Cutting Fluid Selection and Process Controls for the Gear Manufacturing Industry

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Introduction

The last decade has been a period of far-reaching change for the metal working industry. The effect of higher lubricant costs, technical advances in machine design and increasing competition are making it essential that manufacturers of gears pay more attention to testing, selecting and controlling cutting fluid systems. Lubricant costs are not a large percentage of the process cost relative to items such as raw materials, equipment and labor, and this small relative cost has tended to reduce the economic incentive to evaluate and to change cutting fluids. Nevertheless, one of the largest factors in lost production during gear manufacturing is excess tool wear, tool failure and subsequent product rejection. In this day and age of economic war of survival, it has become essential to consider and to evaluate new cutting fluids with an eye towards increasing tool life, improving overall productivity and product quality and lowering costs.

Gear Cutting and Finishing

A wide variety of manufacturing techniques are used to manufacture gears. Specifically, this article addresses the selection and process controls for the fluids used for gear hobbing, gear shaping and hard gear finishing.

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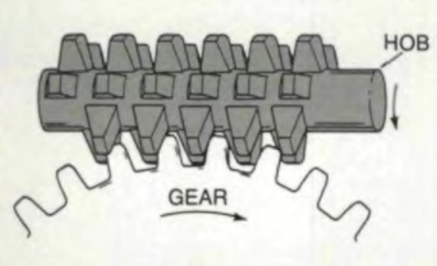

Fig. 1—Gear hobbing

The cutting tool used in gear hobbing is called the "hob". (See Fig. 1.) The majority of hobs are cylindrical in form and greater in length than in diameter. The cutting teeth on the hob are arranged in a helical thread corresponding to the thread of a worm. As the hob rotates in timed relationship with the gear blank, each row of teeth successively cuts the next portion of the gear tooth-space. The cutting action is continuous in one direction until the gear is completed.

Conversely, the gear shaping method operates on the principle of two gears rolling in mesh. In molding generating processes, a gear-like cutter called a shaper tool is rotated and reciprocated in the correct ratio with a gear blank. (See Fig. 2.) The gear blank rotates while the cutter rotates and reciprocates to provide the cutting action. The shaper only cuts in one direction so relief is provided for the return stroke.

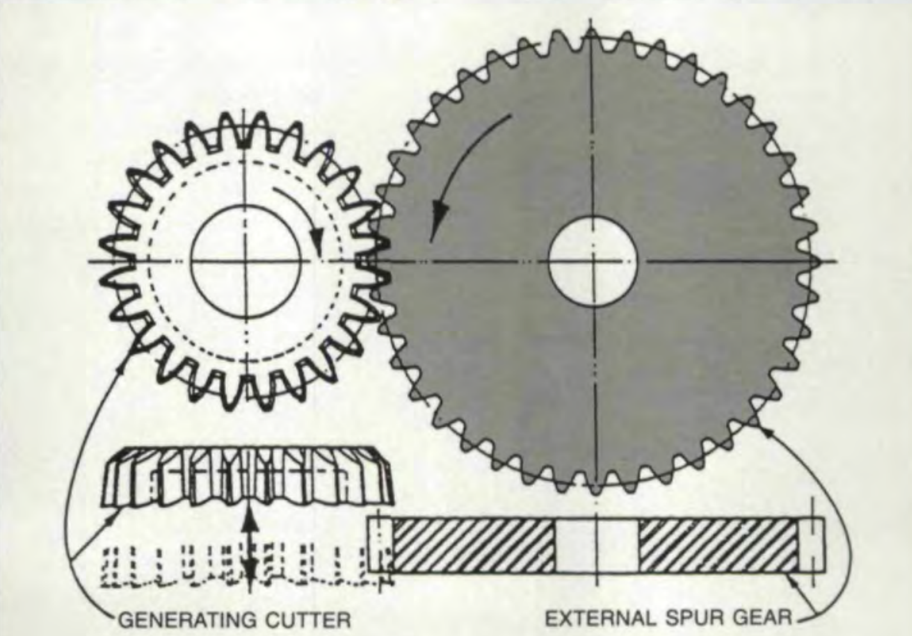

Fig. 2—Gear Shaping

Hard gear finishing is a process which uses either generative grinding or formed wheel grinding to finish the flanks of parallel axis spur or helical gears after they have been hardened by heat treatment. The hard gear finishing technique usually removes .002/.0025" from each side of the gear teeth.

