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Coolant Care

By Brian Gedlinske

As disposal of spent cutting fluid becomes increasingly difficult and expensive, small machine shops are looking for ways to maintain fluid quality and performance. The Iowa Waste Reduction Center suggests some practices that can be readily adopted to prevent fluid degradation, extend fluid life, and reduce waste.

Dispose-and-replenish routines used to be a common practice at the onset of metalworking-fluid degradation and less-than-optimal performance. In the past, it was easier and more economical for machine shops to dispose of fluids than to manage them and extend their service life. But now, with waste disposal becoming more complex and costly, even small shops are replacing this practice with in-house fluid-management programs.

With the arrival of tighter environmental regulations, stricter sanitary sewer-discharge limits, rising fluid-procurement and -disposal costs, and additional environmental-liability concerns, the environmental and economic advantages associated with prolonging fluid life have become apparent. Fluid management is an even more attractive pollution-prevention alternative now that increased automation in the metalworking industry allows costs to be kept at an acceptable level.

Effective programs can keep metalworking fluid as clean as the initial raw product, significantly prolonging its service life. In addition to waste reduction, a number of other incentives exist for establishing a fluid-management program. These include:

- Reduced environmental liability due to less waste and reduced off-site disposal;
- Easier compliance with environmental regulations;
- Reduced fluid consumption (up to 40%) and reduced purchase costs and disposal expenses;
- Improved productivity due to decreased downtime and tool wear, more consistent machining tolerances, and higher quality finished parts;
- Cleaner machines that require less maintenance and repair;
- Longer cutting tool life; and
- A healthier and safer work environment for the machine operator.

Facilities may realize a 15% to 50% savings in operating costs by implementing a thorough fluid-management program. Payback for establishing such a program is often achieved within one or two years.

Monitoring and maintaining fluid quality are crucial elements of a successful fluid-management program. A fluid must be monitored to anticipate problems. Fluid monitoring includes system inspections and periodic measurements of fluid parameters such as concentration, biological growth, and pH. Changes from optimal fluid quality must be corrected with appropriate adjustments (such as fluid-concentration adjustments, biocide addition, tramp-oil and chip removal, and pH adjustments). It is important for a shop to know what changes may take place in its system and why they occur. This allows fluid-management personnel to take the appropriate steps needed to bring fluid quality back online and prevent fluid-quality problems from recurring.

Preparation

Sound fluid preparation is the first step toward extending fluid life, achieving the best fluid performance, and using fluid concentrate efficiently to avoid problems associated with high or low fluid concentrations. Coolant mixtures should be prepared according to the manufacturer's directions (as obtained through the fluid supplier and/or product literature). Specifications regarding the recommended water quality, concentrate-to-water dilution ratio, and additive requirements should be followed. Information about the product's life expectancy and acceptable operating range for parameters such as pH and contaminant levels should also be available. These ranges provide benchmarks for coolant adjustment or recycling.

Mixing. The manner in which the concentrate is mixed with water is important. Many machine shops have experienced poor fluid performance and wasted concentrate due to improper mixing. To achieve proper fluid performance, concentrate and water should always be mixed in a container outside the sump according to the manufacturer's directions. Although mixing concentrate and water directly in the sump is a quick and easy method of fluid preparation, it results in incomplete mixing and improper fluid concentration. Fluid performance suffers, resulting in problems such as parts oxidizing or staining, dermatitis, and machine downtime due to plugged lines, excessive tool wear, and poor performance or failure of the tool or machine.

Water quality. Since water-miscible fluids may consist of up to 99% water, the quality of the water used to dilute the concentrate is an important consideration in fluid preparation. Dissolved minerals and gases, organic matter, microorganisms, or combinations of these impurities can lead to problems. Water-quality characteristics such as hardness and dissolved solids should be monitored to achieve the best fluid performance and extend fluid life.

