White Paper

Often Overlooked, Lubricants Can Help Lower Energy Consumption

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Abstract

It is a simple fact: Better lubrication can lead to dramatic energy savings and an improved bottom line. This ought to interest any plant manager who is looking for ways to reduce operating costs, and is especially significant at a time when stricter government regulations are in direct contradiction to reducing costs. Lubrication reliability is the solution. This paper will describe how manufacturing plants can use lubrication reliability best practices to reduce their energy consumption, emissions and operating costs – all at the same time.

Introduction

Energy usage is a cornerstone of today's society. Economic development and improved standards of living both rely upon the availability of energy. According to **The Outlook for Energy: A View to 2030** by Exxon Mobil, energy usage per person varies dramatically around the world but equates to an average of 200,000 Btu a day, which is 15 billion Btu per second. (1) This same study points out that each person has direct and indirect energy demands. Direct demand of energy is the energy that drives their personal vehicles and operates their homes, while indirect demand is the energy that heats and cools buildings, generates power, produces goods and services, and provides mass transportation of goods and people.

As the lesser developed parts of the world modernize, their needs for energy will grow, resulting in increased costs for fuel worldwide. Along with this, many of the world's governments are passing stricter laws regulating clean air and water, toxic waste, pesticides, endangered species and more. These factors – combined with a struggling economy – result in a challenge for plant operations managers, which is to reduce operating costs. Often, this means doing more with less.

One way to reduce operating costs is to reduce energy consumption. Upgrading plant equipment to take advantage of newer, more energy-efficient technologies can reduce energy costs. Unfortunately, in a challenging economic environment capital may not be available for plant upgrades. Simple changes in habits can also create considerable savings. One such change is improving the lubrication reliability program. According to Peter Thorpe, product application specialist at Shell South Africa, "From a cost point of view alone, lubricant costs are negligible when compared to energy costs, even before the production efficiencies of high-performance lubricants are factored in." (2)

Electric utility bills generally dwarf maintenance and lubricant costs. All three are part of any manufacturing operation. So, while controlling or reducing maintenance and lubricant costs is important, reducing electric utility usage is critical. This paper will show that tremendous opportunities exist to use an improved lubrication reliability program to decrease plant energy costs, thereby increasing profitability.

Sources of Energy

There are various forms of energy, as illustrated in Table 1. Note: Mechanical energy is further broken down into two types – kinetic energy, which is the energy of motion, and potential energy, which is associated with an object's position.

Table 1: Forms of Energy
Chemical
Nuclear
Radiant (light)
Thermal
Sound
Electrical
Mechanical (kinetic/potential)

(3)

Energy often transforms from one form to another for an end-use purpose. For example, oil when combusted contains chemical energy that converts to thermal energy, then to electrical energy or mechanical energy.

Energy for Work

During conversions from one form of energy to another, some useable energy is lost. These energy losses can be extremely costly to society. The science of physics reveals that lubrication can play a role in reducing energy losses by reducing friction.

Society uses many automated tools to perform everyday activities, often called work. These tools frequently include many moving parts to accomplish the chore they are designed to perform. It turns out that work and kinetic energy – also called the energy of motion – are directly related. In 1687, Sir Isaac Newton published his laws of motion in **Principia Mathematica**. With these laws, Newton determined that the mathematical expression for kinetic energy (K) is:

a) $K = \frac{1}{2} mv^2$ (where m is a mass and v is a velocity that the mass is moved)

So, it can be stated that it takes energy to move an object.

