Synthetic Lubes for Forming and Postprocessing

Growth in value-added services require metal-working companies to develop new strategies for lubricant use—synthetics meet the challenge.

BY PAUL BOSLER JR.

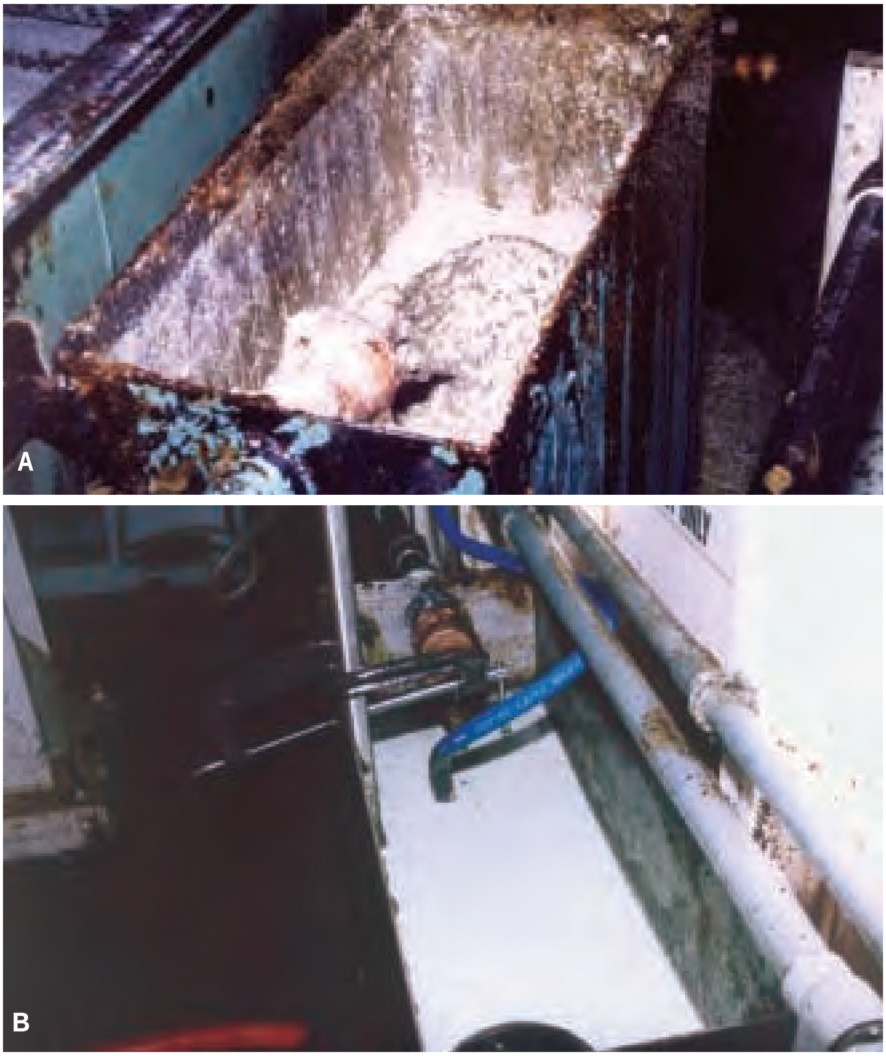

Fig.1—Emulsifiers in oil-based lubricant can become unstable as they dilute among tramp oils, allowing segregation of lube ingredients such as fats, resins and base oils. This is shown as buildup on a press-lubricant-applicator reservoir (A). Some synthetic lubricants not only do not build up, they can remove previous buildup, as shown on a similar reservoir (B).

Metalforming companies have been faced with competitive challenges that test their abilities to remain profitable. Profit margins on basic metalforming jobs have diminished while associated responsibilities and costs have increased. Today's successful metalforming companies look to create value-added services to distinguish itself and to generate additional profits. These efforts have required companies to establish internal systems or form allegiances with contract companies that provide welding, metal finishing or assembly.

