Save Your Tools from a Watery Grave

Are you using the right water in your metal removal operation?

By John Burke, Alan Cross & Valarie Pearson

Industrial companies and chemists are always seeking to maximize the performance and endurance of metal removal fluids. Many factors can affect product quality, tool life and fluid disposal, all of which significantly impact a manufacturer's productivity and performance. One factor that has been known to affect fluid performance is the level of dissolved salts, or "hardness" of the water that is added to the metal removal fluid.

Recently, a team of chemists from Houghton International set out to quantify the effects of water hardness on lubricity, and reached some surprising conclusions. First, contrary to some industry assumptions, the use of low-hardness water can negatively affect tool life in tapping operations. Alternatively, increasing water hardness can increase tool life with certain fluids. This article provides an overview of this research, which was presented in May at the 2014 annual meeting of the Society of Tribologists & Lubrication Engineers.

Metal removal fluids are generally diluted with water to form emulsions, dispersions, true solutions or combinations thereof. The amount of water added to these solutions varies from 80 percent to 97 percent by volume. Water is added to metal removal fluids to improve cooling properties, ensure proper dilution to reach the point of application, and provide economic value to the end user in the manufacturing process.

Metal removal fluids are used over and over to minimize waste, reduce costs and satisfy oil and grease disposal restrictions imposed by the Clean Water Act of 1970, which created additional incentives to extend the life of metal removal fluids. However, as these fluids are increasingly reused, certain contaminants in the water can interfere with the fluids' properties, thereby reducing their useful life.

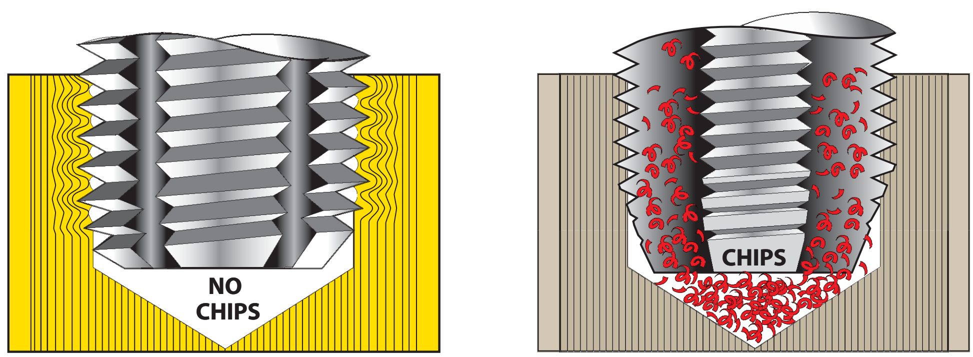
The Rise of Reverse Osmosis

In the early 1970s, fluids with more stability were created, easily doubling the useful life of the fluids in single sump and central systems. However, as chemists pushed the stability to higher and higher levels, the water impurities began to dominate reactions with negative results, especially when the metal removal fluid was used for significant extended periods (years). This performance decline was the result of evaporation of the water phase in the system, which left dissolved salts behind. As a result, the use of purified water instead of ordinary tap water became more popular.

Manufacturers initially used de-ionized water, which is purified by removing most of the cations and anions through a process called "ion exchange." As technologies advanced, the use of water purified by reverse osmosis (or RO) grew in popularity, especially as the cost of RO systems became more competitive versus de-ionization. RO also uses less hazardous chemicals during membrane cleaning compared to the regeneration process used in de-ionization.

In the modern manufacturing environment, the use of RO purified water is much more common than in the 1970s. The STLE Metal Working Fluid Education course advocates pure water for water mixable fluids to extend fluid life. However, the course instructors caution that the use of purified water may reduce tool life in some applications.

Indeed, field observations indicate that systems charged with purified water occasionally see drill, reamer or tap breakage until the systems "harden up" — that is, until the emulsions loosen up due to ingress of metals being machined, tramp oil and other chemical reactions within the fluids. The charts on page 40 help to illustrate this theory.



FORMING TAP

CUTTING TAP

Illustration: Balax Inc.