In the form grinding process, the grinding wheel has a profile mirroring the tooth space between two adjacent gear teeth. As the formed wheel moves between the teeth of the gear, it removes excess stock.

There are several types of machines and tool configurations used in the generative grinding process. These processes either use a cutting tool designed as a spur or helical gear, which grinds the gear using the shaving or gear shaping principle, or a shaper cutter tool that uses a skiving principle or a worm type finishing tool similar to a worm type gear grinding wheel.

Recently, grinding wheels plated with cubic boron nitride (CBN) have been used in place of dressable, conventional abrasive grinding wheels. CBN is a synthetic crystalline material that is very wear resistant, and it has pronounced cutting edges because of its cubic shape. CBN applied by the electroplating process is considered the best for form gear grinding. CBN is very expensive, and its use dictates the need for improved coolants delivered at higher flow rates than used with conventional wheels.

Theory of Lubrication

The aim of fluids used in cutting and grinding operations is to provide cooling and lubrication.

Gear hobbing and gear shaping are metal cutting operations that generate chips. More than 97% of the cutting work appears as heat. Fig. 3 illustrates a two dimensional view of metal cutting. Of the heat generated, about two-thirds is expended in sticking friction in the shearing zone, and one-third is expended in sliding friction at the tool/chip and tool/flank interfaces. The action of the fluid is to lower the heat generated in these two zones, and the lubricant portion of the fluid reduces friction at the tool/chip and tool/flank interface.

A fluid used in hard gear grinding operation functions very much like a cutting fluid, but there are very pronounced differences between the dynamics of the processes. Gear grinding involves negative rake tool angles and random orientation of cutting surfaces. The temperatures and surface feeds are also higher. Most of the heat of deformation is carried into the workpiece so a gear grinding fluid must act to reduce grinding forces, which reduces heat generation. The cooling function of the fluid is considered secondary, but it is still important to the success of a hard gear finishing operation.

Fluids used for gear cutting and grinding must exhibit a number of other properties. They must not be adversely affected by metallic contaminants or tramp oils that can enter a lubrication system. They must not leave excessive residue on the surface of a gear to be subsequently heat treated, and they should aid in the production of a gear that has the desired properties – surface finish, runout, etc.

The study of the subject of wear between two materials in motion relative to one another is very complex. A number of parameters influence wear. Some of these include the shape of the contacting bodies, applied load, relative velocity between the surfaces, surface roughness, the elastic and plastic properties of the contacting materials (particularly those of the surface layers), and the environment of deformation.

Types of Cutting Fluids

A number of gear cutting and grinding fluids meet the requirement of providing adequate lubrication. This range of availability was not always present, as lubricant research and development was once a black art with few practitioners. Now, through scientific research and the cooperative efforts of vendors and buyers, lubricant development, application and behavior is becoming a science.

For the purposes of this article, lubricating fluids have been classified as either oil-based or water emulsifiable.

Oil-Based Fluids. Oil-based fluids are used for gear cutting and hard gear finishing where water emulsifiable compounds do not have the film strength or wetability to produce acceptable tool life or surface finish. Oil-based fluids are generally compounded with the following items:

1. Mineral oils, either napthenic grade that have a saturated ring type structure, or paraffinic grade, which have a straight or branched chain structure.

2. Mineral oils blended with polar additives, as the oils themselves are nonpolar. The function of the polar additive is to affect the wetting of the metal surface at the tool/workpiece interface by reducing the interfacial tension between the mineral oil carrier and the gear blank. A polar additive has a sort of magnetism for the metal due to its molecular structure.

