Lube-Tech
PUBLISHED BY LUBE: THE EUROPEAN LUBRICANTS INDUSTRY MAGAZINE
No.123 page 1

Transforming Technologies in Grease Industry Biobased Grease and Microwave Based Reactors

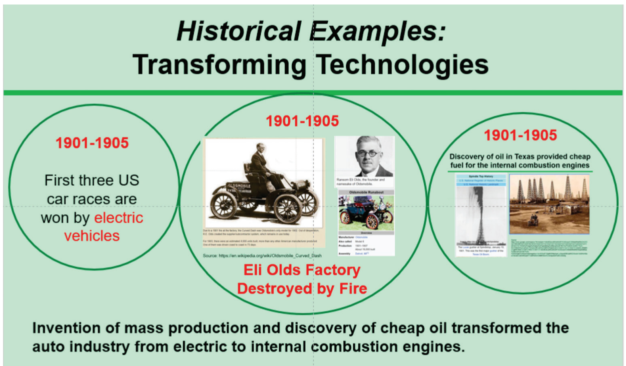
Are there Waveguides in our future?

Dr. Lou A. Honary, *President, Environmental Lubricants Manufacturing, Inc.*

Introduction

Chances are a decade from now the majority of the automobiles produced will be electric vehicles. The availability of Global Positioning System (GPS) too is transforming driving and autonomous electric vehicle will further transform the nature of personal transportation. We may also see product processed using microwaves instead of heat transfer oil or steam; and lubricants will be mostly environment friendly and bio-based.

The history of bio-based technology is rich with examples of accidental transformational events resulting in long lasting impacts. In 1901, a fire in a small automobile manufacturing plant destroyed all the vehicles that were under construction. Out of necessity, the owner of the plant, Mr. Eli R. Olds, who had only one of the then famous Curved Dash Oldsmobiles in his garage, disassembled the vehicle and contracted with different shops in Detroit to manufacture each piece in a way that would be fully interchangeable. This led to the invention of mass assembly; and Detroit became famous as Motor City (later Motown). Henry Ford utilised conveyors and created the mass production technique with significant impact on the cost and availability of internal combustion engines. Coincidentally also in 1901, the discovery of cheap oil in Spindletop Texas led to the availability of an abundance of cheap fuel for the internal combustion engines. At a critical time in the history of automobiles these events played a significant role in the popularity of the internal combustion engines as the selected power plant for over a century. The electric vehicle that at the time had won three of the first automobile races with a much cleaner and more efficient power plant lost the market to internal combustion engines which transformed the nature of our transportation for the worse. A century later, electric vehicles are making a comeback with the promise of better energy efficiency and cleaner environment.



On 20 March 2007, a chain of events resulted in a small fire in the heat transfer system at ELM a leading bio-based lubricants manufacturing plant and grew out of control. Later research showed that heat transfer oils, while a mature technology, require significant fire prevention schemes. The ELM devastating experience dealt a blow to the growth of bio-based greases; but also inspired an active search for alternative heating methods.

Among many possible candidate heating methods considered, the use of microwaves was selected as showing the best potential for processing grease and lubricants. Initial laboratory success was followed by further experiments at AMTek Microwave Technology, a leading industrial microwave company that collaborated with the researchers at University of Northern Iowa. In 2010 the first microwave-based grease processing plant began producing grease at a new ELM manufacturing plant. The use of microwaves for heating products goes far beyond the grease and lubricants manufacturing. It promises to replace steam and hot oil heat transfer heating, and jackets for the vessels in many food and chemical processing applications. The expected savings in energy and in capital expenditure by switching to microwave processing parallels the conversion of automobiles from internal combustion engines to electric motors in electric vehicles. It appears that an accidental grease plant fire in 2007, may have well become the catalyst to eventually transforming the processing industry for the better.

Manufacturing Grease

Manufacturing grease requires reacting a strong base and an [fatty] acid to make soap. The reaction results in water as by-product which requires high temperatures for dehydration. Most processing vessels are jacketed and use a heat transfer oil to heat the walls of the vessel and subsequently heat the product inside. This often requires scrape-surface arms to wipe the walls of the vessel and an additional mechanism with propellers to mix the product for effective and uniform heating. While mature and very well developed, this process in general is inefficient because of indirect heating of the product. Despite common misconceptions, microwaves can be applied to products in a metallic vessel to heat them directly. Microwave technology is also mature and is used in many households and industrial applications including drying, tempering, and cooking. But, the application of microwaves to a metal vessel for processing grease started in 2010 and was patented in 2012. This article provides an update on the enhancements to the technology and changes that should help to grow the use of microwaves in varied industrial uses.