The successful metalforming company also distinguishes itself through

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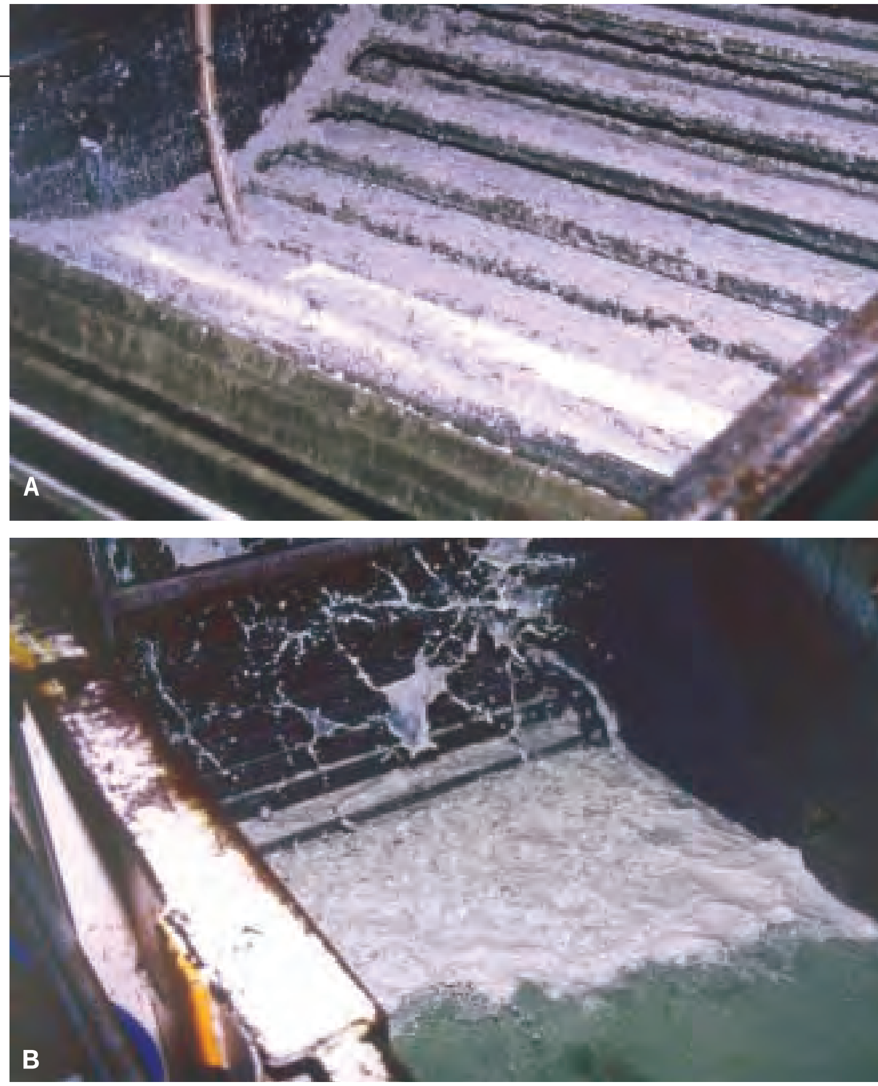


Fig. 2—This photo of a blank-wash reservoir shows how tramp oils remain in the emulsion of an oil-based lubricant (A), complicating recycling operations. A photo of the same reservoir with synthetic lubricant (B) shows how green prelube contamination floats rather than emulsifying into the bath, making contamination removal a more simple process.

higher-exposure programs. Quality-control certifications such as ISO or QS 9000 and environmental programs such as ISO 14000 provide saleable features for a company, and subject it to plant tours and customer audits. To optimize this scrutiny, the successful company strives to exhibit pride in its appearance, procedures, safety and technology. In such endeavors, the company must reevaluate many aspects of its overall processes.

Any continuous improvement must begin with the most basic aspects of production that offer the most far-reaching effect. Using this criterion, there is no better candidate than the lubricant used in metalforming operations.

Lube History

A metalforming lubricant must protect tooling and facilitate formation of quality parts. It must protect against galling and promote controlled material flow to avoid fractures, thinning or wrinkling.

Age-old petroleum-based lubricants, especially oils with extreme-pressure (EP) additives, generally had been accepted as the most effective products for severe work. Draws that experience highly localized pressures and temperatures—heavy-gauge crush-and-forms, ironing operations, tight-tolerance parts, etc.—require exceptional lubricant performance. But ingredients that promote high performance in petroleum lubricants also can adversely affect post-processing, plant housekeeping, safety and disposal. These problems create costs and liabilities. In this sense, petroleum-based lubricants fulfill only some needs of a value-added metalforming company.

