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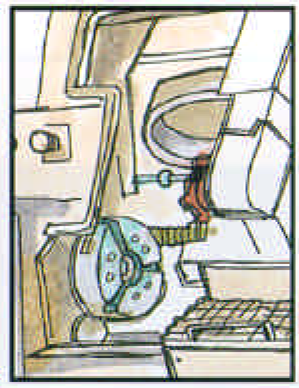
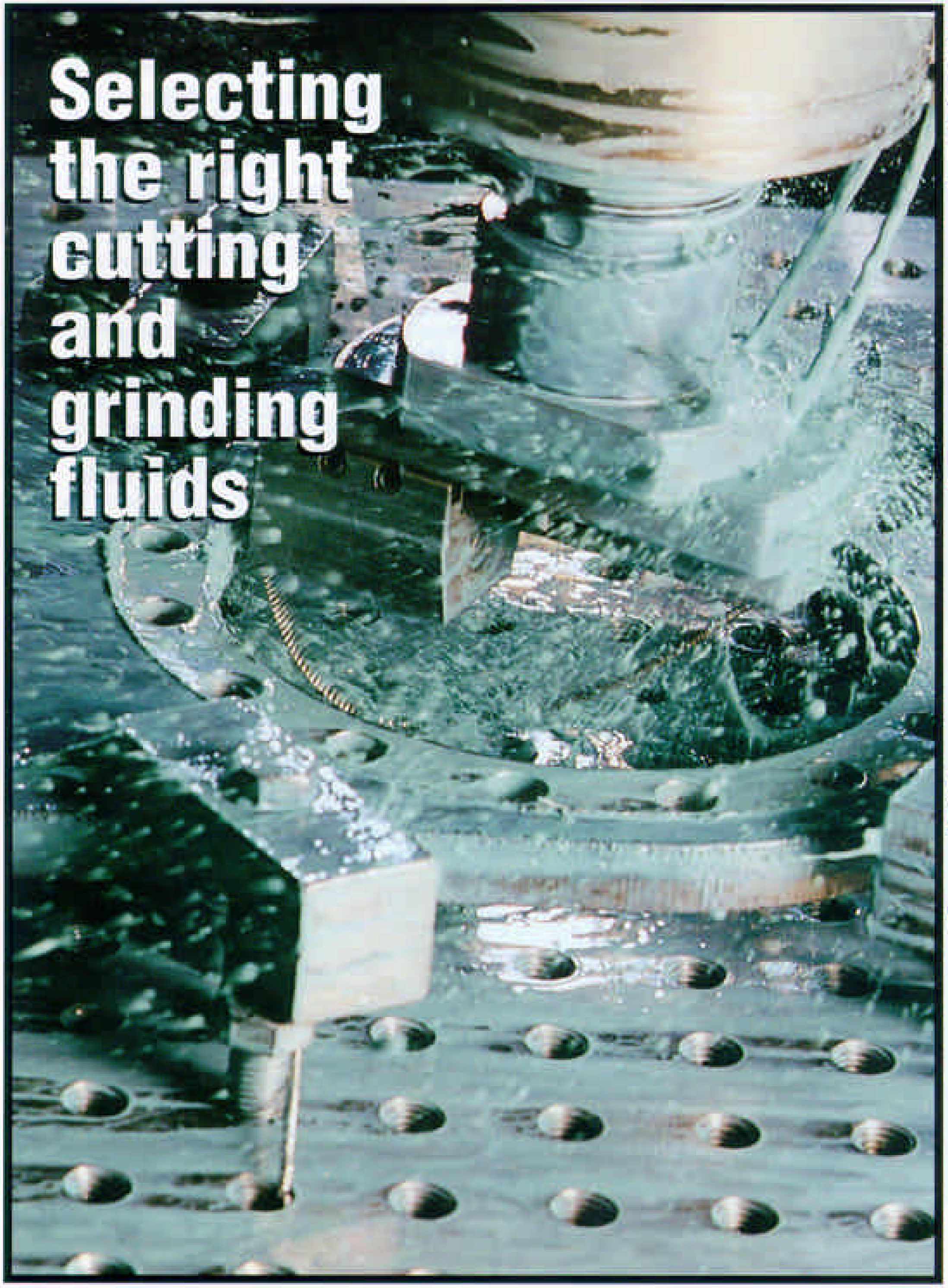
Providing solutions for metalworking manufacturers