Polar active additives come from several sources. Animal fats and oils are derived by rendering the fatty tissues of animals such as cattle, pigs and sheep. Vegetable fats and oils are derived by

Fig. 3 – Two-dimensional metal cutting diagram

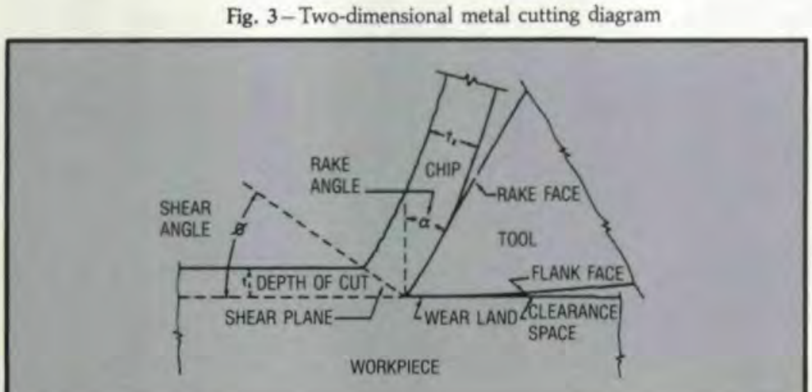

Table 1 – Coolants Grades by Contents

	FERROUS	NON-FERROUS
HEAVY DUTY	2-5% SULPHUR AND/OR 10-15% CHLORINE WITH 20-30% FAT *	UP TO 40% FAT POSSIBLY 2-4% CHLORINE
MEDIUM DUTY	5-9% CHLORINE 5-15% FAT	10-20% FAT
LIGHT DUTY	3-5% FAT	3-5% FAT
SEMI-SYNTHETIC	SEE MEDIUM DUTY	SEE MEDIUM DUTY
SYNTHETIC	NEW E.P. ADDITIVES	NEW E.P. ADDITIVES

*Sometimes 1-2% Phosphate

crushing and rendering the fruits of plants such as palm or coconut trees. Marine fats and oils are derived from crushing and rendering the fatty tissues of fish.

The mineral oils and polar additives are then often compounded with supplemental polar additives, which act as extreme pressure agents. The primary extreme pressure agents utilized are sulfur, chlorine or phosphorous. When subjected to the elevated temperatures at the tool/workpiece interface, these extreme pressure additives react to form an organo-metallic film which minimizes friction and lowers heat generation.

Water Emulsifiable Fluids. Water emulsifiable fluids are defined as those where water is the continuous phase. Basically, water emulsifiable fluids combine the cooling properties of water with the lubricating properties of oil and/or various chemicals.

Over the years, a good deal of jargon has evolved in the industry to describe water emulsifiable fluids for the gear manufacturing industry. Water miscible or emulsifiable lubricants are available in many forms. They can be classed based on their components, performances and appearance.

Water soluble oils, sometimes called emulsions or water miscible fluids, are made by blending oil, either paraffinic or napthenic, with emulsifying agents, so the oil forms small droplets called micells, which range in size from .0002" to 0.00008" in diameter when mixed with water. The emulsion appears milky as the particles of oil reflect almost all incident light, making them opaque. Soluble oils are subdivided into light, medium and heavy grades, depending on the components used in their formulation. (See Table 1.)

Semi-synthetic fluids are mixtures of emulsifiers and surface-active chemicals and have a low oil content of 10% to 25%. A typical soluble oil contains 45% to 70% oil. Because a semi-synthetic contains less oil than a water soluble lubricant, it can vary from being translucent to completely clear, as the micells range in size between .000004" and .000001" in diameter. They can only be seen under an electron microscope.

Synthetic solutions are almost always clear, as the particle size of the surface-active agents and chemicals used in the formulation of the product are small enough to transmit almost all incident light. True synthetics contain no mineral oil, and each component used in the formulation is soluble in water on its own. The particles are smaller than .00000004" in diameter and cannot be viewed under any microscope.

Generally most of the water emulsifiable fluids available contain a napthenic oil made soluble through the use of emulsifiers or surface-active agents.

The formulation of a commercially acceptable product depends on investigating hundreds of emulsifiers which can be classed as:

1. Anionic – These are emulsifiers whose electrolytic properties are based on the formation of anionic ions. Examples include sulfonated polyester or sulfonated castor oils.
2. Cationic – These are emulsifiers whose electrolytic properties are based on the formation of cationic ions. Examples include organic salts

or polyethoxylated amines.

3. Non-ionic – These emulsifiers do not behave as electrolytes and do not ionize in water. Examples include ethoxylated vegetable oils.