Microwave heating eliminates the need for jackets on vessels and the heat transfer media. Instead, electrical energy is converted to microwaves; and microwaves are applied directly to the product to heat. This process, in general does not require scraped surface agitation and mechanical mixing as microwaves can penetrate the product and heat uniformly with some required mixing through pump circulation. In case of thicker products mixing arms can be used for better mixing but no surface scraping is needed since the vessel walls are not heated externally.

Microwave Heating Process

Industrial microwaves operate at 915 MHz which is different than the frequency of household microwaves operating at 2450 MHz. These waves carry an electric field and a magnetic field. At 915 MHz, the polarity of the waves changes 915 million cycles per second. Simplified, a di-polar molecule like that of water exposed to such change in polarity attempts to align its N and S poles with those of the magnetic field of the incoming waves. This results in the water molecules vibrating and colliding with each other resulting in frictional heat. The heat is then conducted throughout the product causing an expansion of the molecules. The expansion of the molecules further increases impacts resulting in faster heating. Polarity of mineral oils is different than vegetable oils and as a result microwave absorption is slower for mineral oils. But this has been remedied through the use of susceptors.

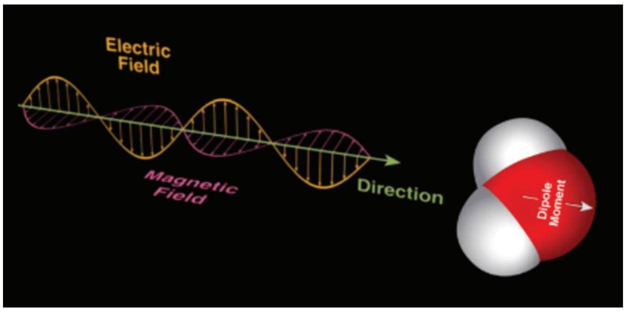


Figure 1: *Microwaves with a Magnetic and an Electrical Field interact with a Dipolar Molecule*

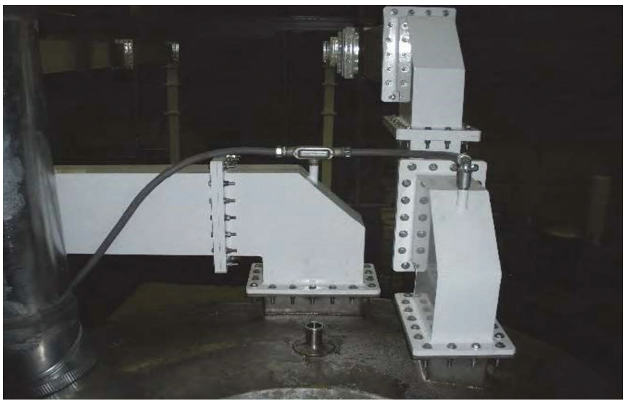


Figure 2: *Two Waveguides from two 75KW Microwave Transmitters attached to top of the Grease Reactor*

Improvements

Aluminium or calcium greases tend to thicken up as soon as the reaction begins. This renders circulation alone useless and circulation leads to the creation of worm holes where hotter materials would find their way to the inlet of the pump from circulation jets. Without actively turning the thick product, the microwaves would superheat its top layers while leaving the products at the bottom of the vessel unheated. Figure 3 shows the inside of a reactor with mixing arms designed for turning the products.

Figure 3: *Inside view of the new modified reactor with mixing arms*

When applying microwaves to metallic vessels, arcing could occur if there are gaps between metal components where the waves could resonate. Also, a rotating metal shaft could act as an antenna and a conduit for the microwaves to escape from the shaft ends. A new design was incorporated that utilises mixing arms but overcomes the microwave seepage at the shaft ends through the use of chokes. Its design incorporated a means to prevent arcing as the paddles approach the surface walls of the vessel and form momentary narrow metal to metal gaps. Chokes refer to various ways to contain microwaves. The metal screen in front of the window of household microwaves is considered a choke without which microwaves could escape through the glass.

