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Historical Development of Vegetable Oil-based Lubricants

1.1 Introduction

Lubrication has probably been known to humans since the invention of the wheel. Recorded pictorial documents point to the use of water or edible oils as a lubricity liquid used by Egyptian pyramid builders when rolling large pieces of rocks on wooden rollers. Figure 1.1 shows a painting from an inner wall of the Tehuti-Hetep tomb. In this painting one worker is depicted as pouring a liquid in front of the rollers while others are pulling on the load [1].

The use of animal fat or vegetable oils for lubricating the wheels of horse-drawn carts and carriages has been well documented. It is not hard to visualize that the use of wooden axles and wheels, or even a combination of metallic wheels and axles would create friction and wear. Lubrication then becomes instinctive for human-made mechanical machinery, always seeking the most stable and efficient lubricant. Examples of these mechanical machines include Persian carriages, wind turbines running in wooden shafts, and waterwheels, all requiring some form of lubrication (Figure 1.2).

When we concern ourselves with actions or processes that help reduce friction we are engaged in tribology (tri-ball-ogy). The word tribology is used esoterically in lubrication and engineering sciences but is somewhat unknown outside these fields. Tribology is the science related to friction and wear or of reducing friction and wear. *Tribo*, is a Greek root meaning "rub" or friction combined with the word *logos* meaning "related" or, "the logic of." The Society of Tribologists and Lubrication Engineers (STLE) has a large membership in countries around the world. Many other technical and engineering societies devote a section to tribology-related subjects.

The industrial revolution saw drastically higher demands for lubricants to both lubricate moving parts and for energy transfer, like in hydraulic fluids. The hydraulic fluid acts as an energy transfer medium in hydraulic piping and at the same time helps to lubricate, seal, and remove heat and contaminants from components.

Biobased Lubricants and Greases: Technology and Products, First Edition. Lou A.T. Honary and Erwin Richter

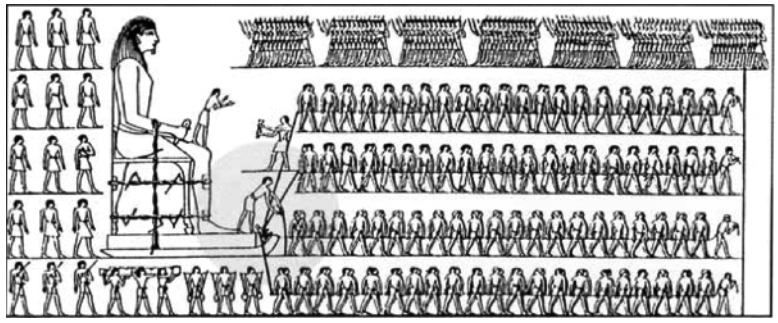

Figure 1.1 Egyptian pyramid builder applying oil on rollers to reduce friction [1]. Reproduced with permission from Dowson, D., *History of Tribology*, 1998, John Wiley & Sons, Ltd, Chichester

Joseph Bramah (1749–1814) is known for a number of inventions including the hydraulic press. In 1795, Bramah invented the hydraulic press capable of exerting huge forces for forming metals. Bramah applied the known hydraulic principle of Pascal's Law to a practical application of gaining mechanical advantage by the use of cylinders. His press offered a real and practical application of Pascal's Law to manufacturers that had to otherwise rely on often less efficient bulky mechanical systems. Applications of Bramah's invention include the hydraulic car lift, presses for forming metals, and the hydraulic brakes. Bramah's press is considered to have been a major contributor toward the advances made during the Industrial Revolution (Figure 1.3).

The need for more stable oils concurrent with the need for better sealing materials for high pressure hydraulic cylinders in presses led to the development of oils and the use of chemical additives. Initial seals used in hydraulic cylinders were made of leather, which would absorb the lubricant, causing it to swell and seal but also needing more frequent replacement than the current elastomeric seals. Water was one of the initial fluids used for hydraulic cylinders.

The automobile's brake system is a good example of how hydraulic oil transfers the force of the driver's foot to the brake pads to stop the vehicle. In this case, the main purpose of the brake fluid is energy transfer, although it also lubricates and seals the pistons in the master and wheel cylinders (Figure 1.4).