Alternatively, because synthetic lubricants are water-soluble, they generally are understood to facilitate post-processing procedures. But no post-processing benefit can compensate for problems in stamping or interim parts storage, properties traditionally sought by metalformers in choosing lubricants. Historically, synthetic lubricants had not been considered to be high-performance products. They cannot incorporate the high percentage level of EP additives, such as chlorine and sulfur, found in many oils. Also, water-based lubricants were regarded as incapable of providing adequate interim anticorrosion protection. Water-soluble products allow water to contact material substrate and can promote corrosion, especially in zinc-coated alloys. Zinc, a sacrificial coating, easily forms zinc oxide as a barrier that protects the base material from red rust. This reaction often occurs when wet parts are stacked together. Water acts as a conducting medium between material surfaces, promoting galvanic bridging that results in corrosion. Most synthetic lubricants incorporate ingredients found in water-soluble antirust products such as amines, carboxylates or borates. However, when used as antirust products, these types of rust-prevention agents usually are dried on the material prior to storage. In a wet-stack condition these ingredients are ineffective in inhibiting galvanic bridging.

Automotive Requirements Raised the Bar

In the late 1980s, automotive companies required job shops to adhere more stringently to the use of their approved lubricants. Until recently, no true synthetic lubricant had passed the anticorrosion criteria established by the Auto/Steel Partnership (A/SP).

The OEM approval process sought to ensure that lubricant residue on parts was compatible with automotive body-in-white painting processes and with sealers and adhesives. Part of this test criteria required that parts would not rust prior to processing. Originally, OEM lube-approval lists provided an internal benchmark of products that could be used for fabrication of Class A body panels.

Traditionally approved lubricants included petroleum oils—mill oils or prelubes, or emulsifiable oils generally used in blank-wash operations. Oils containing the most effective EP additives such as chlorinated paraffins generally could not pass the test regime, so the approved oils were medium-duty products that did not incorporate the best ingredients available to enhance petroleum performance in metalforming. As a result, automotive job shops had no approvals for heavy-duty lubricants for severe metalforming jobs on parts that enter body-in-white paint systems.

But recently, one synthetic lubricant, Mid-State Chemical's Eco Draw HVE-1, passed these stringent requirements and was approved by most automotive companies. Now, at least one synthetic lubricant can provide substantial anticorrosion protection on relevant materials. This lubricant also is among the many developing synthetic lubricants that provide high performance in stamping operations and benefits to post-processing.

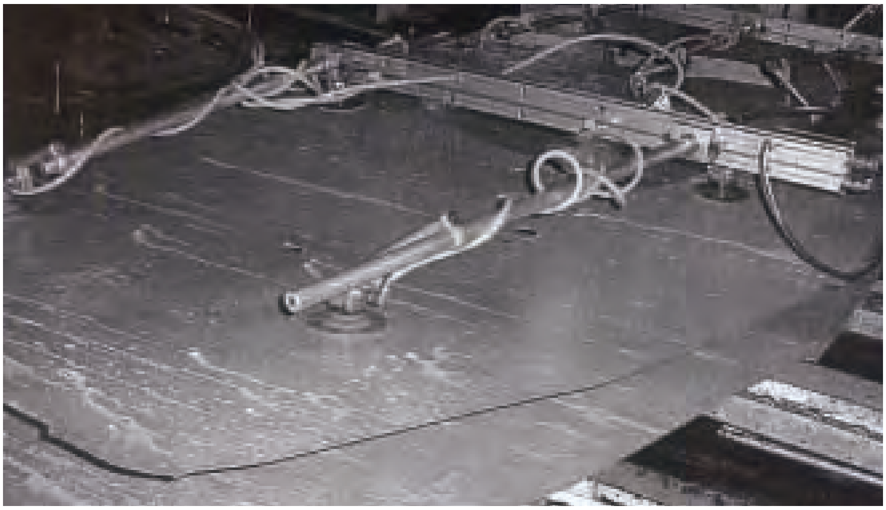


Fig. 3—Mill-oil coatings can repel emulsions and some water-based lubricants, which tend to puddle on blanks in the migration lines of mill oil.

Oil-Based vs. Synthetic Lubricants

To understand the developments and benefits of synthetic lubricants, one must first compare aspects of this technology to the formula systems of oils. In general, oil-based lubricants are available in three forms: nonemulsifiable straight oils and two types of emulsifiable oils. For stamping, nonemulsifiable straight oils generally find use as mill oils or as prelubes, applied at the steel mills to steel coils primarily for corrosion protection. Prelubes contain mechanical EP additives that can enhance forming, and even mill oils provide some limited lubricating properties. If used as press-applied lubricants, these products usually are neither comparatively efficient nor economical. Oils retain heat and these products cannot reasonably be diluted. By the same token, no lubricant, petroleum or synthetic, that is diluted with water will provide sufficient anticorrosion protection for steel-coil storage. Extreme compression occurring in the steel coil negates any chemical or boundary film in any water-containing lubricant system.

