

"NEXT GENERATION SYNTHETIC FORMING FLUIDS"
BYLINE: ADVANCED TECHNOLOGY LUBRICANTS IMPROVE PRODUCTIVITY
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Introduction and Types of Fluids

Besides the metal forming equipment, metal forming, stamping, or drawing are dependent upon three basic elements: the metal substrate, tooling, and lubrication. The deformation process and its severity create both friction and heat that lubrication is designed to reduce. Lubricants perform when they control and aid the following:

- 1.) Friction reduction between the metal and the forming tools or dies.
- 2.) Lowering wear rate of dies and tooling.
- 3.) Allowing smooth surface finishes by preventing metal pick-up, welding or scoring.
- 4.) Cooling the metal to minimize any effect on the metal's gauge or metallurgical properties.
- 5.) Maintaining the desired shape of the parts.

The various forming operations can be categorized as:

- a.) Bending
- b.) Blanking
- c.) Drawing
- d.) Extruding
- e.) Piercing
- f.) Punching
- g.) Stamping

Each of these can range in severity from easy to very difficult depending on the metal's size, thickness, surface condition, and metallurgical properties. Lubrication application techniques can vary widely and include spray, flood, roller coat, immersion, drip, and manual methods. The fluids can be recirculated or applied with electrostatic precision to minimize costs or they can be dried after application to provide a tightly adhering film. Some lubricants are chemically bonded to surfaces.

The types of lubricants available are:

1. **Straight Oils** or neat oils. These products use a petroleum oil base and are compounded with boundary, and EP (extreme pressure) additives. They are usually easy to apply, offer good corrosion protection, but can be more expensive than water solubles. Straight oils are typically used as is with no dilution.
2. **Water Soluble Oils** or emulsifiable oils. These products are similarly formulated as straight oils but with emulsifiers. When mixed with water, they form emulsions and provide most of the additive benefits along with more efficient cooling. Corrosion and product stability issues can be draw backs. These soluble oils are usually easier to clean

than the neat oils in alkaline wash systems.

3. **Synthetic Lubricants** are always water based and by definition free of petroleum oils. These products dissipate heat very effectively, are clean running, remain very stable under severe conditions, and are easy to clean. They are often limited in performance when used in severe applications.
4. **Semi-Synthetic Lubricants** are blends of water, petroleum oils and emulsifiers. When mixed with water, they form opaque emulsions. They offer the benefits of synthetic lubricants and additional lubrication for utilization on both ferrous and non-ferrous metals.
5. **Dry-Film Lubricants** are normally composed of soaps and/or polymers in an aqueous matrix and then dried before being used in the forming process. Their tight films often offer excellent benefits in performance, handling, equipment cleanliness, and cleanability. They need special application equipment to ensure uniform films and complete drying. However, they may not be applicable to all metal shapes or forming processes especially when lubricant reapplication is required.
6. **Chemically Bonded Agents** such as metal-plated coatings offer outstanding lubrication as the metal deforms and stretches, but are expensive and require very specialized coating processes. Additional lubrication may be required, thus increasing costs. Waste treatment issues are often major concerns with chemically bonded films.

Lubricant manufacturers understand that the composition of the lubricant can have a dramatic impact on the process. Viscosity, wettability, lubrication properties, extreme pressure additives, and cooling properties can significantly impact tool life, part quality and productivity. The quantity of additives and their stability under the metal forming processes are also very important considerations. Lubricant mechanisms that the formulator and application can utilize to reduce friction, dissipate heat and prevent metal galling are:

- a.) **Hydrodynamic (fluid lubrication)**: The lubricating fluid acts as a film separator under moderate pressure conditions.
- b.) **Boundary**: Polar additives such as fats or solids like graphite provide a cushion or separation under heavier pressures. Boundary lubricants form a passive film on the metallic substrate and tooling.
- c.) **Extreme pressure**: These chemical agents such as sulfur, chlorine, and phosphorous during the metal deformation processes form compounds with iron under the heaviest pressure and temperature conditions. Extreme pressure lubricants form a chemical film that bonds to the metallic substrate and tooling.