The laws of physics also state that work is the force required to move an object a certain distance as shown in equation (b). Work is also equal to the change in kinetic energy, indicated in equation (c).

b) $W = F\Delta x$ (where F is a force and Δx is the change in position)

c) $W = \Delta K$

It turns out that friction is a force that exists in two forms, static friction (F_s) and kinetic friction (F_k). Friction is represented mathematically by the following two equations:

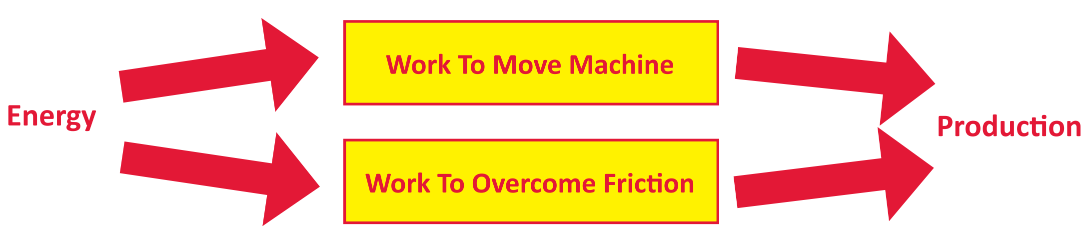
d) $F_s = \mu sN$ & $F_k = \mu_k N$ (where μ_s and μ_k are the static and kinetic coefficients of friction, respectively, and N is a force normal to the moving surfaces)

The coefficient of friction is a unit-less number that varies depending upon the composition of materials which the moving surfaces are made. Obviously, the higher the coefficient of friction is, the higher the friction force.

Finally, the equation that describes the total change of kinetic energy (E_T) required in a moving system is the following:

e) $E_T = W_m + W_F$ (where W_m is the work to move the machine and W_F is the work required to overcome friction)

So, physics shows that reduced friction would result in less energy needed to complete the desired work. Placed between two moving surfaces, a lubricant decreases the coefficient of friction. Naturally, this would also mean the more a lubricant decreases friction, the less energy the lubricated machine consumes.



Lubricant Formulation Basics

It has been said that "Oil's oil … just pour it in," but this statement is far from the truth. Simply described, a lubricant is composed of a base fluid and additives. However, many lubricant suppliers formulate their lubricants according to unique recipes intended for specific purposes. The following is a primer on the basic types of lubricants and the specific ingredient-driven categories.

Table 2: Lubricant Types

Automotive (Transportation)	***Industrial (Factories)***
Heavy-duty diesel engine oils	Compressors
Passenger car engine oils	Bearings
Automatic transmission fluids	Gear boxes
Aviation engine oils	Hydraulics
Mobile hydraulic	Turbines
Differential fluids	Chains/wire ropes
Torque fluids	Slideways
Chassis lubricants (grease)	Grease

Each of the above lubricant types are usually broken down into narrower descriptions based upon the product formulation chemistry. Table 3 lists the categories and the additive types that dictate the categorical description. These descriptions are extremely simplified, as there are various base fluid types and even more additive types. Each formula category has its strengths and weaknesses and should be chosen based upon the needs of the application type. (See Table 2.)

Table 3: Lubricant Categories by Ingredient

Category	***Ingredients described***
Mineral oil	Base fluid derived from refined crude oil
Synthetic	Synthesized base fluids such as: PAO, esters, PIB, PAG and more
R&O (rust & oxidation)	Contains rust and oxidation inhibition additives
AW (anti-wear)	Contains wear-reducing additives
EP (extreme pressure)	Contains extreme pressure wear reducing additives
Multigrade	Contains viscosity index improving additives
DI (detergent inhibitor)	Contains detergent, dispersant, oxidation, wear, anti-corrosion additives
Others	Defoamants, emulsifiers, demulsifiers, pour point depressants, thickeners

It becomes obvious that lubricant formulations can be rather complex. When searching for the best lubricant to minimize energy loss due to friction, it is often a case of "you get what you pay for." In other words, an inexpensively priced lubricant does not necessarily provide maximum lubrication performance. As such, they may require a higher amount of energy consumption, sometimes at higher costs than with a more expensive, better-performing lubricant. However, just buying an expensive lubricant does not ensure maximum lubricant performance and energy savings. The lubricant must be the right one for the application and must be properly maintained in order for it to provide maximum performance. This means proper storage and handling, filtration, oil analysis, training and more.