Surface-active or polar extreme pressure additives are also added to the formulation of a water emulsifiable fluid to wet out and to penetrate the tool/workpiece interface. These agents reduce the interfacial tension between the water, lubricant and the metal. The polar additives have an affinity for the metal substrate and form an organo-metallic film which provides lubrication by reducing friction at the tool/workpiece interface. There are a variety of oils, fats, waxes and synthetic polar additives such as esters or complex alcohols used as surface-active agents.

Fluid Selection. A number of factors affect the type of fluid used in a gear hobbing, gear shaping or hard gear finishing operation. The primary criteria for selection of material, which determines machinability, speed and severity of operation and the acceptability of a fluid, are all interrelated. Table 2 illustrates the additives utilized when severity is compared to difficulty of machinability.

Table 2

BROACHING SLOW SF/M	ACTIVE SULFUR	SULFUR & CHLORINE	ACTIVE
	LESS ACTIVE		SULFO-CHLORINATED
SEVERITY OF METAL-WORKING OPERATION ↑			
	INACTIVE	LOW CHLORINE	INACTIVE
HIGH SF/M			
HIGH SPEED CUTTING	FAT	FAT & CHLORINE	HIGH CHLORINE
	NON-FERROUS FREE MACHINING	DIFFICULTY OF MACHINABILITY →	STAINLESS AND HIGH ALLOY

The primary fluids used on CBN grinding of hard gears are oil-based because grinding wheel wear has been found to be related to the temperature of the wheel matrix. As the temperature of the wheel matrix increases, the wear of the wheel increases. Testing with both oil-based and water-based fluids has shown that oil-based fluids provided better lubricity and lower temperatures of the wheel matrix.

Another factor that influences grinding wheel life is the cleanliness of the oil-based lubricant. The hard gear finishing process generates very fine swarf which must be removed so as to maximize wheel life and improve surface finish. The most effective method of filtering a grinding oil-based fluid is a horizontal plate pre-coat filter. The filtering capability of a typical pre-coat filter is between one and three microns.

Testing and Process Controls

Selecting the appropriate lubricant for gear hobbing, gear shaping or hard gear finishing is very difficult. Effective tests for screening the wide variety of candidate fluids must be developed. These compounds vary greatly in their chemical and physical properties, and because of the critical need for optimum tool life, any variation in the physical and chemical properties of a given fluid becomes important. To assure the reliability of a given fluid, many lubricant manufacturers perform a number of tests to assess its physical, chemical, metallurgical and human compatibility. These tests yield data that can be used to screen fluids prior to in-plant testing.

Physical Laboratory Tests. These lab tests are designed to simulate as closely as possible actual production conditions and to generate data as to the reliability of a fluid under actual conditions of use.

1. Stability of a neat oil. The product should be stable under normal and adverse conditions. The following tests can point out stability problems: Place an eight ounce sample in a closed sample bottle and allow it to stand 21 to 30 days at ambient temperature. Monitor for any changes; i.e., separation, gelling. To test the effects of freezing and thawing, put an eight ounce sample of the neat oil in a closed container and place the sample in a freezer for 24 hours. Thaw, then refreeze for 24 hours and thaw again. Examine the neat oil for changes; i.e., separation, sedimentation.

2. Nonferrous corrosion. One test for nonferrous corrosion is to place a 30 ml sample of the neat fluid in a 100 ml beaker and then to put a properly abraded and cleaned copper strip in the beaker, heat to 220 F for three hours and check for staining on the strip.

   The effect of a cutting and grinding fluid compound on the gear being manufactured must be assessed for two reasons.

   a. Some of the extreme pressure agents, such as sulfur, used in these compounds might corrode the gear or the nonferrous parts like valve pipes and bearings in the actual manufacturing machine, as well as possibly adversely affecting the finished gear.

   b. Tests have indicated that it is possible for sulfur used in cutting fluids to react with titanium nitride coatings or CBN coatings, causing erosion of the coating and thus lowering tool life.