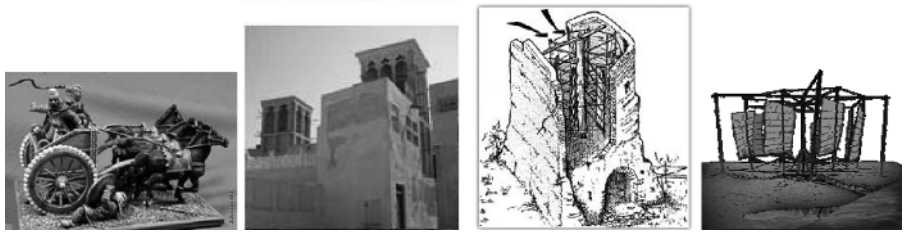

Figure 1.2 Persian war chariots and windmills used animal fat or vegetable oils for lubrication. Courtesy of Grenada Studios, St Petersburg, Russia

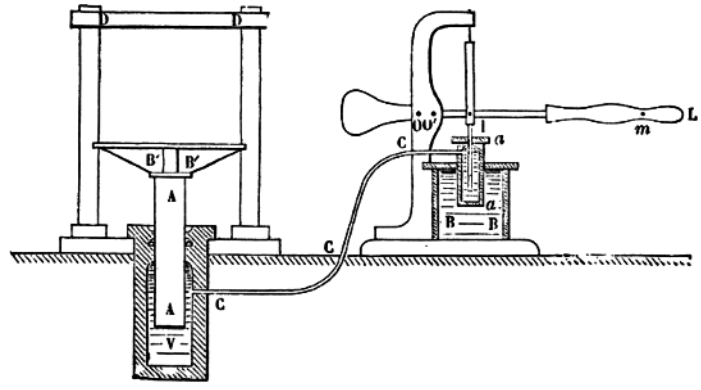

Figure 1.3 Schematic of Bramah's Press

1.2 Pioneering Industrial Uses of Vegetable Oils

The idea of using vegetable-based products as lubricant or fuel is not new. For example, Rudolf Diesel used peanut oil to power one of his diesel engines in 1900 during a power show in Paris. Technology in the use of biolubricants and fuels was put on hold however, due to the abundance and low cost of petroleum.

When investigating the industrial uses of vegetable oils in the United States, two names stand out. The industrialist Henry Ford I and Dr George Washington Carver (Figure 1.5), who was a pioneering agricultural researcher! Henry Ford I had a vision of using crop-based materials in making cars and tractors and creating a closed circle of cradle to grave renewable products.

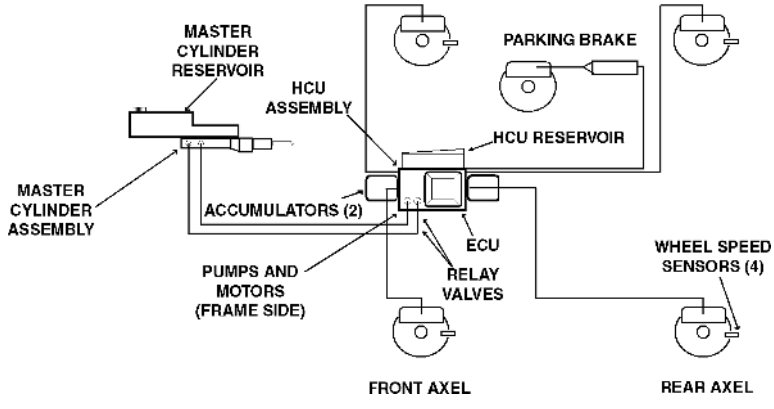

Figure 1.4 A schematic of an automobile brake system with hydraulic lines using oil as the energy transfer medium

Figure 1.5 Henry Ford (right) and George Washington Carver. Courtesy of The Henry Ford

George Washington Carver's research resulted in over 500 products from peanuts, sweet potatoes, and pecans. He graduated in 1894 from Iowa State College of Agriculture and Mechanic Arts (now Iowa State University, in Ames, Iowa). Carver joined the faculty of the college and continued his studies in bacteriological laboratory work in systematic botany. Later he joined the faculty and assumed the directorship of the Department of Agricultural Research at Tuskegee Normal (now Tuskegee University) in 1896. Henry Ford has been credited for leading the development of biobased products in the early twentieth century. He also worked closely with George Washington Carver, recognizing their mutual vision. They shared a vision of a future in which agricultural products would be put to new uses to create products and industries.