Selecting the right cutting and grinding fluids

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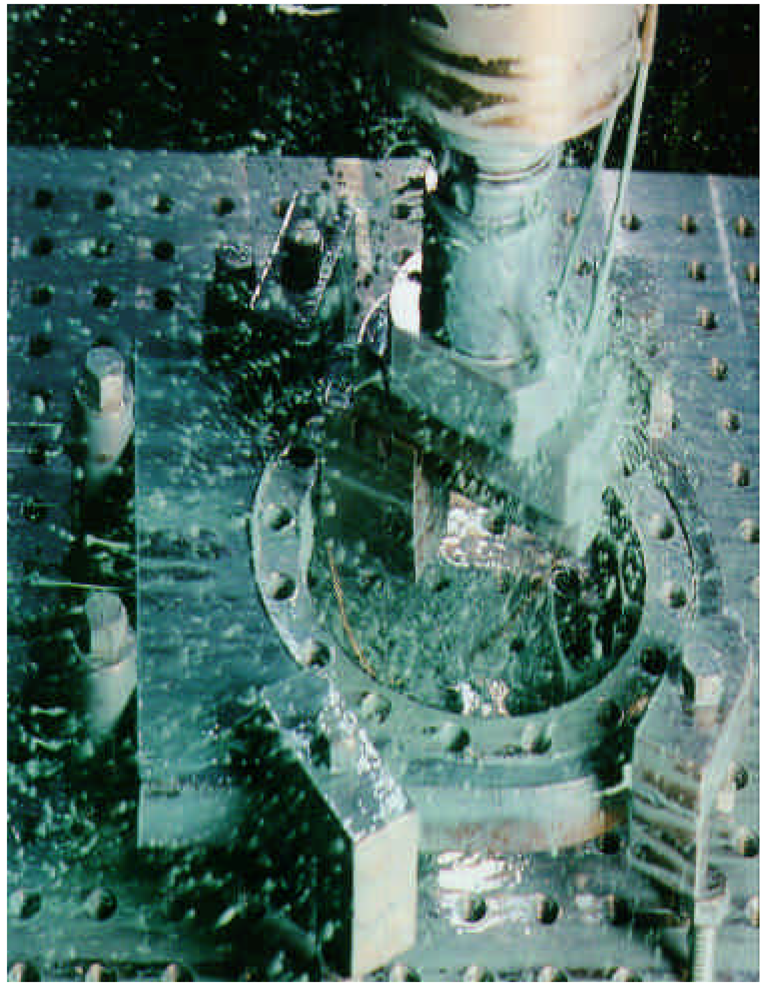
COVER STORY