Figure 4 shows the two current microwave reaction vessels side by side. These vessels are not jacketed which reduces manufacturing cost. Due to the shape of the new vessel being longer in length, the waveguides were split to form four points of entry. Since two microwave transmitters are used, each transmitter feeds its microwaves into two branches (Figure 4 bottom).

Figure 4: *(Top): Original vertical reactor used for manufacturing Lithium based grease with two waveguide entries; (Bottom) Top of the reactor with four microwave waveguide entries*

Process Update and Improvements

Over the last 10 years, several improvements have been incorporated into the current process. They include safe and successful processing of mineral oil-based products and processing of chemicals. Heating with microwave from the top of a vessel is different than the natural convection heating that takes place in conventional cooking. In cooking on a stove in a pot, the hot products rise, and the cooler products flow downward to replace them. This creates a natural convection. In microwave heating however, the products are heated from the top and the heated products remain on top. So, the products need to be circulated or mixed to prevent the formation of hot spots on top. Otherwise, microwave will overheat the top layers of the product while the bottom could remain unheated.

Improvement 1: Application of microwaves from the bottom of the vessel. When applying the microwaves from the top of the vessel, the air space above the product are also exposed to microwaves and are heated. While this is not a problem with atmospheric vessels that include sufficient air flow, it could become a source of hazard in a pressurised vessel when low flash point vapours are present. The patent pending improvement introduced the microwaves from the bottom of the vessel with the use of a microwave transparent barrier.

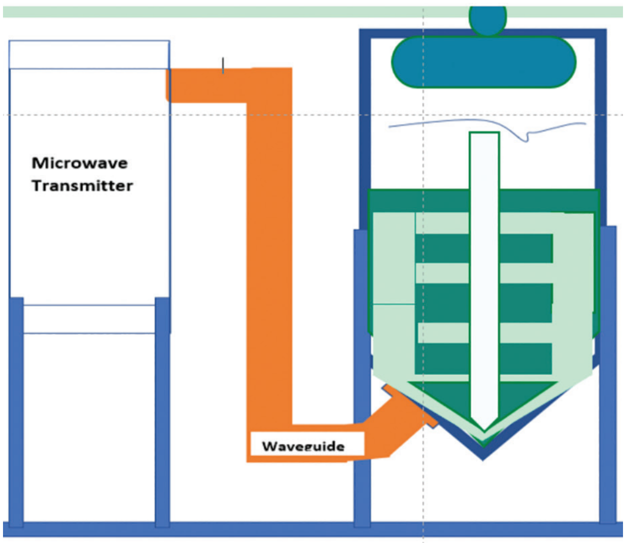


Figure 5: *Illustration of microwave application from the bottom of the vessel*

The barrier is made of materials that are transparent to microwave and does not absorb microwave itself. This is akin to viewing ports used on pressure vessels. The benefits have been spectacularly promising and include:

1. Heating from the bottom of the vessel results in the natural convection as the hot products rise and create a natural circulation in liquid products
2. Moving propellers and scraped surface mixing can be incorporated without arcing at the metal to metal gaps; or microwave leakage through the mixing shaft.

Improvement 2: The application of susceptors in the vessels. Susceptors are materials that absorb microwaves and emit infrared energy. They are used in a variety of applications. A simple example is sandwich wrappings with a coating of susceptor materials that heat up and toast sandwich buns bun when placed in a microwave oven. The use of susceptors in vessels for manufacturing grease requires special attention to the reflectivity and the susceptibility as well as the surface structure. Simply described, some mineral base oils like PAOs are mostly microwave transparent. This means when microwaves are applied, they could penetrate the oil with minimal loss of their magnetic strength and reach the walls of the vessel and bounce back. The reflected energy could return to the generator. If some dipolar materials such as azelaic acid are added to the PAO, then microwave absorption by the azelaic acid would heat quickly and heat the PAO through conduction. But, in order to ensure all products can be heated in a microwave vessel, a new patent pending process incorporates the use of susceptors in the vessel. In this case if the product is microwave transparent, then the waves are absorbed by the susceptor (instead of reflecting back). The susceptor reflects infrared heat energy to heat the material. The incorporation of susceptors in the vessels now allows microwave vessels to be used universally for processing products regardless of their polarity.

