FUEL, LUBRICANT AND GREASE

1 Introduction

According to the report issued in January 2021 by the International Energy Agency (IEA), global oil demand in 2021 remained affected by the COVID-19 pandemic, but nevertheless rose to 96.4 million barrels per day, an increase by 5.4 million barrels per day over the previous year, as the economy began to recover. The widespread availability of vaccines and steady revival of economic activities following the lifting of lockdowns in cities, led to a robust rise in demand of 95.4 million barrels per day (an increase of 2.1 million barrels per day from the previous quarter) in the second quarter to 99.0 million barrels per day (an increase of 1.2 million barrels per day from the previous quarter) in the fourth quarter. By region, the recovery in demand was led by the U.S., China, and other Asian countries, but slow in Europe.

The global oil supply in 2021 rose by 1.5 million barrels per day from the previous year thanks to higher demand, reaching 95.3 million barrels per day. The increase in supply produced by OPEC Plus members was 0.8 million barrels per day. Since demand generally exceeded supply for the year as a whole, decreasing inventories, resulted in the rise in crude oil price discussed later.

Figure 1 shows the changes in the FOB price of West Texas Intermediate (WTI) crude oil futures in 2021. The year opened at below 50 dollars per barrel. Shored up by an economy recovering from the impact of the pandemic, the price then exhibited a moderate upward trend until November, reaching 80 dollars per barrel in October. Prices remained high as their rise did not lead OPEC Plus members to deviate from their original plan to increase production gradually. After November, the U.S. and IEA led an unprecedented strategic collective release of oil stocks to mitigate the rising prices. This action, in conjunction with concerns about the global spread of the Omicron variant of COVID-19, caused unstable fluctuations in oil prices, including a drop of over 10 dollars per barrel.

2 Fuels

2. 1. Fuel Trends

Figure 2 shows the trends in the amount of fuel oil sold in Japan taken from the *Mineral Resources and Petroleum Products Statistics* announced by the Ministry of Economy, Trade and Industry. A total of 154.56 million kL of fuel oil was sold in Japan in 2021, representing a 2% increase from the previous year. The breakdown by oil type compared to the previous year was 45.23 million kL for gasoline, a 1% decrease; 3.22 million kL for jet fuel, a 1% decrease, 32.1 million kL for diesel fuel, a 1% increase, and 10.04 million kL for Class A heavy oil, which remained at the same level. Class B and heavy oils sales increased significantly, to 78.9 million kL, a 27% increase from the previous year. Nevertheless, as with gasoline, they have been declining for the last ten years.

2. 2. Gasoline for Automobiles

There have been no major change to the standards and regulations concerning gasoline for automobiles in the last few years.

One reported technological trend was the research into the ignition characteristics of hydrocarbon structures conducted by the Innovative Combustion Technology project of the Cross-ministerial Strategic Innovation Promotion Program (SIP) which, in 2018, achieved its goal of developing an internal combustion engine with a maximum thermal efficiency of 50% through the establishment of an industry-academia collaboration framework. Research on lean HCCI combustion to achieve clean emissions with high thermal efficiency has also been reported.

Global efforts to achieve carbon neutrality are accelerating, and gasoline for automobiles needs to contribute to those efforts. Setting their sights on the 2030 market, the Petroleum Association of Japan and the Japan Automobile Manufacturers Association, Inc. have started joint

Fig. 1 Changes in FOB Price of WTI Crude Oil Futures

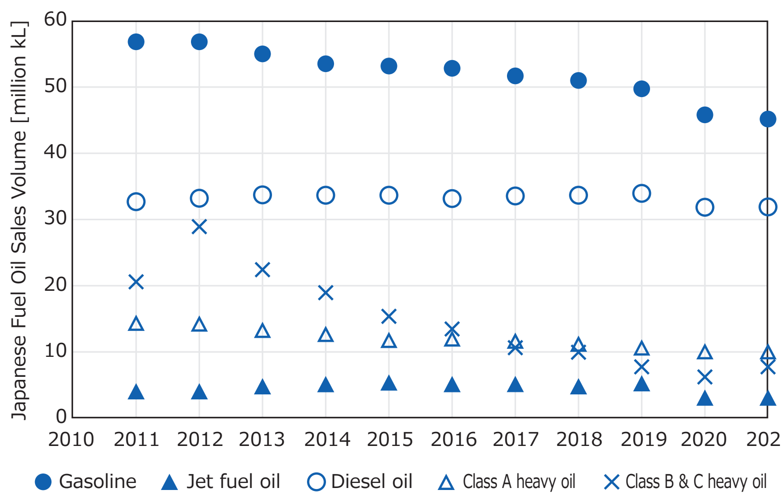

Fig. 2 Changes in Japanese Fuel Oil Sales Volume by Oil Type

research on reducing CO_2 by optimizing combinations future engine combustion methods and future fuel types.

2. 3. Diesel Fuel for Automobiles

There was no notable activity concerning automobile diesel quality, standards, regulations or research. In contrast, the diversification of diesel fuel was highlighted by the announcement of the field testing of next-generation biodiesel fuel entirely derived from used cooking oil or microalgae oil as the fuel powering endurance race cars, conventional diesel railway trains, high-speed sightseeing boats, and fishing boats. Moreover, service stations have started trial sales of diesel oil blends containing 10% next-generation biodiesel. Such tests are critical given expectations of the widespread use of biomass-derived fuels in the future.

2. 4. Contribution to Future Society That Achieves Carbon Neutrality

The global movement to achieve net zero CO_2 emissions, or carbon neutrality, is growing rapidly. As of April 2021, 125 countries and one region had committed to achieving that target by 2050.