Selecting the right cutting and grinding fluids

By Clyde A. Sluhan

Chairman, Executive Committee
Master Chemical Corporation

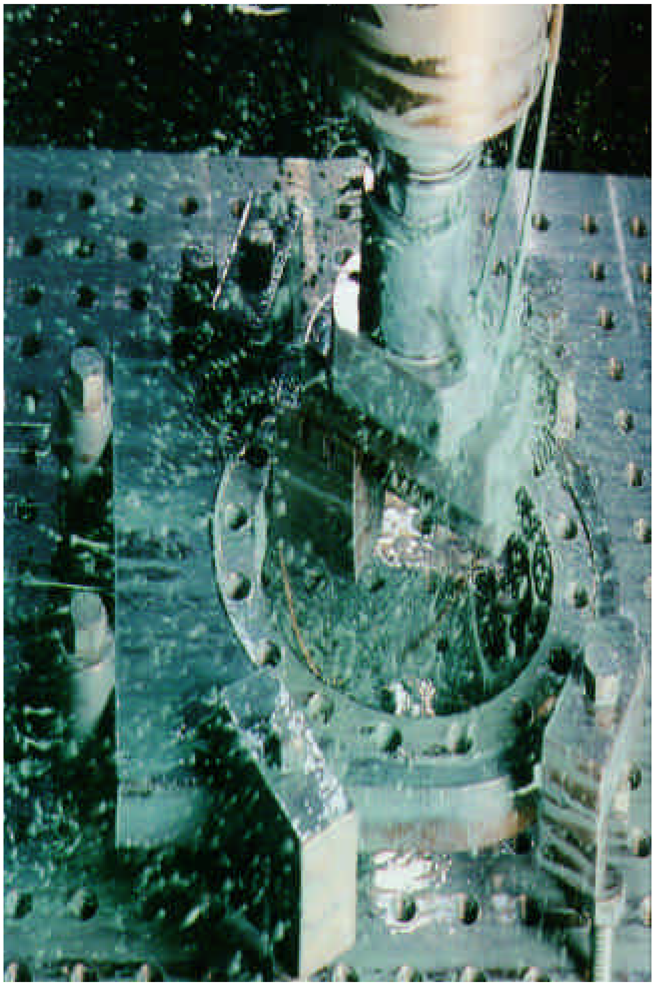
Clyde A. Sluhan is the chairman of the executive committee and founder of Master Chemical Corporation, Perrysburg, OH. Mr. Sluhan built his business on the formulation (at his wife's kitchen sink, he likes to say) of the first truly successful synthetic metalworking fluid. Mr. Sluhan is an internationally recognized authority on coolant formulation and application. SME has honored him by naming its 1994 Outstanding Young Manufacturing Engineer Award the Clyde A. Sluhan Outstanding Young Manufacturing Engineer Award for his long and dedicated service to the Society.



Cutting and grinding fluids provide lubricating and cooling effects which are absolutely essential to the economical production of precisely machined and ground parts. These precision parts, produced at high rates and low unit cost, are absolutely critical to the reliable, high-technology lifestyle we take for granted.

The type and degree of lubrication and the degree of cooling required for various metal removal operations vary according to the kind of operation, the rigidity of the part and its fixturing, the type of metal and its hardness and microstructure, the tool material and its geometry, and the speed, feed, and depth of cut selected. With the possible exceptions of ceramic turning and carbide and ceramic milling, which can frequently be accomplished satisfactorily and economically without cutting fluids, all other metalworking operations require fluids of one kind or another to produce precision parts economically.

Lubrication from the fluid aids in generating the desired workpiece shape, surface finish, and surface integrity while increasing tool and wheel life.



Lubrication reduces tool wear because cutting forces are decreased as friction at the face and flank of the cutting tool or abrasive grain is reduced. Lubrication also increases shear angles and, thereby, reduces work hardening and workpiece distortion ahead of the tools.

The cooling provided by cutting and grinding fluids extends tool life primarily by preventing tools from exceeding their critical temperature range while in the cut. Beyond the critical temperature, tools will soften and wear rapidly with the concurrent loss of finish and size and with the potential for catastrophic tool failure. Cooling provided by the fluid also helps keep the part thermally stable aiding in control of part size.

No one type of fluid will provide optimum lubrication and optimum cooling for every metalworking operation. In fact, lubrication and cooling characteristics are at "opposite ends of the spectrum." Straight (non-water-miscible) oils provide excellent lubrication but have relatively poor cooling properties. Water, while it is the best coolant known and will remove heat 2.5 times more rapidly than oil, cannot be used "as is" as a practical cutting or grinding fluid. Water has extremely poor lubricating properties and will cause severe corrosion of ferrous (and many nonferrous) metals.