Water-emulsifiable oils represent the alternative petroleum technology. These oil-based formulas can be diluted in water. Generally, two types of emulsifiable oils find use in metalforming environments: those containing chemical EP additives (chlorine, sulfur or phosphorous) and those that do not.

Chemical EP additives react with the material surface to create a sacrificial coating in the form of an iron-chloride or iron-sulfide crystal structure. This coating provides additional protection, especially when heat from friction melts the boundary protection of other ingredients. In fact, heat activates chemical EP additives. In oil-based lubricants, waxes or fats often serve as carrier agents for EP additives. These agents are very tenacious and difficult to weld through or clean. Also, EP additives are potentially corrosive. For these reasons, oils with chlorine or sulfur do not perform well in automotive approval tests but are considered high-performance lubricants.

Water-emulsifiable oils without chemical EP additives may contain base oil and emulsifiers, but more commonly also contain boundary additives such as esters, fats or sulfonates that improve performance. These products make up the bulk of automotive-approved oils.

Note that oils mixed with water commonly are termed "water-soluble oils" whether or not they contain EP additives. However, there is no such thing. Petroleum formulas that mix with water are referred to correctly as "emulsifiable." This distinction is more important than simple semantics. Solutions and emulsions have vastly different properties and perform quite differently. Usually, oil does not mix with water, but oils can be made to emulsify.

Ingredients such as sulfonates and some surfactants are both water and oil soluble and can act as emulsifiers. When blended with oil, and when the resulting formula is mixed with water, these ingredients create a dispersion of oils suspended in water. The dispersed oil droplets remain distinct from the water so that no real synergy occurs with the water—the water acts more as a carrier or dilutant. As a result, the oils offer only limited heat-transfer or cooling effects. Parts and tooling can become very hot, so oils become much more reliant on the effect from EP additives to compensate for the viscosity breakdown and tooling expansion resulting from heat effects.

Importantly, an oil emulsion requires a delicate balance of oil/additives and emulsifiers. These emulsifiers do not react only to the oil in the original formula. If other oils such as mill oil, hydraulic fluids and tramp oils enter the emulsion, the emulsifiers can attach to these oils and make them part of the mixture. This brings three effects:

• The integrity of the mixture is compromised.

• As the formula emulsifiers dilute among tramp oils, emulsion balance is disturbed. The emulsion can become very unstable and allow segregation of ingredients such as fats, resins and base oils (Fig. 1). Also, chlorine corrosion inhibitors can segregate and allow chlorine to attack steel. All of these effects hinder performance and create a mess.

• Tramp oils remain in the emulsion, particularly problematic when trying to maintain formula integrity in recycling operations (Fig. 2). A filter

Batesville Opts for Synthetic Metalforming Lube

Batesville Tool and Die (BT&D), Batesville, IN, as part of its continuous-improvement efforts, recently experimented with synthetic forming lubricant. Testing went well, leading the company to switch to Eco Draw HVE-1 from Mid-State Chemical, Indianapolis, IN.

BT&D provides specialty stampings for automotive and appliance industries among others. As a job shop, it works with a variety of metal alloys and provides a range of stamped parts from heavy-gauge stampings to light-gauge forms. Also, BT&D creates tooling for fabrication of difficult parts via laser cutting. For value-added work, the company operates several gas-metal-arc-welding cells and two parts-finishing lines.

In recent years, the company has grown to become a major producer of motor housings and other deep-drawn parts that require significant performance from a stamping lubricant. Initially, the company used water-emulsifiable chlorinated oils as draw lubricant, which performed satisfactorily in severe stamping operations and generally met fabrication needs. But the company policy toward continuous improvement motivated officials to experiment with synthetic lubricants in stamping operations. To judge lubricant performance Batesville developed a set of parameters, scrutinizing:

- Lubricant use cost
- Part quality after 2000- and 20,000-part runs
- Tool-life comparisons
- Anticorrosion characteristics after six weeks of high humidity
- Weldability
- Part-cleaning characteristics
- Effect on safety and housekeeping
- Effect on waste disposal.

