Selecting Stamping Lubricants
for Advanced High-Strength Steels

Like other parts produced from high-strength steels, these high-strength low-alloy steel seat spring brackets, stamped at Batesville Tool & Die, Batesville, IN, demand enhanced lubricant properties.

What are lube requirements when forming these ever-more-popular steels, and what lubes will work best?

BY MICHAEL BROWN AND PAUL BOSLER JR.

The lubrication of sheetmetal and the associated workpiece plays an important role in metalworking operations, but as the metalforming industry has discovered, the use of the proper lubricant is extremely critical when drawing, stamping, forming or piercing component parts from high-strength low-alloy (HSLA) steel and advanced high-strength steel (AHSS). These steels put demands on the lubricant during the metalforming processes that can confound traditional expectations of lubricant and tooling performance. Features of these steels that provide benefits to the end product also pose challenges during forming. Side effects such as springback can require remedies through tool design or increased press tonnage that place higher demands on lubricant performance.

These unique issues create an environment for production problems and severely tests the properties of stamping lubricants. They also test the knowledge of even the most seasoned tool-and-die engineer, press operator and lubrication specialist. The experiences related to high-strength steel have resulted in many misconceptions, particularly related to lubricants required

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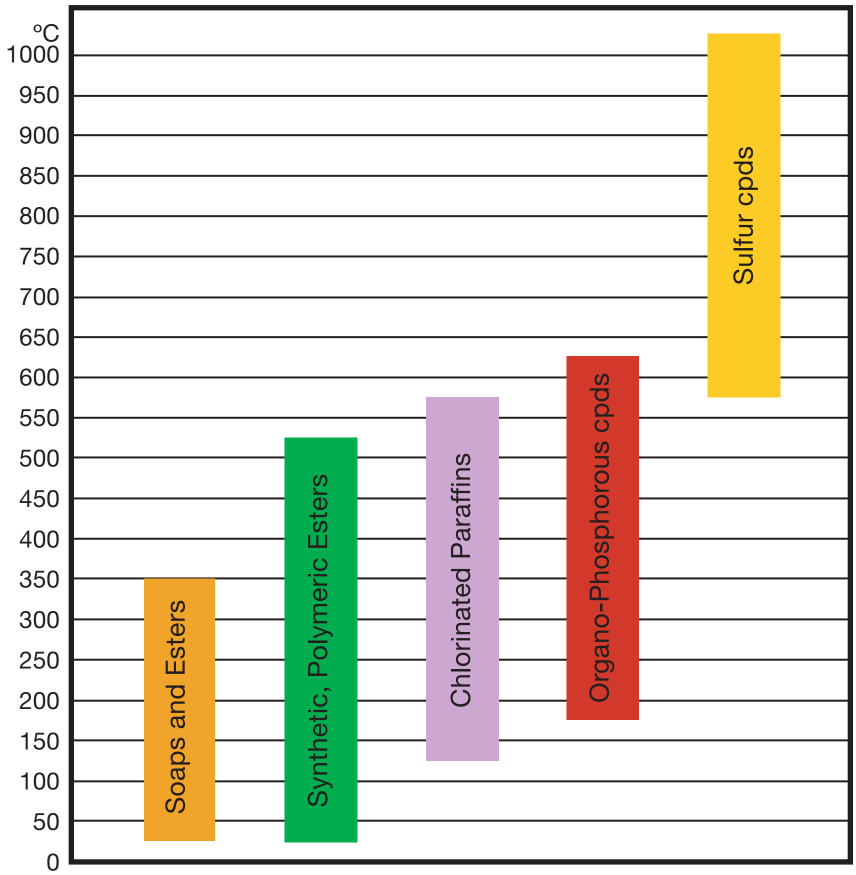
Operating-Temperature Ranges of Extreme-Pressure (EP) Additives



for successful forming. The metalformer can best meet these developing challenges when armed with a basic understanding of characteristics of this steel technology and of the available and developing technologies in stamping lubricants used to form it.

Dramatic Increase in Use of HSLA and AHSS

The use of AHSS has grown dramatically within the automotive industry to improve vehicle safety and fuel economy. As a general rule, AHSS provides greater work-hardening rates and higher tensile strengths than conventional steel. In basic terms, these features are accomplished by alloying with elements such as manganese, chromium, vanadium, niobium and others. Depending on the choice in steel—HSLA, dual-phase (DP), transformation-induced plasticity (TRIP), complex-phase (CP), martensitic (Mart) and other hybrids—the goal usually is to replace a heavier-gauge and weightier steel with a thinner-gauge and lighter-weight steel with the same or improved features. In effect, a door hinge that once required heavier-gauge steel to support a door can be fabricated from a lighter-gauge AHSS to perform the same function. A seat pan made of AHSS provides more secure harnessing during a crash. A body structure made of AHSS can reduce vehicle weight and improve crash-energy absorption. The levels of copper, phosphorous, chromium and silicone in high-strength steel can improve corrosion resistance for structural parts.