To make water usable as a cutting or grinding fluid, metalworking fluid manufacturers formulate numerous fluid concentrates designed to be diluted with water to form a

PROPERTIES OF WATER MISCIBLE COOLANTS

	Lubricity	Cooling	Wetting	Residue	Foam	Corrosion Inhibition			Tramp Oil Rejection	Disposability	Recyclability
						Ferrous	Nonferrous	Cast Iron			
True Chemical Solutions	Poor	Best	Poor	Worst	None to Low	Fair to Good	Poor to Fair	Poor to Good	Best	Poor High BOD/COD*	Poor to Good
Surface Active Solutions	Excellent	Good	Excellent	Poor to Good	Med to High	Good	Fair to Good	Good	Worst	Poor High BOD/COD	Fair to Good
Emulsions	Fair to Good	Poor to Fair	Poor to Fair	Best	None to Med	Fair to Good	Best	Poor	Poor to Fair	Best	Poor to Good
Semichemical (semisynthetic) Solutions	Fair to Good	Fair to Good	Fair to Good	Fair to Good	Low to High	Good	Fair to Good	Fair to Good	Fair	Poor High BOD/COD	Fair to Good

** BOD = biological oxygen demand*

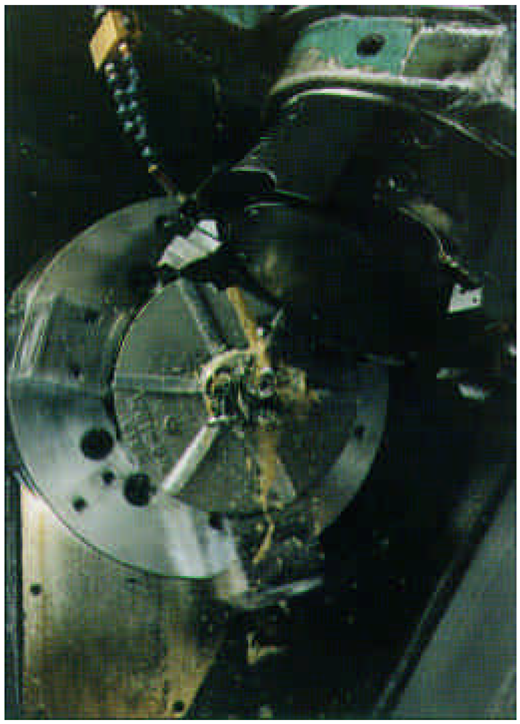
COD = chemical oxygen demand

"working solution." These concentrates can be thought of as "additive packages." They enable the metalworker to take advantage of water's excellent cooling properties while imparting some degree of lubrication to it and preventing it from causing corrosion on either machine tools or workpieces.

The fluid choices
The main types of fluids used for cutting and grinding fall into four categories:

Chemical fluids (also frequently called synthetic fluids since they contain no petroleum or mineral oil as formulated) can be further categorized into two sub-groups: true solutions and surface-active fluids.

- True solution fluids are composed essentially of alkaline inorganic and organic compounds and are formulated to impart corrosion protection to water. The working solutions tend to have very good cooling properties but no lubrication. Their use is usually restricted to high-heat operations such as surface grinding and high-velocity turning with carbide where good cooling and low foam characteristics are important.
- Chemical surface-active fluids are composed of alkaline inorganic and organic corrosion inhibitors combined with anionic non-ionic wetting agents to provide lubrication and improve wetting ability. These fluids may also incorporate conventional extreme-pressure lubricants containing chlorine, sulfur, and phosphorus as well as some of the more recently developed polymer physical extreme-pressure agents. Their good cooling properties, good wetting ability, and physical and extreme pressure lubricating properties place them among the best in heavy-duty cutting and grinding ability especially on tough, difficult-to-machine, and high-temperature alloys. However, their excellent wetting properties give them tendencies to foam and to emulsify hydraulic oils, lubricating and slideway oils, and greases. Those tendencies when combined with their "difficult to treat for disposal" nature tend to restrict their application to those difficult jobs where other fluids will not perform satisfactorily.



Nonchlorinated cooling and lubricating fluid is being used in turning stainless steel pump impellers on a Cincinnati Milacron Cinturn at Aurora/Hydramatic Pump, Ashland, OH. TRIM® SC 210 is free of chlorine and sulfur EP additives, phenols, and nitrates, is easily recycled, has a long sump life, and rejects tramp oil.