Tapping Torque Tests

Houghton chemists conducted tests to verify and quantify the loss of tool life when purified water, rather than hard water, is added to various fluids in metal tapping operations, as indicated by field observations. The basics of the testing regimen were as follows:

• **Water Preparation.** For the purpose of the Houghton testing, the water was prepared by taking tap water supplied from the Audubon Water Co. in Norristown, Pa., softening the water by removing the calcium, magnesium and iron ions with a commercial sodium ion exchange softener, and then processing the water through a RO system. The water hardness before treatment was between 300 and 600 mg/L as $CaCO_3$; after the two stages of treatment, the hardness was less than 1 mg/L as $CaCO_3$. The specific conductance of the water after treatment was less than 20 μS/cm.

The purified water was then artificially hardened by adding calcium chloride hexahydrate and magnesium chloride to make a 1,000 mg/L hardness stock solution. Portions of this stock solution were then diluted with RO water to create the 350 mg/L hardness and 700 mg/L hardness levels for testing. In this water preparation process, the hardness can be duplicated in any laboratory since the water was standardized with known chemical reagents of calcium chloride hexahydrate and magnesium chloride.

• **Fluids.** Fluids chosen for the testing were a basic emulsified oil, a premium emulsified oil, two solution-type synthetic fluids, and a vegetable oil emulsion. For the purpose of this testing, all fluids were diluted at 5 percent v/v, or typically 50 ml of product and 950 ml of water. Fluids were mixed with a low-speed stirrer (100 rpm) and allowed to stand for four hours before being applied to the testing instrument. All mixtures were applied to the test instrument at 21 degrees C (70 F). The basic emulsified oil was not considered to be hard water stable, the premium emulsified oil and the vegetable oil were considered stable to 800 mg/L hardness, and the two synthetic fluids were considered stable to 1,000 mg/L hardness.

• **Metals.** The four metals selected to be machined were cast aluminum ANSI 356, which is abrasive, forms reactive soaps and has a high Si (7 percent wt.) content; aluminum 6061, which also forms reactive soaps and is easier to machine than ANSI 356; mild/low carbon AISI 1018 steel; and Dura Bar G2 cast iron, also easily machined.

• **Machining.** The machining operation was tapping of precision drilled and reamed holes, with taps from YMW Taps USA. The taps were designed specifically for the metal type being tapped (ferrous and non-ferrous). The type of tap used was a "form tap," not a "cutting tap," since previous studies showed the former produces more reliable data than the latter. This is because cutting taps bite into the metal and produce chips that can interfere with precise measurements; form taps press the shape into the metal without taking off chips. The tap diameter was 6 mm and the tap revolutions per minute were varied from 400 RPM to 900 RPM, depending on the metal specimen being tapped.

Tool friction was determined by measuring and recording the average amount of torque required to tap the holes in the metal specimen, on a "LabTap" instrument from Germany's Microtap GmbH. Average torque values were reported in Newton-centimeters (Ncm), and the metal test specimens were specifically designed and drilled for form tapping.

• **Procedure.** Three separate fluid hardness levels were chosen for each fluid group: zero hardness, 350 mg/L and 700 mg/L. Three