3. Load carrying properties. The Four Ball Test and the Falex Test were developed to determine the load carrying properties of cutting and grinding fluids.

   a. Shell Four Ball EP Test ASTM D-2596 and D-2783. The Shell Four Ball Test consists of four 1/2" diameter balls arranged in the form of an equilateral tetrahedron. The lower three balls are held immovably in a clamping pot to form a cradle in which the fourth ball is caused to rotate about a vertical axis. The fluid under test is held in the clamping pot and covers the area of contact of the four balls. During the test, scars are formed on the surface of the stationary balls, and the diameter of the scars depends upon the load, duration, speed of rotation and type of fluid. The scars are measured by a microscope having a calibrated grid at the completion of the test.

   b. An alternative to the Four Ball Test, the Falex test machine provides a rapid means of measuring the load carrying capacities and wear properties of a given fluid. The test consists of rotating a test pin between two loaded journal V-blocks immersed in the fluid sample. The test pin is driven by a 1/3 hp motor at 290 rpm, and the journals are loaded against the test pin by means of a spring gauge micrometer. The Falex machine is also an extreme pressure tester, and can be used to conduct a wear test, ASTM D-2670, to assess the effectiveness of a given fluid.

4. Cast iron corrosion. This test is important as the fluid must be tested to assess its effect on the interior ferrous parts of the gear cutting or grinding machine. A chip test or a Q-Panel test conducted with a Cleveland Condensing Humidity Cabinet can assess the effect of a given compound.

Chemical and Metallurgical Compatibility. A candidate fluid must also be considered from a chemical and metallurgical standpoint. The gear hobbing and gear shaping process and subsequent hard gear finishing process involve the exposure of unprotected, unoxidized metal surfaces to the chemical components of a lubricating fluid at elevated temperatures and pressures. Due to the elevated temperature and pressure, it is important to assess the effects of those reactions prior to in-plant testing.

1. Turbine oil oxidation test ASTM D-943. This test predicts the oxidation life of hydraulic oil, turbine oil, and metalworking oils. The test depends upon the catalytic effect of metals at elevated temperatures in the presence of water to accelerate the rate of oxidation. The degree of oxidation is determined by an increase in the acid number of the oil.

2. Rotary bomb oxidation test ASTM D-2272. The rotary bomb oxidation test is a more rapid method of comparing the oxidation life of fluids in similar formulations.

3. Turbine oil rust test ASTM D-665. Contamination of gear manufacturing fluids with water can produce rapid rusting of ferrous parts unless the oils are adequately treated with inhibitor compounds. The ASTM D-665 rust test is designed to measure the ability of industrial oils to prevent rust.

Process Controls for Oil-Based Compounds

There are many variables, such as feeds, speeds and operator expertise, involved in the gear hobbing, gear shaping and hard gear finishing process; therefore, it follows that any variation in the effectiveness of a given lubricating fluid will become important to overall productivity and profitability. To assure the long term reliability of each compound, it is important to monitor and to maintain certain controls for straight oil compounds.

1. Handling and storage — Oils should be stored at ambient temperature. If the oil is frozen, it should be thawed and mixed prior to use.

2. Temperature — It is important to maintain the temperature of an oil-based fluid at ambient temperature; i.e., approximately 65° - 75°F, or at least to maintain the temperature below 125°F if it is not possible to keep it lower.

   Excessive heat causes oxidation reactions which show up as sludge formation, varnish formation and the formation of acidic by-products which also cause corrosion. These by-products minimize lubricity. Excessive oxidation can be controlled by maintaining correct operating temperatures.

3. Viscosity — The viscosity of a straight oil can change with time because of a number of factors, such as tramp oil leaking into the system or chemical reactions in the oil due to heat and oxidation. Viscosity is an important indication of the condition of the oil.

4. Water and solids content — Proper filtration is necessary for good tool life and product quality, as excess metal fines can plug supply lines or catalyze chemical reactions to form sludge or varnish.

   Water at quantities greater than 0.01% by volume can cause a problem because it turns to steam at the tool/workpiece interface, and this steam blanket minimizes lubricity.

   The level of solids can be controlled through filtration, and the level of solids and water should be checked periodically to monitor the condition of the oil.

5. Acid number — In oil-based fluids the acid number denotes the level of acid-type components that influence the behavior of the fluid. When oil is oxidized, the acid number increases and adverse chemical reactions, such as the formation of insoluble metallic soaps, can occur. Therefore, it is important to monitor the acid number.

6. Additive content — The additives used to blend gear cutting and grinding fluids are depleted through use; therefore, additive levels must be carefully monitored. The load bearing capacity of a fluid is related to the concentration of the additives.

7. Record keeping — A logbook should be maintained to record the test data. This logbook can be used to track the performance of the oil in a system.

