BIOSYNTHETIC TECHNOLOGIES

Water-**Soluble**

METALWORKING FLUID FORMULATIONS

Development of High-Performance, Metalworking Fluids Using Sustainable Base Oils

Innovation and sustainability are key values at Biosynthetic Technologies that drive the strategic direction of the company's development programs. The research team at Biosynthetic Technologies spend most of their time at the interface of these domains, looking for creative ways to solve the world's sustainability challenges.

The operation of metalworking is most simply defined as the process for shaping metal into a part or component. Within thecategory of metalworking exists two subsets: (1) metal forming and (2) metal removal. Metal forming involves shaping the metal through various deforming actions, including forging, rolling, extrusion, drawing, stamping, swaging, and roll forming. Metal removal, however, involves shaping the metal by removing portions of the metal as chips, including turning, milling, broaching, threading, drilling, tapping, cutoff, grinding, polishing, and lapping.

Just as each of these processes is specific and unique in nature, so are the metalworking fluids designed to complement their service. Metalworking fluids serve various purposes, including cooling, lubricating, reducing wear, corrosion and rust protection, improving surface integrity and finish of the metal, and flushing away chips from the cutting zone. In general, metalworking fluids are either sold as straight oils (also referred to as neat oils) or water-soluble oils (also referred to as emulsifiable oils). They can be further subcategorized into mineral oil, semi-synthetic, and synthetic formulation types.

The purpose of this initiative was to develop two water-soluble formulations and compare their performance side-by-side. One formulation would be made from a traditional mineral oil, and the second would be made from a sustainable estolide product.

Water-Soluble Fluids

For applications where heat dissipation is critical, water-soluble versions of metalworking fluids may be the ideal choice. While the oil part of the formulation provides lubricity and protection from wear, the water acts as a coolant, removing heat from the system. These products are commonly mineral oil based, semi-synthetic, or synthetic.

A pair of water-soluble products was created from (1) a mineral oil base fluid and (2) an estolide base fluid, to compare their performance. The formulation data is shown below.

Ingredient	Mineral Oil Formula (% volume)	Estolide Formula (% volume)
100 SUS Naphthenic oil	25.00	-
BT4 (Estolide)	-	25.00
MW 475 Sulfonate	7.50	7.50
BT PRA50 (Polyricinoleic Acid)	7.00	7.00
35% Boramine	4.00	4.00
99% Triethanolamine	6.00	6.00
95% Amino-methyl-propanol	3.00	3.00
TOFA-E 30 (Tall Oil Fatty Acids)	5.00	5.00
Hexylene Glycol	1.00	1.00
Tap Water	41.50	41.50

TABLE 1. WATER-SOLUBLE FLUIDS, FORMULATION DATA. BT PRA50 AND TOFA-E 30 ARE PRODUCTS ALSO OFFERED.

Foam Performance

First, to compare foam performance, the formulations were evaluated using the Waring Blender Test. The blending unit was operated at its highest speed for 3 minutes, using 110 mL of 10:1 diluted concentrate. The contents of the blenders were observed at 30 seconds, 60 seconds, and 300 seconds, to assess the height of foam from the top of the liquid phase (measured in millimeters). It should be noted that both concentrates were formulated and blended without use of any chemical antifoaming agents, to highlight their relative foaming nature. When developing a fully finished fluid, use of an antifoam additive would likely be desired.

Foam Results:
- Mineral oil-based water-soluble formulation: 55/53/20 (mm foam at 30/60/300s)
- Estolide-based water-solube formulatioon: 50/45/18

Both formulations showed a similar tendency for foam, which is a noteworthy point for the estolide formulation. As formulators seek alternatives to petroleum-derived materials, increased foaming tendency is always a potential cause for concern. In this case, the estolide performed comparable to the mineral oil.

Corrosion Performance

To evaluate corrosive potential, a Cast Iron Chip Test was performed on each of the samples to compare relative rust tendency. This test takes oven dried, desiccated cast iron chips and exposes them to 30:1 and 40:1 dilutions of concentrate for 2 hours on a piece of filter paper. The results of the experiment are an area percentage of rust observed. Results were recorded as follows:

Corrosion Results:

- Mineral oil-based water-soluble formulaDon
    - o *30:1 = 5%*
    - o *40:1 = 6%*
- Estolide-based water-solube formulaDon
    - o *30:1 = 6%*
    - o *40:1 = 7%*

While a typical passing result on this test would yield a result <1%, neither of the formulations were optimized for corrosion resistance. In fact, our researchers concluded that an experienced formulator should easily be able to improve this result. However, it is worth noting that while the estolide product caused slightly more rust than the mineral oil formulation, it was very similar. It may be that the hygroscopic nature of the estolide allows marginally more water to make it to the surface of the metal, as compared to the strictly hydrophobic barrier created by the mineral oil.

