Lubricants are required in every machinery and engine for reducing friction, wear, and energy consumption. Depending upon the operating and design parameters of the equipment, a properly formulated lubricant can play a major role in extending equipment life and saving energy. For manufacturing modern lubricating oils, lube base oils and chemical additives are required. While base oils are produced in the refineries, chemical additives are manufactured separately in chemical plants, as it involves chemical reactions between several materials and specialized testing facilities. Currently, about 41 MMT (million metric ton) of lubricants are produced globally, and the market is growing slowly at the rate of about 2% per annum. The demand pattern has been described in several publications [1–5]. The growth is mainly in Asia. India and China are the fastest growing countries in this sector (3–5%). Asia Pacific is the largest consumer of lubricants (35%) followed by North America (28%), central and southern America (13%), western Europe (12%), and others (12%). Asian market is dominated by China (4 MMT), Japan (2.8 MMT), India (2.4 MMT), and Korea (1 MMT/year). Asia Pacific countries contribute to about 14 MMT of lubricant business per year.

These 41 MMT of lubricants constitute more than 600 grades of products to meet automotive and industrial requirements. Lubricants for automotive applications constitute the major share of lubricants (55%) followed by industrial oil (30%), process oil (10%), and marine oils (5%). Among industrial oils, turbine, hydraulic, gear, and compressor oils constitute major products (60%). About 15–20% of industrial oils are metal working oils and 5% are greases. The balance constitutes other miscellaneous industrial oils.

There are large numbers of small and major manufacturers of lubricants around the world, but in the last two decades, major consolidation has taken place, and four major global companies—Exxon-Mobil, Chevron-Texaco-Caltex, BP-Amoco-Castrol, and Total-Fina-Elf—operate. Two major regional companies—Chinese Sinopec/CNPC and India’s, Indian Oil Corporation—have substantial market share in their respective countries.
Synthetic lubricants [6] constitute about 3% of the total world lubricants. These are mainly aviation and high-temperature application fluids used in situations where mineral oil-based products cannot provide adequate service. Synthetic lubricants use several additives that are common in mineral-based products but also use special chemicals that provide high-temperature, high-pressure performance. Synthetic lubricants are based on several synthetic materials as base oils such as alkylated aromatics, polyalphaolefins, organic esters, halogenated hydrocarbons, phosphate esters, polyglycols, polyphenyl esters and ethers, silicate esters, and silicones. Synthetic oils are also used when there is a need for longer drain capabilities, lower oil consumption, fuel economy, and environmental issues like biodegradability, emissions, and recyclability. Low-viscosity multigrade engine oils like 0W-30 or 5W-30 also need synthetic base oils to meet the low-temperature viscosity requirements.

Lubricant market is dynamic, and quality levels are continuously changing. Every year, new specifications of automotive lubricants are generated to meet the OEM requirements. The use of multigrade engine oils in both gasoline and diesel engines has given a new dimension to the engine oil formulations. Multifunctional additives like dispersant viscosity modifiers change the ratio of detergent/dispersant. Use of American Petroleum Institute (API) group II, III, and IV base oils also changes the additive requirements. For example, it is possible to formulate multigrade engine oils with polyalphaolefins without or minimal use of viscosity modifiers and pour point depressants. These variations lead to the reformulation of products, and therefore, the additive pattern also changes. The demand pattern provided earlier, therefore, should serve as broad guideline only.

The last two decades have seen a very fast-track upgradation of engines, fuels, and lubricants. U.S., European, and Japanese OEM efforts have resulted in several upgraded engine oil specifications and test procedures. The highest diesel engine oil quality till 1985 was API CD level and gasoline engine oil till 1988 was API SF category. However, after 1988, there has been upgradation every year. Currently, API SN and ILSAC GF-5 for gasoline and API CJ4 for diesel engine are the latest standards for automotive lubricants. There has been a similar trend in the development of automatic transmission fluid specifications. These were, however, heavily driven by two major OEMs, General Motors and Ford, whose Dexron and Mercon fluid specifications are accepted worldwide.

This improvement in oil quality led to higher oil drain intervals, improved fuel economy, and reduced emissions. Simultaneously, the gasoline and diesel fuel quality was also improved to match the emission standards imposed by legislation. From gasoline, lead was phased out, octane number was improved, and benzene content and sulfur content were drastically reduced. Gasoline was reformulated to allow the use of oxygenates and multifunctional additives. Similarly, the diesel fuel quality was improved with respect to improved cetane number, reduced aromatics and olefin content, distillation, and drastic reduction of sulfur content. To formulate improved lubricants, it was also necessary to improve the base oil quality. API responded to this need and came out with its base oil classification, where all base oils were categorized into five groups (groups I–V). In groups II and III, sulfur levels
have been reduced to less than 300 ppm and saturate content to minimum 90%. The viscosity index for group III base oil has been specified as 120 minimum. All synthetic polyalphaolefins have been categorized in group IV and remaining synthetic oil of different molecular structure in group V. To match this development in lubricant specifications, fuel quality, and base oil quality, it is obvious that the additive technology has to improve. The new specification of diesel engine oil API CJ-4 imposes restrictions on sulfur, phosphorus, and ash content, which will restrict the use of ZDDP or sulfonate/phenate detergent. Newer additives would therefore be required to formulate these and future lubricants. Biodegradability, environmental friendliness, and toxicity would further impose restrictions on the choice of additives.

Oil is limited and reserves are depleting. The search for alternate fuels is currently at its peak. Following options are currently being considered as an alternative to petroleum fuel:

1. Biofuels such as biodiesel
2. Light gaseous hydrocarbons (CH₄ based) such as CNG, LNG, coal bed methane, gas hydrate, propane, and butane (LPG)
3. Oxygen-containing fuels such as methanol, ethanol, dimethyl ether, and ethers
4. Hydrogen

The increasingly higher cost of crude petroleum and its depleting reserves is driving the development of alternate fuels. In the next few decades, we may witness a shift in the use of alternative fuels depending on the techno-commercial viability of these options. The application of CNG and biodiesel has already taken place in several countries. There is considerable activity in the development and use of biodiesel, which is nontoxic, free from aromatics, low in sulfur, and biodegradable. Biodiesel can be manufactured from renewable sources using varieties of vegetable oils and animal fats through a process of trans-esterification with methyl/ethyl alcohol. These are called fatty acid methyl esters or FAME. It may be necessary to have a separate biodiesel lubricant to take care of specific character of this fuel.

There are several technological issues, like cost of manufacture, energy requirement in the production of hydrogen, and its use in the field that needs to be addressed before hydrogen can be adopted as a transportation fuel. Hydrogen is the most ideal and clean burning fuel. With hydrogen fuel cell-based engines, the crankcase engine oils will not be required. Fuel cell-based engine will have electric motors to drive the wheels, which will require only grease for lubrication. However, hydrogen-fired engine would need special lubricant to meet the changed engine environment.

With these changes, the lubricants and their quality will undergo substantial change, and new innovative technologies need to be developed to meet the challenges lying ahead.

The book discusses various aspects of formulating modern lubricants to meet the modern industrial and automotive vehicle requirements while complying with the environmental regulations. The changes that are taking place in lubricant technology are discussed specifically.
REFERENCES