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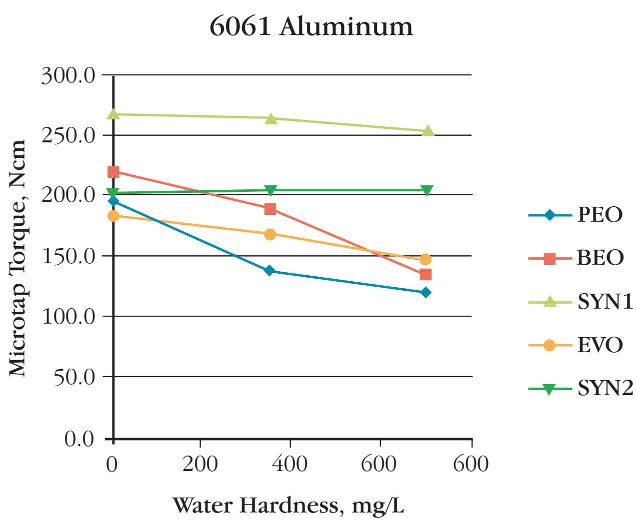
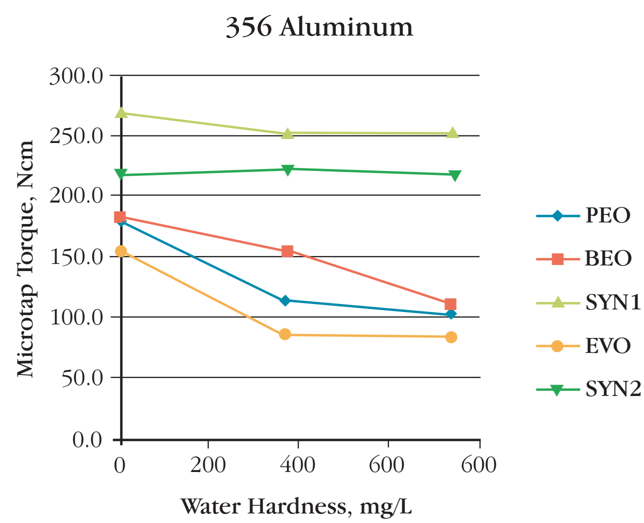
Tapping Test Results A lower value indicates lower tap torque, and thus improved lubricity at the point of cut.

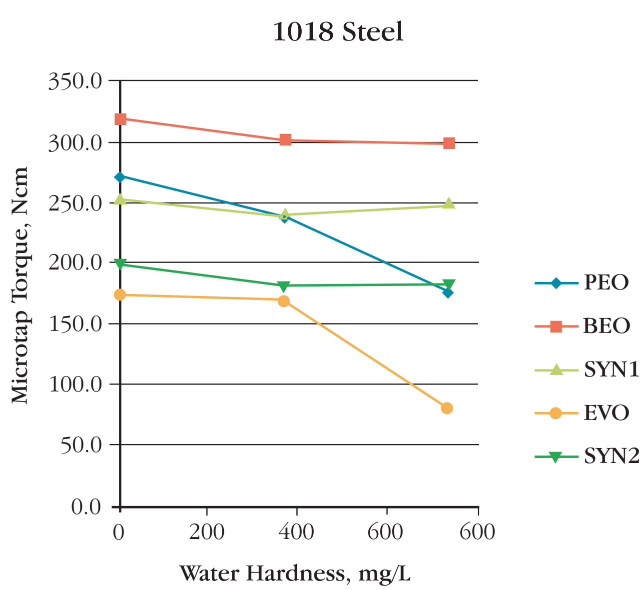
Premium Emulsified Oil — Basic Emulsified Oil — Synthetic 1 — Synthetic 2 — Veg. Oil Emulsion



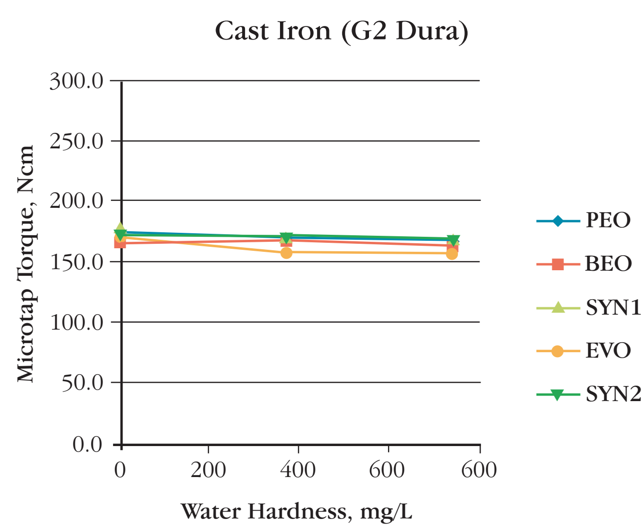
When tapping 6061 aluminum, as this graph shows, the two synthetic fluids were least affected by the increase of water hardness, whereas the basic and premium oil emulsions showed improved lubricity as the water hardness increased.