New Steels, New Lube Challenges

While these features provide obvious benefits to end products, the required steel characteristics create new challenges in the metalforming process. Metalformers often select lubricant based on the gauge of steel and the severity of the draw or form. Traditionally, conventional heavy-gauge steel and complex forms mandated more heavy-duty lubricants while conventional lighter-gauge steel and more moderate forms required less robust lubricants to successfully form parts. High-strength steel can skew this notion. The tensile strength, initial hardness and workhardening characteristics require that the lubricant be every bit as robust as any lube used for heavy-gauge steel. In fact, other issues make high-strength steel even more difficult to work with and expose the stamping lubricant to new levels of duress.

A properly performing stamping lubricant must protect the tooling, tool coating and part from the abrasive affects of friction that can occur as the steel is formed or pierced. The lubricant also should allow controlled flow of the sheet stock into the form to prevent necking and wrinkling. In simple operations, the lubricant requires little more than a boundary film and slip agents. More-difficult operations require the use of extreme-pressure (EP) additives. High-strength steel poses some of the most complex situations in metalforming and, for best results, requires advanced-technology lubrication.

Conventional steel, in heavier gauges, historically was the choice in forming difficult and high-strength parts. Owing to such applications, lubricants were developed that contain substantial boundary and EP additives. Most metalformers are familiar with petroleum-based lubricants that contain chlorinated paraffin or olefin, sulfur and/or phosphorous serving as significant EP additives. Synthetic lubricants have been developed that contain EP additives, tacifiers and enhanced boundary additives that perform well in severe stamping applications (see above chart detailing EP-additive operating-temperature ranges). And hybrid semi-synthetic lubricants have been employed successfully in stamping applications to form conventional steel. Choices regarding the use of these lubricants for these steels tend to revolve around environmental, safety and post-process issues. Similar concerns apply to the selection of lubricants for use with high-strength steel with additional consideration given to the new complexities they bring in the metalforming process.

Metalforming operations for conventional steels and high-strength steels differ, due primarily to the unique characteristics of the latter. With both types of steel, an initial stress experienced at the point of initial deformation requires the full complement of a lubricant's properties. The boundary protection (hydrodynamic and/or elastodynamic film and fluid-pressure characteristics) must remain present throughout the part-to-tooling contact. If friction degrades the boundary film, the associated heat needs to activate EP additives that create molecular metallic coatings and provide residual protection. Ideally, the fluid itself will delay the need for this effect by dissipating the heat and protecting the boundary film and fluid viscosity. With conventional steel, as the part forms it generally softens or at least does not harden, and the strain upon the lubricant properties generally subsides. In effect, a lubricant must survive the initial stress of each deformation to perform effectively. However, high strength-steel requires multi-phase performance from the lubricant.

Performance Needed as Steel is Worked

High-strength steel also requires lubricant performance during the initial deformation, but requires even more enhanced performance as the steel is worked. High-strength steels contain alloys that improve the strength and formability of lighter-weight steel. These alloys increase yield strength and further increase yield strength as strain increases. This characteristic means that as the steel is shaped, it hardens and gains strength compared to its original composition. That allows the steel to provide excellent crash-energy absorption and allows excellent part formability of lighter-gauge steel prior to it gaining additional strength during the forming process. As a result, the steel also becomes harder and stronger in the working areas of the die. Not only must the lubricant provide traditional property values but its performance must increase throughout the forming process to counteract the increasing friction that occurs as the steel hardens.

Steel Characteristics and Lubricant Requirements

High-Strength-Steel Characteristics	Lubricant Requirements
Workhardens →	Multi-phase protection, increasing during latter stages of deformation
Requires increased forming pressure →	Lubricity to accommodate associated friction
Pad-pressure concerns →	Promote consistent material flow
More adversely affected by corrosion →	Promote corrosion protection

This chart highlights complexities that high-strength steel create for the metalforming process and some of the features required in a stamping lubricant to counter those complexities.

Because similar strength can be achieved with lighter-weight parts, HSLA and AHSS frequently replace heavier-gauge steel to form similar parts. This transition requires more performance diversity from the lubricant. The thinner gauge and relative higher yield strength may result in springback, so a higher force is needed to provide permanence to the deformation. This added pressure can increase friction, which calls upon the multi-phase requirements of the lubricant. At the same time, compared to thicker steel, the thinner-gauge AHSS requires finesse of the holddown or pad pressure during the forming process. In this situation, a singular consistency in film performance is essential to promote controlled metal flow into the form. If stress or inconsistent lubricant performance occurs, part forming will suffer. No die maker wants to see friction occur when a part is formed. However, if a lubricant breaks down enough to adversely affect material flow or the forming process, a heavy-gauge part might experience light scoring. In some cases, this situation causes a cosmetic problem on the part and requires additional tooling maintenance, but the part is structurally sound. But thinner-gauge high-strength steel leaves little room for galling or scoring. Instead, such a lubricant failure can lead to insipient necking or a fracture—obvious compromises to the structural integrity. Finally, corrosion more quickly affects the structural integrity of a thinner-gauge part as compared to a heavy-gauge part. Here, a stamping lubricant must provide significant anti-rust protection.