Quality Control of the Operating Emulsified Fluid. To effectively maintain an operating emulsifiable fluid, the operator is advised to observe several basic points.

1. Handling and storage — A good emulsion starts with good storage conditions for the neat oil. The complex chemical make up of most emulsifiable fluids requires the storage of neat oil at ambient temperatures. If the neat oil is frozen, it should be allowed to return to ambient temperature prior to mixing the emulsion.

2. Mixing — As a general rule, most emulsifiable fluids are added to water in the reservoir while agitating to form the emulsion, but the supplier should always be consulted for correct mixing instructions.

3. Water source and composition — Because water is a major compo-

nent of an operating emulsifiable fluid, its quality plays a large part in operating effectiveness. The life of the emulsion in the reservoir, foam characteristics, tool life and product quality are all influenced by the quality of the water. Make-up water should be as pure as possible. Distilled or deionized water is ideal, as hard water, which is contaminated with minerals and dissolved salts, adversely affects the emulsion. Basically, the minerals and salts can cause corrosion problems in the equipment, and they can react with the emulsifiers in the fluid to produce hard water soaps which adversely affect emulsion stability and lubricity.

A reservoir supplying a gear cutting or grinding machine is hot and aerated, which causes the water to evaporate. As this occurs, dissolved salts and minerals increase in concentration, and, thus, evaporation accelerates the formation of hard water soaps. To counteract this problem, one should consider the use of deionized water, boiler water condensate or softened water to make up water lost to evaporation.

4. Bacteria – In many systems, bacteria can become a problem because bacteria degrade the emulsion by digesting the emulsifiers and fats. This problem becomes more severe as the bacteria secrete acidic wastes which adversely affect the pH of the system. Changes in pH affect emulsion stability and lubricity. There are a number of bactericides available to control the problem.
5. Temperature – The temperature of emulsions used to cut or grind gears must be kept between 100° and 130° F. This is important for several reasons.
   a. If the emulsion is too cold, it may not be fluid enough to be pumped to the tool/workpiece interface. This could "starve" the tool and adversely affect tool life and product quality.
   b. If the emulsion overheats, the high temperature degrades the emulsifier package, which affects stability. The higher temperature also does not allow for efficient heat transfer at the tool/workpiece interface. This lack of cooling can result in poor tool life and product quality, and oxidation of the oil phase of the emulsion. As a corollary to problems caused by heat, the rate of chemical reaction is increased and the formation of insoluble metallic soaps is accelerated.
6. pH – pH is a measure of the acidity-alkalinity of a fluid. pH is controlled by the content of the polar additives, such as fatty acids. As detailed earlier, these polar additives are responsible for a fluid's lubricity. If the pH falls because of exhaustion of polar additives, lubricity will be diminished; whereas, if the pH rises too high, the emulsion will become unstable. Since the fatty acids affect pH, it is important to measure them and maintain pH at recommended operation levels. It is best to maintain pH with regular additions of neat oil.
7. Concentration – Maintaining the correct concentration of neat oil in the reservoir is important because tool life and product quality will suffer if the lubricity of the fluid is excessively diluted. Concentration can be monitored by the Babcock Method or by a hand-held refractometer.
8. Filtration – A clean fluid is essential to maintaining the emulsion, tool life and product quality. Gear manufacturing fluid compounds can be contaminated rapidly with things such as oxide, chips, tramp oil from lubricating or hydraulic systems and even items such as food, rags and mill dirt. If these contaminants are not removed from the system, the effective life of the fluid is shortened and product quality and productivity falls.

   To overcome the inherent problems associated with disposal and replacement of lubricants, it is important to filter the emulsion and extend its useful life.
9. Foaming – Care must be taken to maintain pump seals so as to minimize pump cavitation and reduce foam. Excessive foam minimizes effective cooling and lubrication at the tool/workpiece interface.
10. Record keeping – A log book which can be used to record additions of neat oil, temperature, concentration, pH, etc. is important. The log book is a handy reference, providing a record of the operating systems.

Testing in the Plant

Several steps are required to insure a successful in-plant testing program.