All electro-mechanical equipment requires periodic maintenance to operate at peak efficiency and minimize unscheduled downtime. Inadequate maintenance can increase energy consumption. It also can lead to high operating temperatures, poor moisture control, excessive contamination and unsafe working environments. Depending on the equipment, maintenance may include the addition or replacement of filters and fluids, inspections, adjustments and repairs. (4)

So, how does the end-user know what to do? The answer is to find a lubrication partner that can help develop a comprehensive lubrication reliability program that includes lubricant selection, protection and maintenance. This partner could be a consultant, but it could also be a lubricant manufacturer that offers customized, comprehensive solutions, including lubricants and all of the related lubrication reliability products.

Lubricants and Energy Savings

It is possible to measure energy savings in a variety of ways, including production output, temperature changes or electrical reduction, all mentioned below. Another measurement is fuel consumption.

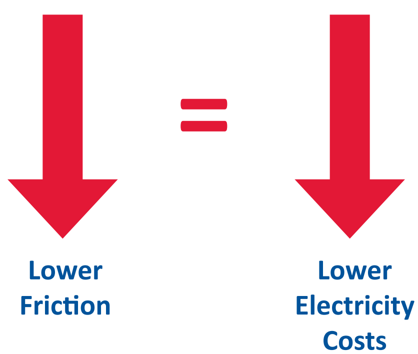
Production Output

When we use equipment to perform work, it is possible to evaluate the equipment's energy efficiency by recording its production output. For example, if a machine is capable of producing a certain number of parts in a given amount of time and the lubricant is changed, resulting in a higher volume of parts being produced in the same amount of time, then the machine has become more energy efficient. One must be careful when using this technique to ensure that nothing changed in the process except the lubricant. This can be overcome by using a larger number of test units or evaluating productivity over a longer amount of time.

Temperature Changes

Monitoring temperature changes is another way to optimize lubrication program performance. Increased friction in a piece of moving equipment results in higher operating temperatures. Friction is a result of metal-to-metal contact that occurs between two opposing surfaces moving relative to one another. Even between highly machined surfaces, under microscopic view, asperity contact occurs.

The greater the amount of contact, the greater the amount of friction. As a result, more energy is required to move the surfaces relative to one another. This friction results in higher electrical power costs. Lubricants can reduce that friction. Therefore, when friction is reduced, less electricity is required to drive a gearbox, compressor, pump or other piece of equipment.



Sometimes, the bulk oil temperature is monitored in a piece of operating equipment. Another technique for evaluating lubrication performance is thermography, which involves using infrared detection equipment to look for "hot spots" on a piece of equipment that could result from insufficient lubrication, improper lubricant selection or faulty operating parts. In any of these cases, higher temperatures result in wasted energy. It is important, however, to account for ambient environmental temperatures when performing this type of energy efficiency study. Obviously, a piece of equipment will run hotter on hot days than on cold days.

Case Study: A knitting plant in Hendersonville, N.C., was experiencing overheating problems in its Champion TWT-07 reciprocating compressor while using the recommended commercial grade lubricant. Even after changing to several synthetic products, it still experienced lubricant foaming and overheating. After changing to ashless AW mineral compressor oil, the plant experienced an immediate drop in temperature of 15°F (8°C). Even after three months of continued service, the plant maintained this temperature drop. This study illustrates that certain equipment can have its own lubricant appetite. Just because a fluid is synthetic does not necessarily mean that it is always the best recommendation for every piece of equipment.

Electrical Reduction

When most think about energy consumption, they immediately think about electrical consumption. Tracking electrical consumption is a highly reliable way to evaluate improvements in plant energy use. In fact, various companies have been able to document improvements in electrical energy efficiency related to their lubrication programs. Typically, companies that upgrade their lubricants and reliability practices have been able to document a 5 to 15 percent reduction in power requirements, more than enough to pay for a better-performing lubricant. Average documented savings were 15 percent in gearboxes, 12 percent in air compressors and 4 percent in electric motors. (5)

Typical Savings with 5% Amperage Reduction		
Electric Motor (hp rating)	**Type of Operation** 40 hrs/week	**Continuous**
10	$74	$297
50	$372	$1,487
100	$746	$2,986
200	$1,493	$5,472
*$0.10 kWh Electricity Rate		