The table, Steel Characteristics and Lubricant Requirements, highlights some complexities that high-strength steel creates for the metalforming process and some of the associated features required in a stamping lubricant.

Lubricant Choices for High-Strength Steels

High-EP Petroleum—Based upon the performance requirements explained above, the two most viable lubricant technologies for high-strength steel consist of some petroleum-based and some water-based synthetic lubricants. Petroleum-based products should contain a high level of EP additives such as chlorine and/or sulfur, and provide realistic choices for use in high-strength-steel forming operations because they can contain the highest level of EP additives. The most economically significant EP additives are oil-soluble and are only feasibly blended into oil-based formulas. Some literature has discussed the adverse or thinning effect that heat from friction has upon petroleum-based lubricants. However, base oils can be adjusted using high-viscosity index oils

These high-strength-steel panels show the sheeting action of various lubricants. The first two, from left, show good and medium sheeting action respectively, from two different advanced technology synthetic lubricants; the third, a standard synthetic lubricant—poor sheeting; and the fourth, a standard emulsifiable chlorinated oil—poor sheeting.

to lessen this effect. Such studies on the effect of heat to viscosity depend entirely upon the original viscosity of the base oil. Most importantly, such studies neglect to account for the tremendous effects of EP additives owing to their activation by the same heat that thins viscosity. High levels of EP in a lubricant provide exceptional potential protection to parts and tooling. However, the petroleum content retains heat and, as a result, provides very poor heat transfer or cooling effect. This characteristic becomes problematic as increased friction develops during the workhardening process. In extreme situations, heated dies can turn petroleum into a lacquer on parts and tooling. Most relevant, oils pose the greatest post-process, housekeeping and environmental concerns.

Emulsifiable Oils—Water-emulsifiable oils, sometimes called soluble oils, provide similar advantages and concerns. Due to the water content in the dilution, these products provide some limited heat-transfer effect. Aside from the environmental and post-process concerns, emulsifiable oils do not generally wet or coat uniformly on steel. This characteristic may unfavorably affect material flow during the forming process. Emulsifiable oils are prone to bacteria contamination, so generally are less bio-stable. Finally, EP additives such as chlorine and sulfur used in both straight oils and emulsifiable oils can become volatile when exposed to high temperature and humidity. These lubricant residues may provide limited anti-rust protection.

Advanced-Technology Synthetics—Water-based synthetic lubricants provide the widest range for development and potential success in AHSS forming. Most synthetic lubricants developed for heavy-duty use or even those specifically marketed for AHSS consist of the ubiquitous polymer families, boundary films, thermal-resistant additives and wetting agents. These products provide exceptional heat dissipation to cool parts and maintain fluid viscosity, and generally run at lower temperatures. Recently, proprietary additives have been developed to increase film tenacity. This characteristic provides the multiphase function essential to successful use with AHSS. The fluid viscosity, boundary agents and cling properties provide protection through the initial metalforming stress. As friction heat is developed during the workhardening phase of the process, the fluid forms an apparent viscosity of a residual film that plates on the part and tooling. This tenacious film provides a new and fundamental boundary protection for the latter stages of the forming processes, and protects punches during withdrawal. Primarily composed of water-soluble ingredients, residues allow for simplified removal in cleaning systems and frequently require no cleaning prior to welding operations.

Other Lube Traits Affect Forming

Various versions of synthetic lubricants with enhanced residual films have been developed by suppliers that utilize polymers, boundary agents and thermal-resistant additives. Such features are essential if a synthetic lubricant is to perform successfully in high-strength-steel forming applications. But the ancillary or mechanical features of the product may be just as important. Most significantly, a lubricant must sheet uniformly over the steel surface without roll-back or beading. Regardless of the chemistry present in the product mix, if the fluid does not remain with the sheet stock or cannot uniformly coat the tooling, the lubricant cannot protect against friction and will not allow consistent material flow. Poor wetting characteristics also can leave areas unprotected against corrosion.

Second, older-technology lubricants relied heavily upon the product viscosity to provide boundary protection in forming processes. High-strength steel often requires tighter die tolerances, so heavily viscous lubricants can create problems. Also, many operations apply lubricants through spray systems. A lubricant that is too viscious cannot be sprayed efficiently. Advanced-technology lubricants operate primarily through initial boundary effect, heat transfer and the apparent viscosity of the film on parts and tooling. The fluid viscosity does not have to be heavy for these products to perform effectively.

Third, to diminish lubricant use and disposal, lubricants frequently operate in recirculating systems. As a result, the lubricant should reject tramp oil, be bio-stable and have low foaming characteristics.

Finally, synthetic lubricants provide significant advantages for post-process operations, housekeeping, plant safety and environmental compliance. They are generally clean to work with and easily clean off of parts. Often, cleaning operations can be eliminated, for example, prior to welding. And because synthetic lubricants contain few to no hazardous ingredients, they facilitate safety and environmental programs. **MF**