Emulsion fluids (also called soluble oils) are composed of a base of petroleum or mineral oil combined with emulsifiers and blending agents. When mixed with water, the emulsifiers and blending agents cause the oil to disperse in the water to form a stable oil in water emulsion. Emulsion fluids can also incorporate wetting agents and chlorine, sulfur, and/or phosphorus extreme-pressure lubricants for increased lubricating properties. Because emulsions contain a high percentage of oil, and oil does not cool as well as water, the cooling properties of emulsions are not as good as those of the chemical fluids. Their lubricating properties are not quite as good as the chemical, surface-active fluids; nevertheless, emulsion fluids, because they are largely composed of oil and oil-like materials, tend to leave protective, lubricating oil films on the moving parts of machine tools, and they exhibit far less tendency to emulsify greases and slideway oils. In addition, because emulsions are not soluble in water, they are the easiest of the water-miscible fluids to treat for disposal and respond well to both chemical separation techniques and to ultra-filter treatment.

Semichemical fluids (also called semisynthetics) are essentially combinations of the chemical, surface-active fluids and emulsion and, as such, have characteristics and properties common to both types. Chemical, surface-active fluids have residues which range from semicrystalline to gummy (especially in hard water), and none tend to be "kind" to moving parts of machines. Semichemical fluids were developed in an attempt to improve the residues of chemical surface-active fluids by incorporating a percentage of oil into the product. The effort has been largely successful, and the semichemical fluids tend to be fairly broad application, medium-duty fluids. Drawbacks, however, are that the concentrates frequently are unable to withstand freezing without the concentrate separating and sometimes being rendered unusable as a result. They also exhibit the same "difficult to treat for disposal" characteristics common to chemical fluids.

All water-miscible fluids are subject to biological deterioration from bacteria and fungus with emulsions being somewhat more subject to bacterial attack and with the chemical and semichemical fluids being somewhat more more subject to fungal attack. As a consequence, quality fluid formulators are involved in a never-ending search to make their fluids ever more resistant to biological deterioration and, thereby, longer lived by careful raw material selection and, frequently, by incorporating microbiocides in the formulations.

Fluid users ban best aid in this effort to achieve extended fluid life by controlling fluid concentration, by mixing fluid concentrates with pure (mineral-free) water, by controlling contamination of the fluid (especially from hydraulic and slideway oils) and by thoroughly cleaning the cooling sumps and systems periodically.

King Machine Tool, Massillon, OH, finish grinds 4340 steel with 0.002" depth of cut using TRIM® E 190, a water-soluble, nonchlorinated fluid that can be recycled easily, and Radiac 80J 1" wheel, 24" in diameter.

Straight (nonemulsifiable) cutting and grinding oils are used without dilution "as they come from the drum" and provide the greatest lubricating (and poorest cooling) properties of fluids in common use today. They are composed of a base mineral or petroleum oil and often contain polar lubricants such as fats, vegetable oils, and esters, as well as extreme-pressure additives of chlorine, sulfur and phosphorus.

They are still in wide use today. However, because of their "messy" nature, their fire and health hazards, and the fact that they are best removed from parts with solvents at a time when solvents are being supplanted by aqueous cleaners for environmental reasons, straight cutting oil use is declining. Their use is largely restricted to heavy-duty cutting and grinding operations where water-miscible fluids cannot provide sufficient lubrication, and to older machine tools which were originally designed to operate with straight oils and which simply cannot be operated with water miscibles. In most plants, the poor cooling properties of oil so restrict production rates that they are only used where water-miscible fluids cannot be used.

Selection criteria

In the 1960's the selection process for metalworking fluids in most plants was relatively informal and heavily influenced by the perception that fluids were "maintenance items" and not true contributors to the manufacturing process. As a consequence, "price-per-gallon" was a major determinant in the selection process and little attention was paid to the fluid's effect on tool or wheel life, machine maintenance costs, operators' skin problems, disposal costs or the plant's overall economic performance. Since fluids were perceived to be primarily a "necessary nuisance," as long as the fluid machined reasonably well for a couple of weeks or so without causing operators to "break out," a majority of firms saw that level of performance as good enough and paid the lower price per gallon.