EMERGING TRENDS AND FLUID SELECTION FACTORS

The current marketplace for forming lubricants is being driven by many factors including two predominant trial factors, which are significantly intertwined. First and foremost, manufacturing technologies are escalating rapidly, both in response to customer demands and requirements,

increasing competitive pressure from overseas manufacturers, and the resulting shrinking domestic market share and improvements in machine, tool design, and composition.

Manufacturing technologies continue to place greater demands on the forming lubricants and other process lubricants they require to efficiently perform up to today's critical standards. These technologies include:

1. Companies switching from long production runs of single parts to an ever changing blend of customized runs with short, specialized runs of parts for niche applications.
2. Need for faster production speeds, often resulting in higher operating temperatures on a regular basis for both tooling, parts, and forming lubricants. Higher operating temperatures have led to the development and increased use of coated tooling, use of in-die tapping, and progressive dies in multi-stage presses. Forming lubricants must exhibit improved oxidation and thermal stability in response to the higher operating temperatures. Development of specialized application equipment in conjunction with faster speeds requires forming lubricants which exhibit improved wetting, penetration, and coverage capabilities on both tooling and part substrates. The lubricants must exhibit compatibility with all facets of the tooling over long term use. Various additives present in the forming lubricants cannot chemically or physically degrade these chemical coatings. Often, specialized corrosion inhibitors are incorporated into the forming lubricants to improve long term capability.
3. Changing metallic substrates being used for global applications. The increasing use of aluminum, galvanized and other non-ferrous substrates in automobile, appliance, and other durable good markets has increased and changed the lubrication demands of today's forming lubricants. Aluminum content of automobiles is increasing on an average of 4% per annum in the United States. Improved surface finish requirements are necessary to address customer demands for aesthetics or preparation for post treatment operations such as painting. This has resulted in changes in the types of boundary and extreme pressure lubricant additives used and is eliminating others such as chlorine. The increasing trend toward the use of non-ferrous, galvanized and coated metals also requires specialized chemistries in terms of corrosion inhibitors and alkalinity. Normal use pH for metals is usually limited to range of 8.0 to 9.2 for non-ferrous metals versus 8.0 to 10.5 for ferrous substrates. Corrosion inhibitors with a high degree of surface activity are required to prevent formation of aluminum oxides and zinc oxides which can lead to subsequent staining or corrosion.

Lower grade metals with specialized coatings are also being used more for specialized applications where lower material costs can help offset higher production costs for short run jobs requiring long set up times or specialized tooling.

4. Evolving technologies for the post treatment of formed metals including the use of rivets and structure adhesives as replacements for traditional welding. Automotive manufacturers are increasingly turning towards the use of specialized rivets and structural adhesives for the joining of auto body components such as quarter panels, floor panels, and doors (inner to outer). Often, applied structural adhesives do not fully cure until the car has been painted and fully cured. Hydroforming has also increased the size of structural elements, reducing the actual number of elements and subsequent methods of attachment, such as welds. Regardless of the method, surface cleanliness is

of the utmost and forming lubricants must exhibit excellent cleanability with the mildly alkaline or near neutral aqueous cleaners used today in many industries. Aqueous cleaning agents and processes used in other industries must also be capable of removing traces of forming lubricants to allow for proper and successful post treatment processes including adhesive bonding, application of phosphate coatings, and all types of painting.

Secondly, new synthetic chemical technologies are being introduced to the marketplace for use in both drawing and stamping lubricants. Today's synthetic technologies have been developed in response to several market driven factors. The most significant are the requirements for non-petroleum, oil based products. Seeking viable replacements for petroleum based products parallels a strong trend seen over the past few years in machining fluids (cutting and grinding fluids). The development of successful synthetic fluids (containing no petroleum hydrocarbon) to replace semi-synthetics, water soluble oils, and straight machining oils has advanced significantly with the development of new lubricant base stocks in both the United States and Europe. Processing and environmental issues have also stimulated these changes.