Hardness is a measure of the dissolved calcium, magnesium, and iron salts in water. For metalworking fluids, the ideal hardness for makeup water is generally 80 to 125 ppm. Foaming may become a problem when concentrate is mixed with water having a hardness below this range, particularly in systems in which the fluid is agitated excessively. A hardness above this range may cause dissolved minerals to react with fluid additives, degrading fluid performance. Hard-water minerals combine with emulsifiers contained in synthetic or semisynthetic concentrates to form scum deposits on sumps, pipes, filters, and even the machine. Hard water can also cause the oil to separate out of suspension.

The total-dissolved-solids (TDS) concentration of water is also a concern in fluid management. To maintain proper fluid chemistry, use untreated water with an acceptable mineral content for initial fluid makeup. TDS concentrations should be less than 80 ppm for chlorides and sulfates and less than 30 ppm for phosphates. When replenishing evaporation losses, machine operators should add premixed fluid, not just water, to the system. Adding fresh fluid to the system ensures that needed additives such as rust inhibitors and emulsifiers are maintained at desired concentrations. Demineralized or deionized water should be used as the makeup water for fluid additions to prevent TDS levels from building up in the fluid.

Concentration

Fluid concentration measures the active ingredients present in the mixture. Monitoring and maintaining proper fluid concentration is essential in assuring product quality, maximizing tool life, and controlling microbial growth rates. High fluid concentrations may result in increased fluid costs through wasted concentrate, reduced dissipation of heat, foaming, reduced lubrication, residue formation, and a greater incidence of built-up edge on the cutting tool. Highly concentrated fluid may also stain the workpiece and/or machine tool and increase the toxicity of the fluid, particularly if the fluid becomes superconcentrated due to evaporation. This results in increased skin irritation and an undesirable work environment for the machine operator. Overly diluted concentrations may result in poor lubricity, shorter tool life, increased biological activity, and an increased risk of rust formation on newly machined surfaces.

Evaporation can lead to a 3% to 10% loss of water from the fluid per day. But concentrate can be lost along with the fluid as a result of splashing, misting, and dragout. A total daily fluid loss of 5% to 20% may occur from the combination of these processes. The amount of fluid lost vs. the amount of concentrate lost can vary greatly. Consequently, coolant concentration will vary and must be monitored regularly to determine if the fluid is too diluted or too rich. Monitoring provides data for calculating the amount of concentrate and water needed to replenish the system and keep the fluid at its recommended operating concentration. Best monitoring frequencies range from daily monitoring for small sumps or stand-alone machines to weekly monitoring for larger systems. These monitoring frequencies are site-specific, however, and are best determined through experience.

Fluid concentration may also be controlled through the installation of closed-loop and open-loop cooling units on machine sumps or central reservoirs. These cooling units reduce evaporation losses by regulating fluid temperature. Cooling the fluid helps tighten tolerances, extend tool life by inhibiting microbial activity, and increase the fluid's ability to remove heat from the tool/workpiece interface. Fluid concentration can be measured using a refractometer or through chemical titration.

Contamination

Microbial contamination is a major cause of fluid spoilage. All water-miscible fluids are susceptible to microbial contamination that can significantly reduce fluid life. Fluid manufacturers are constantly developing formulations that are more resistant to microbial degradation. They accomplish this by using high-quality ingredients and incorporating biocides in the product.

Tramp oil and other contaminants are food for microorganisms and can make a sump an ideal breeding ground for bacteria. Bacteria populations can double as frequently as every 30 minutes. If allowed to multiply, microorganisms will ruin a fluid.

Fungi, which include mold and yeast, may degrade metalworking fluids by depleting rust inhibitors. Fungi also cause musty or mildew-like odors and form slimy, rubber-like masses on machine-system components that may eventually plug fluid lines. Successful control of bacteria and fungi is a must.

Two common tests for microbial monitoring include plate counts and dipslide tests. Both tests involve growing cultures using a sample of the fluid. However, dipslides provide a simpler, faster screening method than plate counts, since cultures are grown overnight and a visual approximation is used to assess microbial contamination. Weekly or biweekly monitoring is typically recommended for detection of microbial contamination, especially during the early stages of developing a fluid-management program.