Pin and Vee Performance

Pin & Vee Block testing was performed using a Falex Pin & Vee Block machine. The test works by rotating a 0.25-inch diameter test pin against two vee blocks (each 0.5-inch diameter) that have a specified applied load (200-3000 pounds).

During this process, the Pin & Vee block machine can evaluate wear, friction, operating temperatures, torque, and extreme pressure properties in real time. The method is an ideal method to assess metalworking fluids since parameters like wear and friction can be indicators of tool life, efficiency, and performance during the machining of metal work pieces.

When comparing the results, depicted below, the estolide formulation outperformed the mineral oil formulation in the areas of fluid temperature, wear, and coefficient of friction.

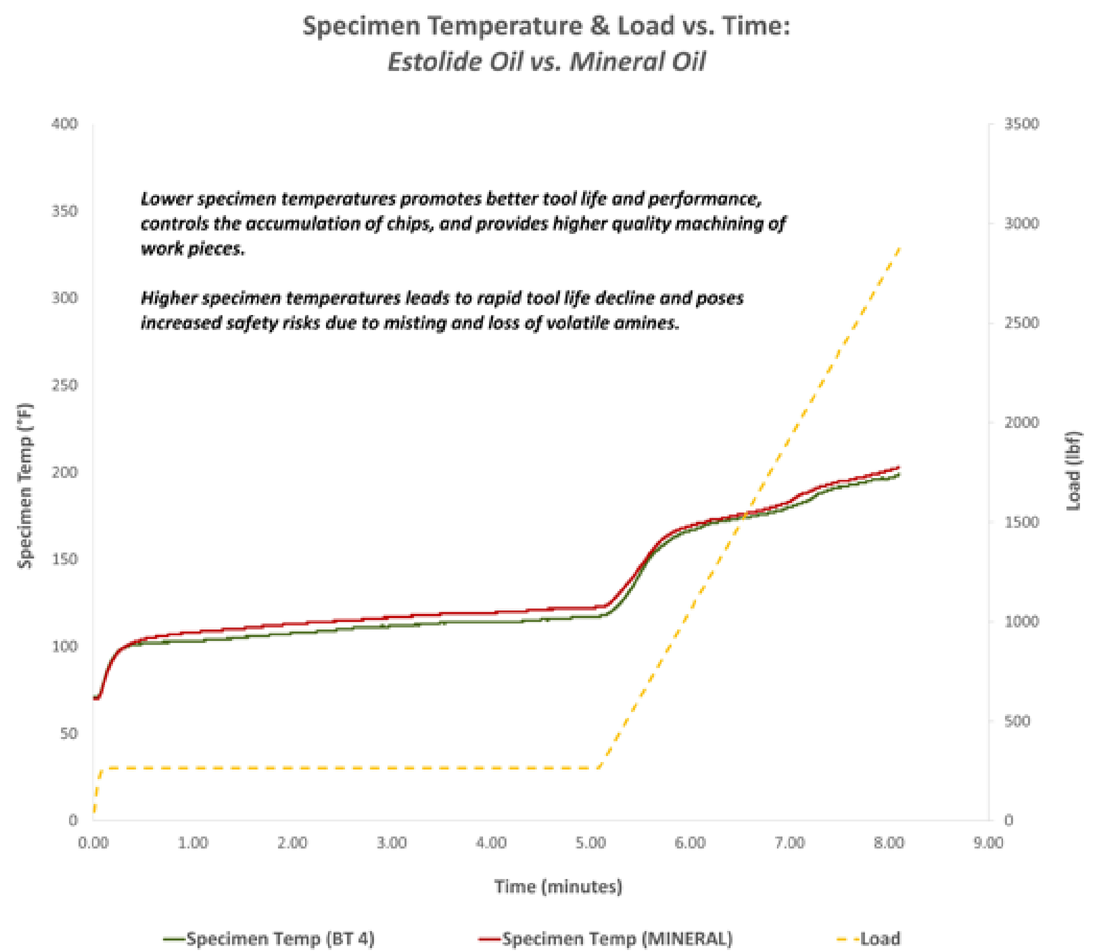

FIGURE 1. PIN & VEE TEMPERATURE DATA. TEMPERATURES WERE SLIGHTLY LOWER FOR THE ESTOLIDE FORMULATION.