Several issues exist regarding the use of petroleum oils in forming and machining fluids. Unstable petroleum prices due to world conditions have impacted lubricant raw material prices and availability of base stocks. Increasing health concerns with oil mists, especially in the United States and Europe, has pressured users to seek alternate chemical technologies. These have included utilizing chemical agents for mist suppression (short performance life due to shear instability and high costs) and forced the expenditure of millions of dollars for mist collection systems and new equipment designs that reduce or eliminate worker exposure to oil mist. Pending legislation, at the local, state, and Federal levels, has also prompted the time for change to synthetic technologies.

Petroleum oil-based products also create incompatibility problems with many post treatment processes. Cleaning lines often have to incorporate more aggressive cleaning agents, higher operating temperatures or longer exposure times to compensate. While improving cleanability, these conditions are often incompatible with the metallic substrates being cleaned or are too costly. The presence of petroleum hydrocarbon oils also impacts on environmental issues, especially in the Western Hemisphere. Waste treatability processes can successfully remove petroleum hydrocarbons in one of many stages but often requires the use of specialized emulsion breakers or polymeric molecules to physically and chemically separate the oils from the aqueous waste stream. These chemicals are costly, often necessitating additional application equipment and process time. Disposal costs for waste oil continues to increase exponentially, often several hundred dollars per drum depending upon the waste stream content and blend. Landfill and incineration are also expensive and ecologically unsound.

Today's additive suppliers have developed viable and sound lubricant additives as replacements for petroleum oils for use in synthetic forming lubricants. The development process has resulted in both boundary and extreme pressure lubricant additives for synthetic forming lubricants that have commercially replaced oil based products used on both ferrous and non-ferrous metals. Synthetic esters based upon a wide variety of hydrophobes have achieved widespread use in both true solutions and synthetic emulsions. These esters offer outstanding hydrodynamic and boundary lubrication, wetting, solubility characteristics, aqueous cleanability, and waste treatability in a variety of formulations. Polymeric esters of higher molecular weights have exhibited excellent results in many stamping and drawing formulations. Their higher molecular weight offers enhanced lubrication under conditions of high temperatures or high metallic stresses.

Vegetable oil derived base stocks and esters have also found commercial utilization in a variety of formulations. Because of their natural origins, they are environmentally friendly and being utilized in more lubricants for environmentally sensitive applications. These lubricants are readily biodegradable and exhibit excellent lubricating properties over a wide temperature range. Their high viscosity index, i.e., their viscosity does not vary as much with temperature as mineral oils, allows them to be used in forming lubricants, total loss lubricants such as mist lubes and in specialty hydraulic fluids. Vegetable oil based chemistries have also been genetically modified to alter their fatty acid distribution for enhanced high temperature performance and oxidative stability.

Lubrication results for a variety of true solution synthetics are presented in Graph A versus a typical sulfurized water soluble oil utilizing the Tapping Torque Test Machine. Tests were conducted using ASTM D 5619-94, "The standard test method for comparing metal removal fluids using the Tapping Torque Test Machine." Torque required to tap a series of threads with a blank metallic nut is measured and compared between that of a series of lubricant formulations and that of a reference fluid oil. The rates of the average torque values of the reference oil to the test fluids is expressed as the percent relative efficiency. Relative efficiency values can be compared using the average torque values from the reference fluid on taps (tooling) proven to be statistically equivalent. This test regime evaluates lubrication across the entire spectrum from hydrodynamic and boundary zones into extreme pressure. Lubricant depletion ultimately occurs and eventually lubricant film degradation. Results are for a 1:1 dilution in water on 1018 steel. Four synthetics were evaluated versus the commercial sulfurized water soluble oil. The synthetics incorporate a wide range of boundary and extreme pressure lubricants including a base synthetic ester, plus chlorinated ester, plus a block polymer and synthetic ester in conjunction with a vegetable derived ester. Three of the synthetics exhibited significantly high relative efficiencies versus the sulfurized water soluble oil using the 95% confidence interval. The higher the relative efficiency, the better the lubrication. Base synthetic ester in conjunction with vegetable derived ester exhibited a synergistic effect and outperformed all of the other lubricants. These results have been proven out in field testing under commercial conditions.