Biological growth is controlled through a combination of practices:

Water-quality control. Fungi feed on dissolved minerals in water. Controlling the mineral content of the water used for metalworking fluids can control fungi growth.

Maintenance of proper fluid concentration and pH. Many coolant concentrates contain biocides and pH buffers. Therefore, preventing fluid from becoming overly diluted helps control microorganisms.

Routine maintenance of equipment. Microbial contamination is significantly accelerated by poor housekeeping practices. The best method for controlling biological growth is through routine cleaning of machines, coolant lines, and sumps/reservoirs. Machines, exhaust blowers, and hydraulic seals should also be maintained to prevent oil leaks from contaminating the fluid.

Accumulations of chips and fines in a sump also promote bacterial and fungal growth. These particulates increase the surface area available for microbial attachment, and biocides cannot effectively reach the fluid trapped in these chips and fines. Particulates in the bottom of a sump become septic or rancid if not periodically removed. Even if the majority of the fluid is free of bacteria, the sludge in the bottom will continue to harbor bacteria and create a septic condition. This can dissolve metals, possibly increasing the toxicity of the fluid to a level at which disposal through a local wastewater-treatment plant is no longer permitted. Laboratory analysis will reveal whether the toxicity of the fluid makes it a hazardous waste.

Biocide treatment. The addition of biocides inhibits biological degradation of the fluid by controlling bacteria and fungi. Relying strictly on biocides for microbial control is discouraged, however, since these chemicals are expensive and can irritate the operator's skin.

Generally, biocides should be used sparingly in as low a concentration as possible to protect the operator while still effectively controlling bacterial growth. Due to the variety of bacteria that may be present in a fluid, use of only one biocide may control certain bacterial species while allowing others to proliferate. Random use of various types of biocides at different frequencies and in different orders may prove to be more effective.

Biocide-treatment patterns play an important role in controlling microbial growth. During one study on biocide-treatment patterns, fouled fluids were treated with a commercial biocide at various concentrations and frequencies while microorganism populations were monitored. For all biocide-application rates tested, the efficiency of antimicrobial control was found to vary widely with treatment pattern. Less frequent doses with higher concentrations of biocide were found to be much more effective than low-level, frequent doses. The reasons for these reactions were investigated and found to be related to residual biocide concentrations, biocide consumption by microorganisms, and changes in the predominant species of bacteria that populated the fluids. Although low biocide concentrations are recommended for the safety of the operator, this concern must be balanced with acceptable control of biological activity.

Aeration. Aeration can be used in conjunction with biocide additives to control anaerobic microbial growth in systems during periods of inactivity. Aeration oxygenates the fluid, producing an atmosphere hostile to the odor-producing anaerobic bacteria. While the machine is running or sitting idle, a small pump can bubble air into the sump, either continuously or periodically, to agitate stagnant areas within the sump.

Fluid pH

Ideally, the pH for water-miscible metalworking fluids should be kept in the limited range of 8.6 to 9.0. This slightly alkaline range optimizes the cleaning ability of the fluid while preventing corrosion, minimizes the potential for dermatitis, and controls biological growth. If the pH drops below 8.5, the fluid loses efficiency and can cause rusting of ferrous metals, and biological activity will significantly increase. A pH greater than 9.0 may cause dermatitis and corrosion of nonferrous metals.

Regular monitoring of a fluid's pH is a simple means of anticipating problems. Fluid pH should be measured and recorded daily after the machine is placed in operation. Steady pH readings give an indication of consistent fluid quality. Swings in pH outside the acceptable range indicate a need for machine cleaning, concentration adjustment, or the addition of biocides. Each action taken to adjust the pH to the desired operating range should be documented in the machine log book and evaluated for effectiveness. Any rapid change in pH should be investigated, and action should be taken to prevent damage to the fluid.