1. Obtain management commitment for a testing program.
2. Select a person to coordinate testing. This person will serve as an in-plant consultant and also promote education of employees as to fluids.
3. Identify problem areas and initiate a program to evaluate lubricating fluids.
4. Select vendors who are up to date relative to the OSHA Hazard Communications Program.
5. Monitor direct costs such as cost per gallon, cost per pound and cost of additions.
6. Monitor indirect costs, such as maintenance additives, cost of disposal and dumping frequency.
7. Find out if oil-based compounds can be reclaimed to avoid problems with disposal.
8. Monitor tool life by considering original cost and reconditioning cost.
9. Consider finished product quality versus raw material utilized.
10. Monitor the condition of the fluid and of the gear manufacturing equipment relative to the fluid being used.
11. Evaluate the test program and report results to management.
12. Implement changes where the evaluation justifies the need.

13. Expand and maintain the testing program so as to be prepared for unexpected problems.
14. Be receptive to change as new technology supercedes the old.

After the testing program has been established, it is important to have some means of measuring the effectiveness of a given fluid when it is used on gear hobbing, gear shaping or hard gear finishing operations. Several test techniques are available that go beyond the simple tool life test.

"On-Line" Monitoring — Today's state-of-the-art CNC controls allow "on-line" optimizing and monitoring of cutting conditions during machine operation. The information can be collected on a peripheral microcomputer and analyzed relative to changes in cutting fluids. At the same time, new electronic gear checking equipment can be used to monitor such things as changes in pitch, involute and lead given changes in cutting fluids or grinding fluids.

Statistical Quality Control — With the advent of statistical quality control, it is now possible to monitor product quality relative to changes in the fluids used on a given gear hobber, gear shaper or hard gear finishing machine. The quality of the finished gear can vary significantly based on the type of fluid being tested within the equipment.

Transducers for Force and Torque Measurement — A multi-component transducer can be used for analysis of grinding. This instrument provides a measure of two forces, the vertical force and the vertical torque. In a typical application, this instrument would be mounted on the work table of the grinder and the test piece attached in a fixture on the top of the instrument. The ratio of the vertical force and the feed force is essentially a measure of the grinding fluid's effectiveness.

New Developments

There are several new developments in the field of lubricating fluids for the gear manufacturing industry.

Microemulsions are generally clear like synthetic solutions. Really an offshoot of semi-synthetics, microemulsions contain a small amount of mineral oil in addition to the other components which are soluble in water. The difference is that microemulsions are formulated to have smaller micells than semi-synthetic emulsions; hence, they have more dispersed particles. The small micells allow almost all incident light to be transmitted. The small micells mean microemulsions are generally more stable than soluble oils or semi-synthetics. Microemulsions have a number of other advantages including low tendency to foam, non-corrosive properties, high detergency and wet out, reduced tendency to form insoluble soaps, easy mixability and longer life.

Synthetic hydrocarbons compounded with suitable diester fluids are yielding new high-molecular-weight synthetic fluids with superior viscosity index and shear stability compared to convential polymer-based viscosity improvers in hydrocarbon base stock. Synthetic hydrocarbons exhibit excellent oxidation and hydrolitic stability and have a very high film strength. These synthetics are more resistant to breakdown under high temperature, and they are now being blended into a number of different gear cutting and grinding oils. Synthetic hydrocarbons will probably not come into more widespread use until their cost decreases.

Conclusion

This article has reviewed lubrication theory, fluid formulation, testing and process controls. Particular emphasis was placed on factors affecting fluid selection, classification and testing, to shed light on the chemical background and maintenance of gear cutting and grinding fluids. Rapid advances in gear manufacturing technology, combined with customer demands for improved product quality at lower cost, are making it essential that manufacturers of gears obtain maximum utilization from every fluid used in a plant. Careful attention to the techniques outlined in this article can improve fluid maintenance through systematic checks. The attention paid to lubrication should yield improved product quality, higher productivity and lower overall costs.

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Appendix A

Human Compatibility. Cutting fluids must be assessed not only from a physical, chemical and metallurgical standpoint, but also from the point of view of operator acceptability and safety. Health and safety considerations are discussed in Appendix A.

After the physical, chemical and metallurgical studies have been completed, it is important to assess the fluid's acceptability from a operator's standpoint. The oil-based or water-based fluid of choice should not cause physiological problems. It is important to recognize that no material is competely hazard-

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CUTTING FLUID SELECTION . . .