Forward-looking companies at the time were more aware of the positive influence better performing fluids had on plant efficiency and were operating with more formal fluid selection processes. Their criteria for selection largely followed this order:

Machinability, or the fluid's ability to generate the desired shape, size and finish on work materials while extending tool and wheel life (in short, the fluid's ability to aid in material removal processes), was the most important criterion.

Compatibility, or the fluid's applicability to a wide range of work materials, was next most important followed by the fluid's effect on smooth machine functioning and maintenance costs. Those were followed by the fluid's incompatibility with (or resistance to the growth of) micro-organisms and, finally, by the fluid's ability to tolerate poor quality (hard) water and still give reasonable cutting performance and relatively long life.

Acceptability, or the effect of the fluid on the operators' skin and the operators' acceptance of the fluid's odor, feel, and appearance, was next in importance.

Disposability, or the ease and cost of fluid disposal, was just beginning to appear as a selection criterion. Most fluid was disposed of by introduction (without pretreatment) into sanitary sewer systems, by land fill, or by road oiling - practices that are totally unacceptable today.

Financial return, or the fluid's influence on production costs and overall plant efficiency, was beginning to be recognized by the more forward-looking companies, but most metalworking firms were still suffering from accounting systems that were limited to tracking "what and how many were bought and what was paid for them." Accounting as practiced was unable to attribute increased operating costs and production delays to poor material purchase decisions, and it meshed nicely with the prevalent and simplistic concept that metalworking fluids were simply a necessary nuisance.

Reordering priorities

During the late 1980s and early 1990s, fluid selection criteria have undergone some changes but, more importantly, their rankings have been re-ordered significantly.

Acceptability has been broadened in its scope to mean operator safety, which has now assumed absolute first place in the list of criteria. This is due, not to any historically poor safety record for fluids (actually the reverse is true), but because our society in the last 30 years has turned excessively litigious and irrationally "chemophobic." Users and formulators alike are putting operator safety first; some are taking this approach because they feel they must for "legal defense" reasons. However, the leading manufacturers can point to a long history of product testing to assure operator safety.

The downside of the demand for operator safety lies in the fact that, as soon as a chemical comes under suspicion of being any kind of a health hazard, whether scientifically justified or not, the marketplace demands that it not be used and fluid effectiveness frequently suffers. Reading today's product data sheets one learns far more about what is not in the fluid than one learns about what the fluid is capable of doing. Conversely, the intense interest in fluid safety has brought about a widespread recognition that safety and performance are heavily influenced by fluid cleanliness and proper concentration control. Users are monitoring fluids much more closely today, and operators are benefitting from fluids which are being kept clean and at the correct concentration, and their firms are benefitting from fluids which perform better for longer periods of time.

Compatibility issues

Compatibility of the fluids with work materials and with machine tools still occupies second place. Whereas fluids in the 1960s were much more "metal specific," especially from a corrosion protection standpoint, today's fluids tend to be more broadly applied to a wider range of work materials. In other words, today's fluids tend to work well with a wide range of work materials and operations. This is fortunate given the fact that today's fluids tend to work well with a wide range of work materials and operations. This is fortunate given the fact that today's CNC machining centers do a greater variety of operations than ever before and that production runs are shorter and more varied than ever before. The need to change fluids because the job or material has changed is now almost nonexistent.

Fluid compatibility with the machine tool from the standpoint of the fluid's residues and anti-corrosion properties is now more critical than ever. Multi-axis machining centers with automatic tool changers, position sensors, and the like require fluids which leave oily residual films that do not interfere with machine functioning. As metalworking firms move more and more to "just-in-time" manufacturing, there is broader recognition that for JIT to work, machines must function properly whenever they are needed and that unscheduled downtime cannot be tolerated. Fluids should be incompatible with microbial growth since microbes degrade (chemically alter) the fluid and its cutting and corrosion-inhibiting properties and frequently cause the fluid to give off unpleasant odors. Fluids and microbes are not (and are unlikely ever to be) "incompatible," but some fluids are significantly more microbially resistant than others. Microbial resistance can be enhanced by mixing concentrates with chemically pure water by controlling the fluid's concentration, by periodically thoroughly cleaning machine coolant systems of all debris and sludge, and by preventing/removing contamination of the fluid from hydraulic, slideway and other lubricating oils. Whatever can be done to minimize microbial growth pays off in more consistent fluid performance and significantly longer fluid life.