Improvement 3: Incorporation of 3-D printing in manufacturing custom waveguides. Waveguides require geometrically exact dimensions for safe and efficient transfer of microwaves. Their dimensions are dependent on the frequency of the waves they are designed for.

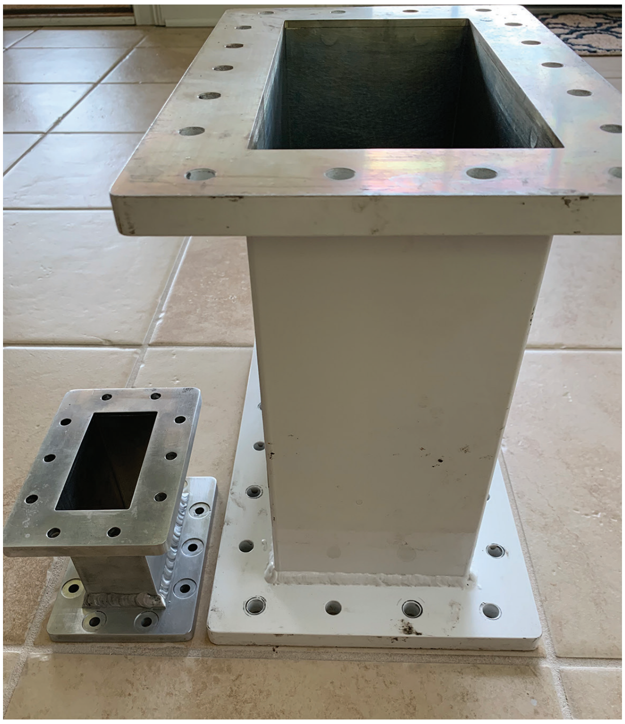


Figure 6: *Waveguides for 2450 MHZ and for 915 MHZ (Top) and 3D printed waveguide with built-in bends and sweeps (bottom)*

Figure 7: *3-D metallic waveguide model*

Figure 6 (Top) shows two different waveguides designed for 2450 MHZ microwaves (household microwaves); and 915MHZ (industrial microwaves). The use of elbows and sweeps or flexible waveguides add significant cost when the vessel location is not easily accessible. 3-D printed waveguides can help to custom manufacture waveguides in any configuration making assembly and maintenance easier. Figure 7 shows a 3-D metallic waveguide model with bends and sweeps.

Potential for future improvements

The use of microwaves to heat products rapidly has proven practical. There is a need for cooling thick products like greases faster than the current method of using chilled water in the vessel's jackets. New technologies are being explored as alternatives to the use of water.

One promising technology is the magnetocaloric cooling technology. It relies on heat absorption of select materials when those materials are exposed to magnetic fields. Commercial wine coolers using magnetocaloric technology are on the market and larger systems are being developed. This technology would still require water or a liquid to remove the heat from magnetocaloric material. But it could eliminate the conventional compressors and expanders and offers promise for the use of electromagnetic applied cooling, which is beyond the scope of this paper.

Conclusions

An accidental fire in the ELM biobased grease plant led to the search and discovery of the microwave use for processing grease. The invention of microwave processing technique described here is analogous to the current rapid and on-going transformation of the automobile power plants from the internal combustion engines to electric motors. The heat transfer oil systems, like internal combustion engines, are well known and technologically mature. But they are inherently inefficient and require expensive jacketed reaction vessels and extensive fire suppression systems. The utilisation of the magnetic fields of radio waves for the process industry is in its early stages with only a decade of production history. But it presents a transformational technology that could improve product quality while reducing energy requirements. In time, the energy requirements for processing products worldwide could be reduced by as much as 67% with the widespread use of microwaves for processing products. The simpler and less expensive process vessels could reduce required capital expenditures.

The faster and more uniform heating of the product results in significantly less damage to the base vegetable oil as observed in the lighter colour of the final product. In the case of bio-based greases, alongside performance the cost has been one of the most important barriers to their wider market acceptability.

The new heating technology has helped to remove those barriers to the market growth of bio-based products that is also transforming the grease use in environmentally sensitive applications.

The new improvements as described have made this technology useable universally beyond the bio-based products. It is certain that beyond the known processes of cooking ketchup or dairy products, for example and or heating for reaction in making soap and grease, there are numerous other uses that are yet to be identified with the wider adoption of this technology.

LINK
www.elmusa.com