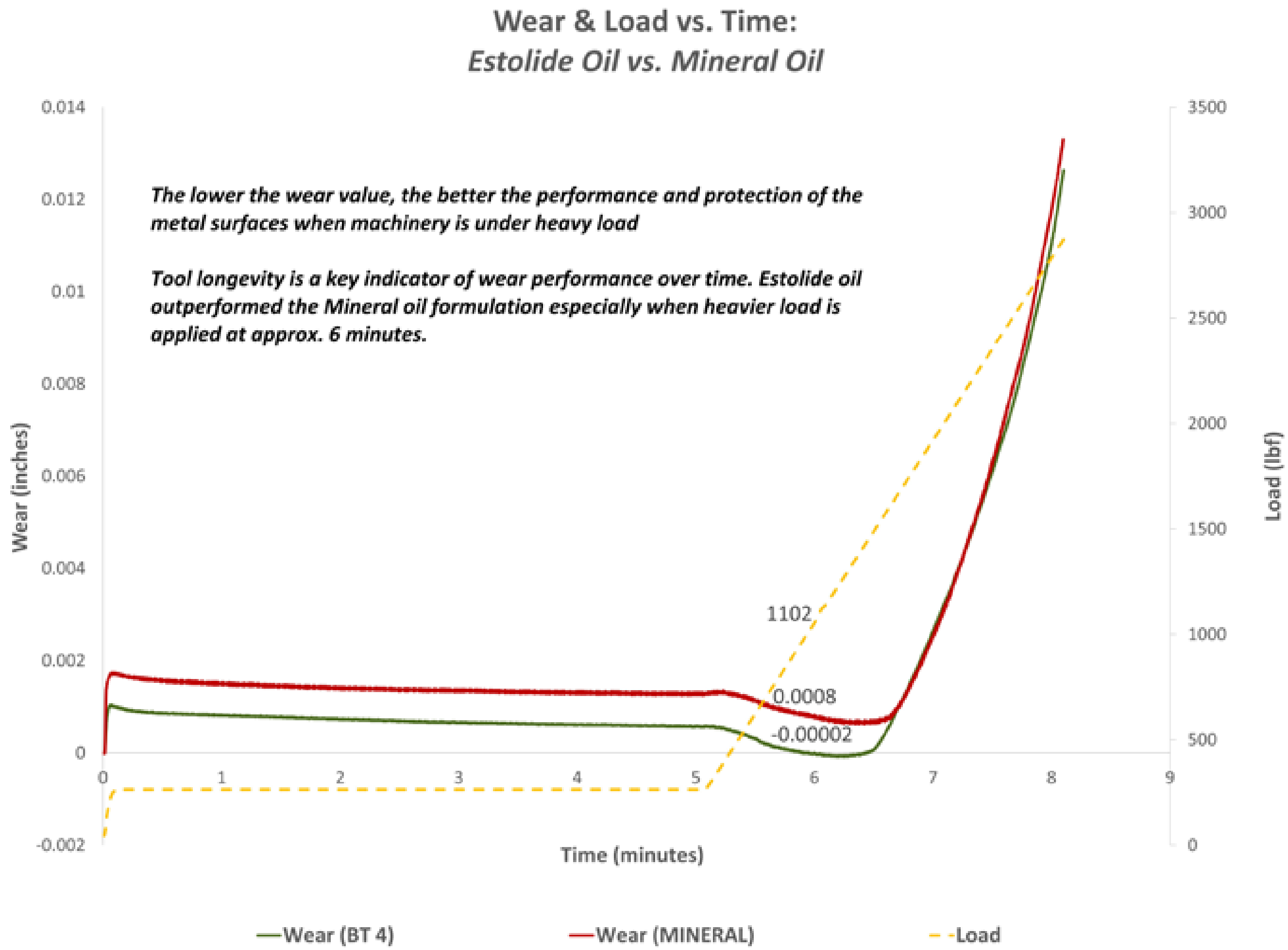

FIGURE 2. PIN & VEE WEAR DATA. WEAR RESULTS WERE LOWER FOR THE ESTOLIDE FORMULATION.