Disposal and recycling

Disposability has moved up in importance significantly due to major changes in environmental regulations. Whereas there was virtually no cost to dispose of spent fluids in the 1960s, today fluid disposal costs generally equal the cost of buying new fluid and frequently exceed the cost of buying new fluids by several times when dilution factors are taken into account. In addition, chemical and semichemical fluids are composed of large percentages of water-soluble organic materials that do not respond well to either chemical or mechanical (ultra-filtration) techniques. Attempts at separation result in a water phase with high BOD and COD levels which can result in hefty sewer surcharges to those manufacturers who introduce the water phase into municipal sewers after paying for the haul away of the "separated" concentrate. Emulsion fluids respond best to present disposal technology, generally at the lowest cost of disposal.

Nevertheless, disposal costs are still significant no matter what fluids are employed and, as a result, coolant recycling technology began to be developed in the 1970s with the intent of continually recycling metalworking fluids and avoiding disposal altogether. The feasibility of recycling is well proven today and the number of plants with coolant recycling systems in operation continues to grow rapidly. Recycling systems generally reduce the purchase of new fluid concentrate by 50%, virtually eliminate the disposal of "spent" fluid, and significantly reduce machine downtime associated with pumping out and recharging machines whose coolant has failed prematurely.

Most important, coolant recycling provides machines with fluid in consistently good condition so that it is a consistent contributor to the plant's material removal processes. Recycling does require the use of high-quality fluids because only high-quality fluids are capable of being continually recycled. Recycling requires that the fluids be maintained according to a formal coolant management program. However, the investment in recycling, high-quality fluids, and good coolant management pays off handsomely in greater plant efficiency and profitability and in having no concerns over the liability from spent fluid disposal.

Machinability capabilities of today's fluids are of considerably less concern than was the case in the 1960s. Today's fluids are better able to handle a wide variety of work materials and machining operations. The greater capabilities of today's fluids simply mean that fewer types of fluids are required to run the whole plant. A plant in the 1960s frequently required as many as six or eight fluids to do everything, whereas today, as few as two or three fluids may be required to handle the same variety of operations and work materials.

Of course, machining and grinding technology continues to advance and places new demands on fluids. A case in point is the development and rapidly increasing acceptance of creep-feed grinding as a highly effective technique for producing complex shapes in "tough" materials. Creep-feed grinding requires fluids with heavy-duty lubrication, high cooling, and, because of the high pressures and flow rates required by the process, low foaming characteristics. High lubrication and low foam have always been conflicting requirements in traditional fluid chemistry, but the market demand for an effective creep-feed grinding fluid led to the development of just such a fluid after nearly eight years of work. It is now finding additional applications such as "hard turning" and gun and Ejector® drilling.

Financial return is still an important criterion in fluid selection. The fluids selected must generate cost savings in excess of the cost to buy, use and dispose of them. Fluids do produce those cost savings and the cost to use good quality fluids with effective control and management is far less than is the cost to use cheap low-quality fluids with little or no control or management.

Fluid choice must be based on operator safety, kindness to the machine, ease of disposal or recyclability, the ability to perform the needed cutting and grinding operations, and to do it all at the lowest overall cost. The decision as to how to control and manage them is a little more complex for this can either be accomplished in-house with an investment in a fluid management recycling system or by contracting with an outside fluid management service. Doing it in-house requires an investment in equipment, manpower, and training, but offers the greater financial return. Contracting it out requires only monetary investment but will yield less savings since fluid management services are in business to make a profit as well. **T&P**

From premier coolants to world leadership in fluid recycling systems,
Master Chemical provides high-tech, economic use and in-depth customer service.

"Maximizing Productivity - Minimizing Waste"

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