Initial results revealed improvements to post-processing, housekeeping and general safety, but ability to positively affect tool life was lacking.

But one synthetic lubricant, Eco Draw HVE-1, surpassed the BT&D parameters, including those related to tool life.

The lubricant contains extreme-pressure additives and film enhancers that allow it to perform as well as chlorinated oils in deep-draw operations, according to Mid-State Chemical officials. BT&D officials found that the lube actually cooled parts as compared to runs with oil, and, as a result, tool life held up well even on longer part runs. When using chlorinated oils, the company experienced sporadic chlorine attack on parts during periods of high temperatures and humidity. Here, the anticorrosion properties of the synthetic lube provided improvements, offering anticorrosion protection lasting to six weeks even on parts shipped to Batesville customers in Mexico. BT&D found that the new lubricant provided significant anticorrosion protection even in diluted form, thus reducing lube cost.

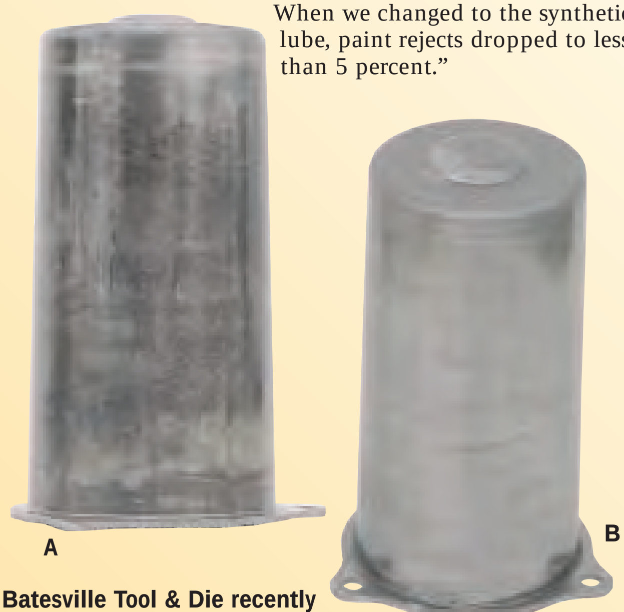
"We saw the benefits right at the press—the tools, bolsters, conveyors and floors all cleaned up almost magically," explains Urban Brackman, production supervisor. "Parts ran fine and we saved some money on use cost. In our weld cells, using oils created heavy smoke. With Eco Draw, the smoke went away and welds improved, as weld areas on the material no longer carbonized.

BT&D, under its 5-S program, is quite concerned with housekeeping and safety, another benefit in switching to Eco Draw, notes Brackman.

"Since we increased our use of this synthetic lube, our plant is easier to keep clean and safer," he says.

Significant benefits were realized in post-processing procedures, too, according to Jody Fledderman, BT&D president. He cites a motor housing produced for Delphi as one example.

"It's a tough part and the oil that we had used heated up in the drawing process and developed high levels of carbon on the part," he explains. "Our finishing partner had trouble cleaning the carbon and experienced a 35-percent reject rate in the painting process. That cost us downtime and money. When we changed to the synthetic lube, paint rejects dropped to less than 5 percent."



Batesville Tool & Die recently switched to synthetic lubricant for drawing work. Shown is an unwashed brake booster housing as drawn using a chlorinated emulsifiable oil (A)—note carbon buildup—and as drawn using a synthetic lubricant (B).

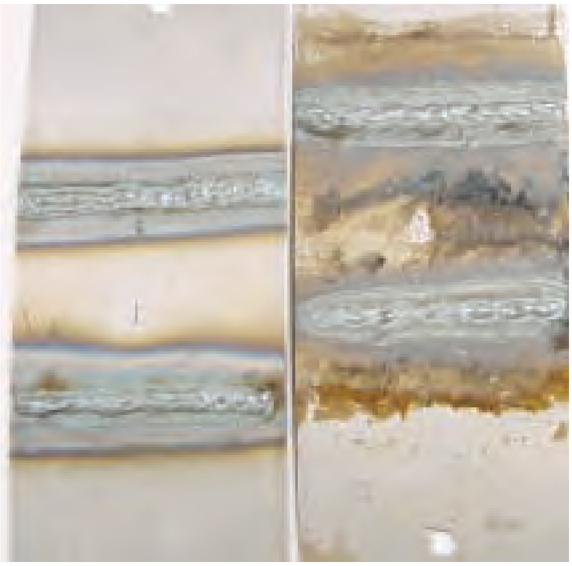


Fig. 4—During welding, synthetic lubricants do not heavily carbonize or varnish. The photos show a welding comparison between a synthetic (left) and oil-based lubricant.

system cannot selectively remove emulsified tramp oil from the mixture.