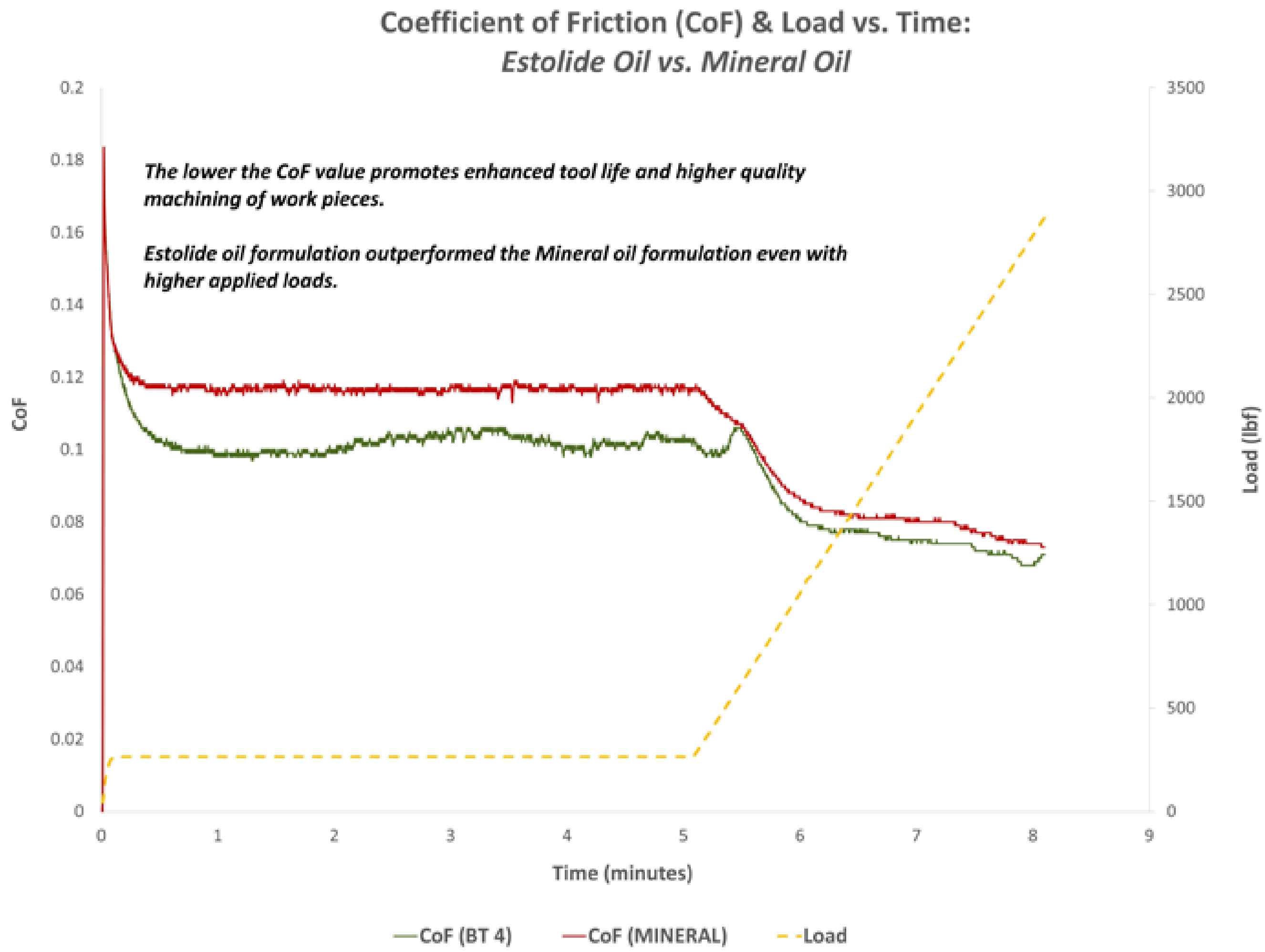

FIGURE 3. PIN & VEE COEFFICIENT OF FRICTION DATA, WATER-SOLUBLE FORMULATIONS. COF WAS LOWER FOR THE ESTOLIDE FORMULATION.

Conclusion

While the various combinations and customizations available to a metalworking fluid formulator are vast, Biosynthetic Technologies' researchers not only demonstrated that estolides can be suitable alternatives to mineral oils, they also actually outperform their counterparts in several key areas. Additionally, for product developers seeking to enhance the environmental characteristics of their offerings, estolides are bio-based, biodegradable, non-toxic, and non-bioaccumulative.

If you're interested in commercial opportunities related to manufacturing these products, or any other projects, please contact Chris Crawford at ccrawford@biosynthetic.com.