Although manufacturers add buffers to the concentrate to maintain the fluid at a constant pH, the pH can change after initial mixing due to water evaporation. Improper control of microbial growth will also alter fluid pH. By-products of microorganisms lower fluid pH. As the fluid becomes rancid or septic, it becomes more acidic. Sudden downshifts in pH usually indicate increased biological activity or a sudden change in concentration due to contamination. If coolant concentration and pH both jump downward, the sump has been contaminated. If coolant concentration remains fairly constant while pH decreases, the fluid is more resistant to biological attack, but biological activity has probably increased significantly. The pH of a metalworking fluid can be readily determined using litmus paper or a hand-held pH meter.

System Maintenance

Machine-system inspection and maintenance help control fluid contaminants. Brief inspections of the fluid and system cleanliness are important aspects in monitoring fluid quality and avoiding premature fluid failure. Operators and maintenance personnel should be aware of signs that indicate a need for fluid maintenance or recycling. Such observations include excessive tramp-oil accumulation, buildup of metal cuttings within the sump, foaming problems, and leaky machinery. Machines must also be inspected for stagnant areas, dirt, and bacterial slime accumulations. Observations regarding fluid quality should also be documented in the machine log book.

A shop may have to modify its equipment to eliminate hard-to-reach or stagnant locations if there are areas that are difficult to see into or clean. Retrofitting machines with external sumps often improves accessibility, allowing particulates and tramp oil to be removed on a regular basis. Maintaining clean machines, coolant lines, and sumps is an integral part of fluid management. Clean machines use metalworking fluids more economically and extend fluid life. Any dirt and oil allowed to remain in the system simply recirculates, resulting in plugged coolant lines and bacterial growth. It is important to perform routine maintenance practices such as particulate removal, tramp-oil control, general housekeeping, and annual cleanouts.

Particulate removal. Excessive chip accumulation reduces sump volume, depletes coolant ingredients, and provides an environment for bacterial growth. Excessive solids buildup can also cause increased fluid temperature. Chips should be removed as often as possible. Mobile sump cleaners such as sump suckers or high-quality drum vacuums are useful for this purpose.

Tramp-oil control. Tramp oils such as hydraulic oil, lubricating oil, or residual-oil film from the workpiece are major causes of premature fluid failure. These oils provide a source of food for bacteria, interfere with the cooling capability of the fluid, and contribute to the formation of oil mist and smoke in the workplace. Tramp oils also interfere with fluid filtration and form residues on machining equipment. Tramp-oil contamination must be controlled through prevention and removal.

Ultimately, the best method for control of tramp oil is to prevent it from contaminating the fluid in the first place. Routine preventive maintenance should be performed on machine systems to prevent oil leaks from contaminating the fluid. Some facilities have reportedly substituted undiluted, petroleum-base fluid concentrate for gear-box oil lubricants, machine-way oils, or hydraulic oils. Instead of becoming contaminated with leaking oil, the fluid is actually enriched by the concentrate. To ensure this practice does not harm the machine’s operation or performance, this should only be done if machines are properly prepared for using a fluid-concentrate substitute. Also available is machining equipment that has been designed to operate using less hydraulic oil or to direct lubricating- and hydraulic-oil leakage away from the machine sump.

Even with the best preventive-maintenance programs, some tramp-oil contamination is inevitable and will require removal. Depending on its water miscibility, tramp oil will either "float out" when the fluid is allowed to sit for a period of time or be emulsified by the fluid. Free-floating tramp oil should be removed on a regular basis (either continuously or periodically) as part of fluid maintenance. Oil skimmers, coalescers, or oil-absorbent pads can remove floating oils. A centrifuge is needed to remove emulsified tramp oils.

Tramp-oil separation and removal can also be improved by purchasing fluids that resist tramp-oil emulsification or by using hydraulic and lubricating oils that won’t readily emulsify with the fluid. Use of high-quality lubricants with ingredients that won’t be a food source for bacteria is another means of inhibiting biological growth associated with tramp oil.