Electric motors power most plant machinery, including gearboxes, compressors, refrigeration systems, pumps, hydraulic systems, and ball mills. Kilowatts (kW) are the common unit for measuring electricity. The following equation can determine the amount of electricity used by an electric motor:

f) **kW = V/1000 x A x 1.73** (where V is volts and A is amperes)

Both are common metric measurements of electrical current measured using a voltmeter or ammeter. For a three-phase motor, 1.73 is a standard factor. Data logging equipment is available that allows one to measure and collect data for either amperes, volts or both. Yet, most electrical consumers pay for electricity by kilowatt-hour (kWh) per month. The following formula is commonly used to determine the electrical charge per month (ECM):

g) **ECM = kW x h x EC** (where h is hours of service and EC is the electrical charge)

Air compressors are an excellent source for energy savings. Compressed air is one of the most expensive uses of energy in a manufacturing plant, and approximately 70 percent of all manufacturers have a compressed air system. These systems power a variety of equipment, including machine tools, material handling and separation equipment, and spray painting equipment. According to the U.S. Department of Energy (DOE), compressed air systems in the U.S. account for 10 percent of all electricity and roughly 16 percent of U.S. industrial motor system energy use. This adds up to $1.5 billion per year in energy costs and 5 percent in emissions. Energy audits conducted by the DOE suggest that more than 50 percent of compressed air systems at industrial facilities have significant energy conservation opportunities. (6)

Following are manufacturing case studies in which lubricant changes in air compressors and other plant equipment helped manufacturers reduce their electrical consumption.

Case Study: A western New York glass and ceramics manufacturer had instituted a program to reduce electricity consumption. The manufacturer targeted its Ingersoll-Rand ESH reciprocating compressor, driven by a 440-volt, 75-hp motor, because this piece of equipment operated at peak capacity 24 hours per day, seven days a week. At the start of the experiment, when the compressor contained the OEM-specified synthetic oil, the average baseline reading was 89 amps.

A week after draining the oil, cleaning the compressor and refilling with a high-performance branded synthetic oil, the manufacturer again collected data and found that the average reading had dropped to 82 amps. Knowing that it was using six fewer amps, applying equations (f) and (g), and knowing that the energy charge was $0.10/kWh, the manufacturer was able to calculate annual monetary savings due lubricant-related electrical efficiency improvements.

kW = 6 amps x 440 volts/1,000 x 1.73 = 4.57
ECM = 4.57 kW x 8,760 h/yr x $0.10 = <u>$4,003/yr</u>

Data collection continued for an entire year, and the new, lower amperage remained unchanged. Valve maintenance was performed at the same intervals as with the previous oil, and this revealed the source of the energy savings. The valves were no longer covered with sticky carbon-varnish build-up, as they had been with the OEM oil, and the new oil appeared to deteriorate less. The manufacturer learned that not all synthetic lubricants are equal.

Case Study: A South Dakota wastewater treatment plant was interested in reducing operating expenses by using higher quality lubricants to achieve extended drain service and possible energy savings in three Spencer 50-hp rotary blowers, which were part of a biological contactor system. The average electrical reading was 50 amps on each of the blowers while using the current lubricant. After changing to a high-performance lubricant, the average dropped to 38 amps. Based upon electrical rates at that time, the estimated yearly savings was $2,968 per blower, or $8,904 total for all three.

Conclusion

Today, there are various reasons to reduce energy consumption, such as conserving natural resources, reducing emissions and improving profitability. Governments and corporate management alike are looking for ways to reduce energy consumption.

Indirect energy use, more commonly called industrial use, is greater in all regions of the world than direct or personal use. That makes industry the largest consumer of energy and, therefore, the greatest source of potential reductions. Energy use can be measured through production output, temperature changes and electrical consumption. It is possible to make dramatic gains in energy efficiency by reducing friction, and one of the best ways to do that is to employ good lubrication practices, including the use of high-performance lubricants and the adoption of lubrication reliability best practices. The key to success is finding a lubricant company that not only can provide the right high-performance lubricants for the applications but also can recommend reliability solutions that will further reduce friction and maximize the efficiency of equipment.

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