With 356 aluminum, results were similar to those with 6061 aluminum. The basic and premium oil emulsions and vegetable oil emulsion improved in lubricity as water hardness increased, whereas the ultra-stable synthetic fluids remained relatively constant.



The ANSI steel 1018 results indicated slightly different values from the aluminum data. The basic oil emulsion and the two synthetic fluids did not improve or decline in torque as the hardness increased, while the premium emulsified oil and the vegetable oil emulsion showed improvement.



Tapping cast iron shows a much different trend pattern than the other metals. Very little change is seen with changes in hardness. The vegetable oil emulsion shows an improvement with increased hardness; however the percent reduction is not nearly as great as the other metals show.

Pros and Cons of Using Purified Water

Advantages

- Easier mixing
- Smaller particle size
- Improved wetting and penetration
- Minimizes gummy residues
- Improved filtration
- Less carry-off
- Greater bacterial resistance
- Greater fungal resistance
- Reduced corrosion
- Less concentrate use
- Less mist
- Better overall stability

Cons

- May reduce tool life in some operations
- Increased risk of generating foam
- Increased levels of entrained air

Tallying the Results

Plus signs indicate that significant torque reductions are seen when hard water is used in various tapping operations.

	Aluminum	Steel	Cast Iron
Premium Emulsified Oil	+	+	–
Basic Emulsified Oil	+	–	–
Vegetable Oil Emulsion	+	+	–
Synthetic Oils	–	–	–

Source for all: Houghton International

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holes were tapped per fluid, per metal, and per hardness. After each hole was tapped, the tap was removed, cleaned with a soft nylon bristle brush to remove chips and wear debris, and then cleaned with isopropanol. The tap was then dried with compressed air and reinstalled on the Microtap instrument.

The four graphics on page 40 demonstrate the results using each metal.

With both types of aluminum, the tests of the mineral oil and vegetable oil products confirm prior field observations that lubricity improves with time, thus torque values decrease as water hardness increases.

In the steel tapping data, only the premium emulsion and vegetable oil emulsion improved as hardness increased. This could be due to the increased lubricity demands of tapping the 1018 steel and the fact that the basic oil emulsion had no added lubricity components.

The cast iron tapping data show very little change in torque values with changes in water hardness.

Of course, this testing is very basic and only involved five fluid types and four metals, and a range of hardness from 1 to 700 mg/L. The authors further acknowledge that high water hardness can have a devastating effect on filtering the fluids, and loss of fluid to chips or swarf can lead to selective depletion of certain additives, as well as emulsion separation.

This testing also disregarded the inclusion of foam or entrained air which can occur with the use of very-low-hardness water, and it intentionally ignored the effects of tramp oil increases or the effects of bacterial contamination.

Nevertheless, as these tests confirm, fluid chemistry can have a dramatic effect on the torque properties of certain fluids, and the use of low-hardness water can negatively affect tool life in tapping operations.

The rate at which water is consumed within a process and the water hardness will affect fluid performance over weeks or years, so a thorough understanding of a system's dynamics and water chemistry is critical to maximizing long term performance. Fluid formulators must carefully evaluate the machining operations and fluid chemistry to choose the ideal water for each application.

Some fluid suppliers can help manufacturers evaluate their unique operations and tailor fluids to maximize performance. As a global fluid supplier, Houghton International offers full-service chemistry and engineering labs to analyze customer systems and fluid requirements, including water chemistry analysis and recommendations.

Ongoing research will reveal more about fluid optimization, and Houghton will continue to provide insights, recommendations and engineering services to help manufacturers optimize fluids, processes and equipment performance. ■

John Burke

Alan Cross

Valarie Pearson

John Burke is an STLE Fellow and global director of engineering services at Houghton International, a global leader in metalworking fluids, specialty hydraulic fluids and services. Alan Cross is senior project engineer and Valarie Pearson is technical specialist; both are in Research and Technology at the Valley Forge, Pa.-based company. For information about this article, phone Burke at (216) 235-1995, or e-mail Jburke@houghtonintl.com.