If chemical EP additives are not present in the emulsion, the relatively unstable dispersion system provides one advantage. Where emulsions puddle on steel, the dispersed oils attract to the surface substrate of the part. In effect, an oil micro-coating deposits on the surface and provides some rust protection. But the presence of chlorine or sulphur nullifies this effect. These volatile ingredients, in the presence of heat and humidity, become very corrosive. For example, as chlorine decomposes it forms trace quantities of hydrochloric acid that can negate the barrier effect of even straight oils. Conversely, most water-soluble lubricants allow water to migrate to material surfaces. Amine salts and borates do provide substantial antirust protection in a stand-alone environment, but not on parts nestled together or exposed to condensation.

How Synthetics Work

True water-soluble lubricants include naturally soluble ingredients and insoluble materials. The blending process creates a dynamic synergism between ingredients and with the water itself. Many water-soluble lubricants existed that did not contain petroleum, but they were more aptly described as soaps. They contained seed, coconut or vegetable oils in a hydroxide complex. These products, generally with a high pH value, attacked soft material substrates and dried tacky or stiff. In addition, they contained no EP additives.

As our company conducted lubricant research and development, we sought to define the term "synthetic lubricant." As the name implies, a true synthetic lubricant is made from man-made ingredients. Water-soluble products provide substantial heat transfer or cooling effects compared to oils. As a result they are not as susceptible to a melting of the film or lowering of the viscosity. A few high-performance synthetic lubricants have been formulated using polymer technology. Pronounced polymer formulas provide tenacious boundary protection and have been used successfully in severe operations. These products generally clean easily in post-processing but present some problems in tools, welding and part handling because the residue can become very tacky.

Other synthetic formulas use a combination of boundary film agents, couplers and synergistic surfactants. These ingredients can be manipulated with coupling agents and cloud-point characteristics to react at various temperatures and conditions. This characteristic provides additional EP effects in the forming process beyond the traditional expectations of boundary lubricant additives, and provides a lighter non-tacky film. The synthetic lubricant that received automotive approval contains a unique ingredient system that is attracted to the material surface and provides anticorrosion protection unprecedented in water-based lubricants.

Regardless of the performance quality of a lubricant, it must be present at the work material-die interface to perform. But mill-oil coatings tend to repel emulsions and some water-based lubricants, which then tend to bead-up or puddle on blanks in the migration lines of the mill oil (Fig. 3). Here, surfactant-based synthetics provide superior sheeting and wetting effects. Rather than bead up or puddle, they allow for surface-oil permeation and provide a light continuous film on blanks, improving lubricant efficiency and reducing the amount of dripping from blanks during transfer.

Also, the inherent lubricity and cooling characteristics provide advantages. Even in dilute solutions, they affect fluid surface tension to promote material flow. Finally, the heat transfer effect common to all water-soluble products resists viscosity change, cools localized friction points, and minimizes die and punch expansion.

Synthetic Lube: Post-Processing Advantages

With synthetic lubricant technology developing to meet the priority demands of metalforming companies, the more traditional post-processing benefits deserve a look.

Improved Part Appearance: The superior heat-transfer effects of synthetic lubricants cool parts to reduce the level of carbon drawn from ferrous material. Synthetic lubricants do not contain the high level of carbon-based organics found in petroleum products, and do not carbonize as readily as petroleum. As a result, smut on parts coming out of the forming operation is reduced, improving subsequent cleaning operations.

Improved Inspections/Reduced Glove Use: Instead of a milky or dark residue, synthetic lubricants coat parts in a light, transparent film, simplifying formal and informal part inspections. The cleaner film does not readily saturate gloves. Another advantage: In assembly operations, operators can handle parts without significant transfer of smut and soils to finished assemblies.

Improved Welding: In welding operations, synthetic lubricants do not carbonize heavily or varnish (Fig. 4). Cleaning operations prior to welding—general cleaning, equipment use, effluent disposal and labor—can be expensive. In most operations, when using synthetic lubricants, parts cleaning can be eliminated prior to welding. For parts not ordinarily cleaned, petroleum residues can carbonize and create smoke and noxious fumes. But synthetic lubricants dissipate into steam and significantly reduce smoke created in welding, eliminating maintenance costs associated with exhaust systems and scrubbers.