General housekeeping. Cutting-fluid contaminants such as lubricating oils, greases, and metal particulates are an expected part of machining operations. Many of the contaminants that force shops to dispose of fluids prematurely consist of foreign materials such as floor sweepings, cleaners, solvents, dirt, waste oils, tobacco, and food wastes. These contaminants have obvious detrimental effects on fluid quality and should be eliminated through improved housekeeping and revised shop practices. Facility personnel should learn not to dispose of these materials in machine sumps.

Annual cleanout. Machine systems must be thoroughly cleaned at least once a year to keep biological growth in check and maintain proper system operation. During cleanout, each machine should be thoroughly cleaned and disinfected. Simple flushing of cleaning solution through the system does not provide adequate cleaning. To clean a machine system properly, biocide should be added to the dirty fluid and allowed to circulate before pumping out the reservoir. All chips, swarf, and visible deposits should be removed.

Although accessibility is often an inherent problem because of a machine's design, extra effort should be made to thoroughly clean all hidden areas. If these difficult-to-reach areas are not addressed, they simply become a source of bacteria that rapidly attack the fluid used to refill the sump after cleaning.

Following cleanout of the sump/ reservoir, the system should be charged with water (preferably hot water) and mixed with a machine cleaner. This mixture should then be circulated through the system for several hours to loosen and remove any hardened deposits, oily films, or gummy residues. The cleaner must be 1) compatible with the metalworking fluid (in case some cleaner remains in the system after rinsing); 2) low-foaming to prevent pump cavitation, which is the sudden formation and collapse of low-pressure bubbles induced by the pump's mechanical forces; and 3) resistant to short-term rusting between cleanout and recharge. Chemical suppliers often provide instructions for equipment cleaning, including information about safe, effective, and compatible cleaning materials.

Bacteria flourish in machines that leak lubricating or hydraulic oils into the metalworking fluid. While the cleaning solution is circulating, leaking equipment should be repaired and the outside of the machine cleaned. If possible, troublesome areas should be steam cleaned. Finally, once the machine has been thoroughly cleaned and inspected, any residual cleaning solution must be rinsed from the equipment. Fresh water should be circulated through the system at least twice to rinse off any remaining cleaner. To protect against flash rusting, a small amount of fluid concentrate (0.5% to 1.0%) should be added to the rinse water. After it is completely drained of the rinse solution, the system can be charged with fresh fluid. The fluid should then be circulated for at least 15 minutes prior to production. These cleanout procedures are provided as general guidance. Each individual facility should develop a cleanout schedule and system suitable for its own operation.

About the Author

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Components of a Fluid-Management Program

Administration

- [ ] Commit the personnel, equipment, and other resources necessary for the program.
- [ ] Encourage employee support and participation.
- [ ] Designate fluid-management personnel to implement the program.
- [ ] Survey the fluids, machines, and sump capacities of the shop.
- [ ] Develop a record-keeping system to track the program.

Monitoring and Maintenance

- [ ] Prepare and mix the fluid according to the manufacturer's directions.
- [ ] Use high-quality water to dilute fluid concentrate and replenish evaporation losses.
- [ ] Monitor and maintain proper fluid concentration.
- [ ] Monitor fluid for microbial contamination and control microbial growth through water-quality control maintenance of proper fluid concentration and pH, routine maintenance of

equipment, addition of biocides, and aeration.

- Monitor pH for signs of fluid degradation.
- Perform regular machine-system inspections and maintenance practices, particulate removal, tramp-oil control, general housekeeping, and annual cleanouts.
- Prevent foaming with proper fluid concentration, high-quality water, and elimination of mechanical effects that agitate cutting fluid.

Recycling

- Recycle fluid well before it becomes significantly degraded; never attempt to recycle rancid fluid.
- Select fluid-recycling equipment based on the needs, objectives, and financial resources of the shop.
- Determine a fluid-recycling schedule for the shop based on fluid type, water quality, fluid contamination, machine usage, machine filtration, fluid control, and fluid age.
