."

EDM Oils

There are currently numerous choices of mineral oils formulated specifically for EDM. They are available with a wide range of properties and pricing. These oils are currently the most commonly used sinker dielectric fluids.

Synthetic Oils

According to Wikipedia ***"Synthetic oil is oil consisting of chemical compounds which were not originally present in crude oil (petroleum), but were artificially made (synthesized) from other compounds."*** Synthetic oil is used as a substitute for oil refined from petroleum, stated, to provide superior mechanical and chemical properties than those found in traditional mineral oils.

In the EDM industry, there is considerable controversy among dielectric oil manufacturers as to whether certain oils are truly synthetic or merely super refined mineral oils. I'll leave that controversy for the chemists to resolve.

The fact of the matter is that synthetic EDM dielectric oil is revolutionary in terms of the benefits provided:

- Longer life
- Low evaporation and volatility
- Extremely low odor
- Improved health and safety for operators

Synthetic oils are "*game changing*" in terms of the benefits they provide to the EDM operator. As many of the components of these dielectric oils are "cosmetic grade", you can immerse your hands in certain synthetic oils and wipe them off with a paper towel, with no evidence that you were even near an EDM. To anyone who has spent a considerable amount of time actually running an EDM, these products offer benefits.

It has been my experience that the performance of synthetic dielectric oils is similar to the performance of high quality mineral dielectric oils. However, the operator benefits alone make them a product that should be strongly considered.

While the cost of a synthetic EDM oil is almost double that of a mineral oil, the life is usually double that of a mineral oil, and thus the purchase cost disadvantage disappears.

Silicone Oils

In those instances where mineral and synthetic oils cannot be used, such as the previously mentioned aerospace application in which the solvent action of the oil is not tolerated by the wax filler material, silicone based EDM oil is used. Silcone oil works well as an EDM dielectric but *is very expensive,* limiting its use to specialty applications.

Choosing a Dielectric Oil

Choosing the best dielectric oil for your particular application is an exercise in compromise, since optimizing one property will be accomplished at the expense of another property as outlined below:

- An oil with very low viscosity usually will have a low flash point, high volatility, and invade the pours of the skin.
- An oil with a high flash point may also have high viscosity.
- An oil with the lowest cost may not have any redeeming qualities.

Dielectric Oil Maintenance

When to Change

Proper dielectric oil maintenance, in addition to continual filtration, consists of changing it at the proper interval, since the oil immediately adjacent to the discharge is likely to be degraded somewhat by the heat of the discharge which, in

> "Most suppliers of dielectric oils offer a free analysis of their oils."

turn, will gradually degrade the properties of the oil in the machine reservoir over time. That interval of oil change-out can be affected by the following factors:

- Number of hours sparking time per year
- High or low amperage burns
- Type of dielectric fluid
- Electrode material— metallic or graphite

With tool room operating conditions, I normally recommend changing mineral oils annually and synthetic oils every other year.

Regardless of the recommended change-out interval, any of the following conditions would suggest that the oil be changed:

- The oil is cloudy when cold, and clear when warm— This indicates either moisture absorption or an excessive concentration of waxy long molecule chains in the oil.
- Change in color of clean oil from clear to a varnish-like color
- Increase in viscosity
- Increase in odor
- Increase in cutting times
- Decrease in cutting stability
- Changes in surface quality of workpieces

Most suppliers of dielectric oils offer a free analysis of their oils. You just supply them with a sample of your oil (they'll even supply the sample bottle) and they'll give you a report on its condition. If your are in doubt, I suggest you avail yourself of this service.

Change-out Procedure

After draining the old oil you should clean the sump of the dirty tank. Mucking out the oily debris from inside the oil reservoir is probably one of the more unpleasant maintenance tasks in the shop. But, it needs to be done! (By the way, please remember to order the replacement oil, filters, and a new tank door gasket before you start the job.) After cleaning, pour some of the old oil back in, and run the pumps for a while to pick up any of the loose debris in the system. Then, drain the oil, change the filters and put in the new oil.

Disposal

While EDM dielectric oil is not generally considered to be hazardous waste, it is always considered to be combustible and petroleum waste. Thus, it needs to be disposed of properly. This usually means that a properly licensed waste oil disposal company needs to be called in. Please refer to my prior "Safe & Green" article for further details.

Some shops dispose of their used EDM oil in a waste oil furnace. Before attempting this, you need to get a determination from your state EPA office as to whether this is permissible, as well as checking with your waste oil furnace supplier to determine if your particular oil is compatible with your furnace burner. ***Do not attempt to burn your waste EDM dielectric oil in a furnace designed for No. 2 heating oil!***

Any suggestions for future topics are welcome.
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