Chlorine has been utilized for years as an economical source of extreme pressure lubrication in all types of forming lubricants. Chlorine has come under increasing scrutiny for environmental issues. Many companies have now severely restricted or banned its use in forming lubricants. Chlorinated chemistries also exhibit limited solubility characteristics and can contribute significantly to corrosion problems due to its poor hydrolytic stability. Sulfur has also found limited use in synthetics for similar reasons. Physical properties and aesthetics of sulfur have also limited its use to water soluble oils and straight oils.

Phosphorus is enjoying a resurgence as an extreme pressure additive in forming lubricants. Lubricants based upon phosphorus exhibit good solubility characteristics and hydrolytic stability. In addition, they contribute to corrosion inhibition and improved wetting characteristics of most synthetic formulations. Phosphorus based chemistries are easily formulated into both true solution and emulsion type synthetics. Esters based upon phosphorus exhibit excellent extreme pressure properties for forming of both ferrous and non-ferrous metals. Polymeric esters, based upon different hydrophobes and phosphorus, offer a balanced blend of both hydrodynamic, boundary, and extreme pressure lubrication properties. Polymeric esters containing phosphorus also offer improved resistance to formation of calcium and magnesium soaps in hard water applications over normal phosphate esters. Synthetic formulations containing phosphorus may exhibit susceptibility to microbiological degradation, requiring the incorporation of enhanced alkalinity and microbiological resistance into their formulations.

MARKET TRENDS

With the advances in chemistries, applications, and equipment, there are new and better technologies for synthetic drawing and stamping compounds. From these developments, the next generation of synthetic stamping and drawing fluids are entering the marketplace. These products are oil-free and water reducible. This new technology is significantly advanced over the so-called synthetics that are presently in the market place. The newer chemistries have vastly improved lubricating properties, lower solids which are easier to clean and extend the life of the cleaner bath. They also offer excellent corrosion protection, exhibit less die build-up, improve welding properties, and most of all are economically favorable to the user's bottom line – improved profitability.

The affinity of these new lubricants to the metal surfaces reduces and/or prevents metal to metal contact. The severity of the job will dictate the dilution ratio of the base product. Modifications and variations of the formulation can vary the type of film characteristics from a chemical adhesion (extreme pressure) thin film at the surface of the metal to a combination of the chemical adhesion film and an additional film former (boundary lubricant, i.e., heavier film). These product variations are dictated by the operations, metals, and type of equipment (automatic or mechanical presses).

The heat reduction on the workpiece is significant. Parts come off the press cool to the touch, eliminating the need for gloves to handle the parts. The selection of the drawing/stamping product is a job by job consideration depending on the application.

The new generation of synthetic lubricants is very environmentally friendly. They are infinitely diluted in water. The disposal of any fluids is dictated by the local regulations for waste disposal. There are no hazardous materials in the product. They are very operator friendly.

CONCLUSION

Advances in lubricant technology will continue to be demanded by manufacturers facing global competition. Although lubricant prices may climb because of rising costs of specialized additives, the overall lubricant production economies will be realized through higher production rates, improved surface quality, lubricant abilities to handle a variety of metal substrates, and reduced down stream problems including waste treatment costs. More synthetic lubricants and formulations without chlorine will gain market share as manufacturers experience and recognize the benefits of these modern chemistries.

PICO Chemical Corporation has been in business since 1976 and is an ISO 9001:2000 registered manufacturer of value-enhanced specialty chemicals and lubricants to clean, condition, lubricate and protect steel, metalworking, metal finishing and related industrial processes. The company ships its products to both domestic locations and overseas locations.