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free, but most fluids can be handled safely given adequate safeguards.

One cannot simply pay lip service to the acceptability of a given lubricating fluid. Both labor and the general public are now demanding that industry operate in a responsible manner that protects the health of workers, the general public and the environment. Increasing public pressure prompted by major chemical accidents in Bhopal, India, and several similar, but less serious, accidents that occurred in West Virginia, has prompted the federal and state governments to enact a number of new laws aimed at eliminating or reducing risk of exposure to hazardous chemicals.

One such law is the new federal standard on Hazard Communication (29 CFR 1910:1200) that was established by the Department of Labor, Occupational Safety and Health Administration (OSHA). As of November 25, 1985, chemical manufacturers, importers and distributors are required to:

a. Label containers of hazardous materials and to provide Material Safety Data Sheets (MSDS) to anyone purchasing these chemicals,
b. Notify their employees of the hazardous materials in the workplace,
c. Demand appropriate training as to the safe handling and use of these materials,
d. Properly label all hazardous materials at the workplace,
e. Properly label all products shipped from suppliers,
f. File Material Safety Data Sheets (MSDS) that provide additional health and safety information on all hazardous materials in the workplace,
g. Post employee rights under the act,
h. Be in compliance with all requirements of the Standard as of May 25, 1986, as an employer in SIC Codes 20-39.

The new federal Standard on Hazard Communication has had a significant impact on all compounds containing petroleum derived base stocks because OSHA has adopted the reports of several major research groups into the Standard.

The International Agency for Research on Cancer (IARC) has determined that some base oils are carcinogenic. An oil product which contains more than 0.1% of such a base oil will be required by OSHA to have a statement on the Material Safety Data Sheet that it contains a carcinogenic component, and that component must be identified. The product container must also be labeled with such information. The oils in question are primarily napthenic oils that have not undergone severe hydrogenation or solvent extraction.

At the same time, OSHA also requires that any product that contains a component having a polynuclear aromatic (PNA) content greater than 0.1% to contain a statement to that effect on the MSDS, as substances that contain PNA are considered carcinogenic. Again, the product container must be labeled with such information.

Chlorine in the form of chlorinated paraffin is a widely used extreme pressure agent. Chlorinated paraffins have been tested, and OSHA requires that two types of these materials must indicate the presence of a carcinogen on both the drum label and the MSDS.

The concern over the carcinogenic nature of some base oils is justifiable from a health standpoint, as well as from the viewpoint of potential for adverse employee reaction and litigation. Users of all types of lubricating fluids are advised to be familiar with the Standard and come into compliance.

Most manufacturers of gears use a wide variety of lubricating fluids and various chemicals, but do not actually manufacture or import them for sale to others. Therefore, the May 25, 1986, date was the important cutoff for employers in SIC Codes 20-39, in that their Hazard Communications training program had to be in place by that date.

There is a good deal of confusion relating to the labeling of non-chemical products. The OSHA standard does not require manufacturers of non-chemical products to label or to supply Material Safety Data Sheets to customers. The Standard provides complete exclusion for four categories of items including articles. Gears are an example of an article. While customers of those items may request Material Safety Data Sheets from their suppliers, it is not a legal requirement for the supplier to provide one. Ultimately, many suppliers of articles are providing Material Safety Data Sheets, but it really is not necessary.

The OSHA Hazard Communication requirement is a good one, and management should support the law to the fullest extent possible. There has to be a genuine commitment to increasing the health and safety of both labor and management. The compliance program must start from a base of respect for every individual employed by a company. No company has ever gotten into financial difficulty or in trouble with OSHA because it adhered to a strict set of ethical principles.

Acknowledgement: *Presented at the SME Gear Processing and Manufacturing Clinic, November 11-13, Schaumburg, IL.*

TECHNICAL CALENDAR

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CALL FOR PAPERS

ASME 5TH INTERNATIONAL POWER TRANSMISSION AND GEARING CONFERENCE

The sponsors are issuing a call for papers to be presented at this conference to be held in the fall of next year. The deadline for submissions is Sept. 30, 1987.

This conference will focus on such topics as gear efficiency, noise, dynamics, geometry and lubrication, chain and belt drives, bearings, shafting, clutches and brakes.

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