Henry Ford believed that agriculture could supply the industry with renewable raw materials. His invention of the Ford Model T was designed as an economical vehicle for the masses. The concept of mass production and increased production were also promoted by Ford. During World War II, he began designing vehicles that would use biobased plastic bodies and corn-based fuels, now known as ethanol (Figure 1.6).

Paying attention to the mechanization of the farm machinery, Ford was convinced that farmers could become self sufficient in creating their own lubricants, food and fuels from their farm renewable products. Towards that end, Henry Ford sponsored the research activities of George Washington Carver, whom he considered as another visionary in the use of biobased products.

The car was lightweight and constructed of plant-based plastic. To demonstrate the stability of a flexible plastic car body, Ford used an ax to simulate minor crashes which would result in the ax bouncing off (Figure 1.7).

In 2004 the Ford Motor Company created a concept vehicle that included many of the existing biobased technologies, including soybean oil-based grease and gear oils. This was appropriately called Model U as a follow up to the popular model T that was created by the founder of the company decades earlier (Figure 1.8). The authors provided biobased grease for use in this concept vehicle.

Figure 1.6 A "soybean car" containing biobased materials. Courtesy of The Henry Ford

1.3 Petroleum

Petroleums from different regions of the world have different properties but in general, petroleum is decayed plant and animal remains with the main constituents being the same regardless of the source. In the early twentieth century United States, the discovery of petroleum in Spindletop, Texas (Figure 1.9) created a rush for drilling, which resulted in the availability of cheap crude oil. The Gladys City Oil, Gas, and Manufacturing Company, was the first oil company to drill in Spindletop. In its first year, Spindletop production reached 3.59 million barrels of oil. By the second year, production had reached 17.4 million barrels.

Figure 1.7 Henry Ford demonstrating the strength of the bioplastic car body. Courtesy of The Henry Ford

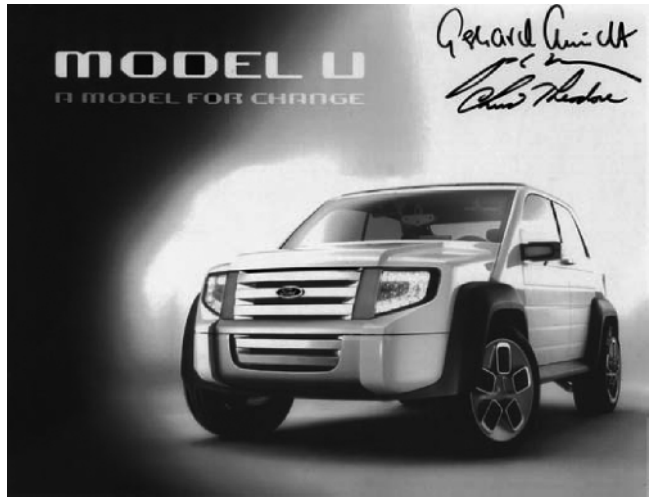

Figure 1.8 Ford Model U utilizing biobased materials where possible. Photo courtesy of the Ford Motor Company

Eventually production reached nearly 100,000 barrels per day leading to a major economic boom for the area [2].

With the high-energy intensity of petroleum as a motor vehicle fuel, no other automotive power plant (like steam engines and electrically driven motors for vehicles), nor any other base oils (like vegetable oils) had a chance to compete. The cheap petroleum oil was a blessing for the growth of the fledgling automotive industry and for the use of gasoline byproducts, which are heavier hydrocarbons, for lubricants and greases. At the same time, however, it was

Figure 1.9 Discovery of oil: Spindletop, Texas led to popularity of gasoline as fuel and mineral oils for lubrication

a curse for creating an ever-increasing demand for petroleum at the expense of all other alternatives. This included electric and steam power plants for vehicles, and animal fat or vegetable oils for lubricants. Only during the two World Wars did petroleum supply interruptions result in a shift in attention towards the use of vegetable oils for fuels as biodiesel and lubricants for machinery or hydraulic energy transfer.