Use Efficiency and Recycling: Synthetic lubricants promote lubricant-use efficiency because they mix easily into stable solutions, facilitating the use of proportion equipment. These lubricants do not clog plumbing lines, spray nozzles or central-fed roller-applicator equipment. Also, synthetic lubricants are ideal for recycling programs.

Recycled lubricants inevitably collect contaminants such as mill oils, hydraulic fluids and machinery greases. Petroleum emulsions may emulsify some of these contaminants into the concoction and adversely affect emulsion stability. Synthetic lubricants readily reject or float most of the contaminant oils, allowing simple removal. In addition, petroleum oils and fats in these emulsions provide a haven for bacteria, making employee exposure to the fluid unsafe.

Bactericide added to such fluid to control rancidity presents more health issues. When fluids become rancid, pH is reduced and the fluid can become acidic, adversely affecting anticorrosion protection. Synthetic lubricants do not have the level and nature of organic material to promote bacteria, making them resistant to rancidity. Also, tramp oils do not affect synthetic-lubricant stability. These oils can be segregated easily.

Improved Parts Cleaning: In cleaning operations oils tend to repel aqueous cleaners, so mechanical contact and heavy alkalis must be used to permeate oil-based films. In general, parts-cleaning or pretreatment operations easily remove water-soluble products via simple contact with the cleaning fluid—especially beneficial to parts configured to crimp lubricant residues. Without exposure to spray impingement or immersion agitation, oil in crimped areas may not be removed. Later, in paint-cure ovens, the oils thin and bleed out of the crimped areas to ruin paint or plating finishes. Because synthetic lubricants do not varnish or oxidize when they dry, they reduce carbon development as well as rejects caused by inadequate cleaning.

Synthetic lubricants mix readily with aqueous cleaners, seemingly a disadvantage because the soils do not float like oils to facilitate skimming. But a quick analysis of typical cleaning systems reveals that the majority of petroleum-based soils do not float either. The high alkaline and surfactant levels of most cleaners are designed to permeate and emulsify oils from the part surface. Particularly, regarding emulsifiable oils, this feature in cleaners mixes petroleum into the cleaner bath. Petroleum soil levels as low as 2 percent by volume can deplete the detergency of a typical cleaner by 50 percent. Synthetic lubricants have much less adverse effect on cleaners. As a result, when compared to petroleum-based soils, synthetic residues can extend cleaner life by as much as 300 percent. This feature reduces the cost of the cleaning operation, and the cost of treating effluent from cleaner-bath discharges.

Improved Housekeeping: The better wetting effect on steel resulting from synthetic lubricant use reduces the amount of fluid that drips from blanks in the press and from parts on conveyors or in part bins. Inevitably, some lubricant ends up on the floor. Here, mild cleaners can remove synthetic lubricants. In fact, the lubricant itself provides some cleaning. Synthetic lubricants will flush clean oil and fat buildup from petroleum lubricants found on dies, applicators, plumbing lines, nozzles, reservoirs and scrap conveyors—reducing maintenance costs and promoting a safer and cleaner workplace.

Improved Safety: Using synthetic lubricants reduces weld smoke and residue on the floors. In addition, synthetic technology is biodegradable, contains no reportable hazardous ingredients and reduces volatile-organic-compound levels. Also, unlike combustible oils, synthetic lubricants have no flash point.

Reduced Disposal Costs: Due to their biodegradable characteristics, synthetic lubricants generally require no special treatment for disposal. They may affect the biochemical oxygen demand in effluent water, but generally this spike falls within municipal parameters or can be surcharged if parameters levels are too high. Work material, mill oil and hydraulic fluids can contaminate lubricant. These effluent collections are not usually waste treated but, rather, are hauled away. The biodegradable feature of the lubricant does not change requirements for press-pit sludge. In press pits, the lubricant's resistance to bacteria provides the biggest advantage.

Finally, municipalities and various government agencies now target stormwater runoff from parking lots and outdoor storage areas at manufacturing sites. The sign on the door between the production area and the office may say, "Wipe Your Feet," but foot and forklift traffic travels readily through the outside doors. If you are going to make tracks or drip lube from scrap steel in your parking lot, make sure the washout from rain is biodegradable. **MF**