The advances made in extraction and refining of petroleum resulted in the creation of fuels, oils, and chemicals to complement each other. The single viscosity engine oils, for example, required the use of thinner oil in the winter season to be replaced by thicker or higher viscosity oils to use in the summer. Later, by addition of polymeric additives, multiviscosity grade oils were created that would work in any temperature.

The rapidly increasing usage of automobiles in the United States along with the invention of mass production techniques by Eli Olds (and utilized by Henry Ford), created a perfect storm for the superiority of petroleum-based lubricants.

A fire in the Eli Olds production facility destroyed his inventory of parts and vehicles, leaving him with only one unit of his then famous "curved dash automobile" (Figure 1.10) that had been stored in his garage. The necessity of having to produce over two-dozen vehicles on order with no production facility led him to contract with various shops in Detroit. These shops in turn built components of his cars to the exact dimension of the one surviving curved dash vehicle. This, in effect, created the concept of mass production, whereby accurately produced components of the car manufactured by different companies would be assembled in one place to complete vehicles. Detroit thus became Motor Town, or Motown, with almost every shop making parts for some car company.

Figure 1.10 Old's curved dash vehicle started the mass assembly trend. Picture of Eli Olds Car advertisement. See Plate 1 for the color figure

Forces that began to turn the tide toward the use of vegetable oils as a substitute for petroleum products included increased concern for the environment, increased demand for petroleum, and geopolitical pestering. Many factors, such as oil spills like the infamous *Exxon Valdez* spill in Alaska's Prince William Sound of March 1989, the BP oil well explosion in the Gulf Mexico in 2010, global warming, and the demand for oil by developing countries, have created this turning point. It is estimated that in the brief period of 100 years since the discovery of oil in Spindletop, we have exhausted half of the world's petroleum.

During the 1980s, European researchers encouraged by the agriculture community in Europe began to explore the use of vegetable oils as hydraulic fluids and other industrial lubricants. The concern for the environment and lobbying of farmers' organizations led to mandates for the use of biodegradable products in certain parts of Europe. For example, in the 1980s, the German government required the use of biodegradable hydraulic oils in Black Forest regions. During this period, the European community created environmental seals and emblems to identify the "Environmentally Aware" lubricants.

By the 1990s, many North American companies began to follow the Europeans' leads on creating biodegradable products. In the 1990s' conferences held by the American Society for Testing and Materials, over 40 North American companies had representatives in attendance to discuss their efforts in creating biodegradable products and help in establishing standards.

In the United States, for example, The Lubrizol Corporation invested significant amounts of resources in creating additive packages for vegetable oil (specifically sunflower oil) based lubricants. The list of additive packages and products from Lubrizol was comprehensive and included food grade products, two-stroke-cycle engine oils, and universal tractor hydraulic fluids.

Eventually, the relatively low price of petroleum and a lack of mandates for using biodegradable or renewable products diminished the investments in research and development (R&D) for these products. By the late 1990s, the only groups continuing to fund R&D of industrial products and lubricants made from renewable materials were farmers groups like the United Soybean Board, representing US soybean farmers, or the US Department of Agriculture.

In 2000, the United States' Farm Bill, which was a 5-year plan for the advancement of agriculture, included provisions for the promotion and use of biodegradable and renewable products. The US government selected "the leadership by example" approach in an attempt to avoid mandates and allow the free market enterprise to bring about the success of renewable products. This approach required federal agencies to purchase and use biobased products so as to prove viability of performance and eventually lead to commercial success in competitive private sector markets. Biobased and renewable based lubricants now have a presence in the world market and are anticipated to grow in technology and use.

In order to better follow the future of biobased lubricants *vis-à-vis* petroleum lubricants it is important to understand the different plant oils and petroleum oils. Within this context, the basic concepts relating to these two oils will be covered.

References

1. Madius, C. and Smet, W. (2009) *Grease Fundamentals: Covering the Basic of Lubricating Grease*, Axel Christiansson, Heijningen, The Netherlands, www.AXELCH.com.
2. Materials on Spindletop Texas retrieved April 18, 2010: http://www.eoearth.org/article/Spindletop,_Texas.