The *Sixth Strategic Energy Plan* approved by the Cabinet in October 2021 defines a long-term energy policy for Japan that encompasses fuel oils. The plan identifies challenges and solutions for energy transition and decarbonization, in conjunction with a roadmap of government actions, to realize carbon neutrality by 2050 and reach the greenhouse gas emission reduction targets by 2030.

In March 2021, the Petroleum Association of Japan formulated its Vision toward Carbon Neutrality for the Oil Industry. It presents a scenario for the oil industry to achieve society-wide carbon neutrality through measures that address energy consumption and supply, as well as carbon dioxide sinks.

Many of the technologies with the potential to contribute to achieving carbon neutrality by 2050 are still at the research and development stages. At present it is crucial to boldly explore all technologies and possibilities.

3 Lubricants

3. 1. Gasoline Engine Lubricant

(1) Regulatory Trends

In Europe, the European Car Manufacturer's Association (ACEA) revised the ACEA Oil Sequences for the first time since 2016. The new ACEA 2021 standard came into effect on May 1, 2021. In the past, revised standards applied to all classes, but the 2021 revision came into effect only for the A/B, and C classes ahead of the other classes. Unlike the standards of the American Petroleum Institute (API), previous ACEA standards are invalidated by the release of revised standards are. However, there is a grace period during which both standards are recognized.

The main changes between ACEA 2016 to ACEA 2021 are as follows: (1) An A7/B7 category was added, (2) a C6 category was added, and (3) the A3/B3 category was removed. Changes (1) and (2) bring low-speed pre-ignition (LSPI) protection, chain wear protection, and turbocharger compressor deposit (TCCD) protection to the A5/B5 and C5 categories, as well as stricter Sequence IVB regulatory values concerning valve train wear than those of other categories. In the C6 category, JASO M366 replaced CECL-54-96 as the fuel economy test method. The ACEA 2021 standard also adds five new engine tests. One is a TCCD protection test, while the remaining four bring tests already applied in ILSAC GF-6A and JASO GLV-1 to the ACEA standard. A minor revision to ACEA 2021 on May 1, 2022 deleted the base number regulatory values from the C2 category.

(2) Technological Trends

Ultra-low viscosity engine oils such as JASO GLV-1 are effective at improving fuel economy, but using them in engines not designed for such oils can deteriorate wear resistance due to reduced oil film thickness or cause the oil pressure system to fail. Therefore, oils with flat viscosity characteristics are being investigated to achieve both fuel economy and reliability by maintaining a certain minimum level of viscosity in the high temperature range while reducing viscosity in the service temperature range. Producing such oils calls for technologies to raise the viscosity index, and thus requires blending a base oil with a high viscosity index or high-performance viscosity index improver. The viscosity index is generally improved by reducing the viscosity of the base oil and increasing the viscosity index improver content. However, reducing the base oil viscosity worsen the Noack test allowable evaporation loss specified in ASTM D5800. Nevertheless, there are cases where the quantity of evaporation in the Noack test does not correlate to oil consumption in current engines. Therefore, methods of evaluating oil evaporation characteristics that correspond to actual conditions more closely are being studied.

3. 2. Diesel Engine Lubricant

(1) Regulatory Trends

In Europe, the ACEA revised the ACEA Oil Sequences for the first time since 2016 and the new ACEA 2022 standard came into effect on May 1, 2022. The 2021 revision only updated the A/B, and C classes and the 2022 revision updated only the E class. The introduction of an F class fuel economy standard had been discussed but was postponed in this revision. The main changes between ACEA 2016 and ACEA 2022 are as follows: (1) E6 category replaced by E8 category, and (2) E9 category replaced by E11 category. Since both (1) and (2) replace existing categories, the items in the standards generally follow those of the former categories. An oxidation stability test (Volvo T-13) and an aeration test (caterpillar oil aeration test, or COAT) were added to the engine tests. All categories previously conducted the piston detergency test using the same OM501LA engine, but ACEA 2022 has replaced them with tests using different engines in each category.

In Japan, the Japanese Automotive Standards Organization (JASO) revised the JASO M355 automotive diesel engine oil standard, updating it from JASO M355: 2017 to JASO M355: 2021 in May 2021. This revision adds JASO DL-2 as a new standard for light-duty vehicles. The DL-2 category is based on the existing JASO DL-1 category, with a different sulfuric ash content regulatory value than that category. The DL-1 category specifies a sulfuric ash content of 0.6 mass% or less, whereas the DL-2 category specifies a value of 0.7 mass % or more and 0.8 mass% or less, differentiating itself from the DL-1 category while aligning with the sulfuric ash content regulatory values of the C2, C3, C5, and C6 categories in the ACEA standard.

Following the suspension of the engines supplied for previously quoted ASTM D6984 (Sequence IIIF) and ASTM D7320 (Sequence IIIG) high temperature oxidation test, the ASTM D8111 (Sequence IIIH) has been adopted as an alternative test method. The API CH-4 regulatory values have been applied to the DH-1, DH-2, DH-2F, and DL-0 categories, and while the API SL values have been applied to the DL-1 and DL-2 categories.

(2) Technological Trends

Diesel engines usually have diesel particulate filters (DPFs) that catch particulate matter (PM) to comply with emission regulations. The accumulation of PM and ash derived from engine oil in DPFs results in a loss of pressure. Although combustion can remove PM through post injection, the ash content cannot be removed by combustion and is decreased by reducing the metallic components in engine oil. Since preventing the deposition of ash contents helps extend the DPF service life, the mechanism that produces ash content from metallic components in engine oil through an oxidation reaction is being studied. Ash content are caused by the combustion of scattered engine oil. Other than the splashing of oil by the piston, one possible mechanism causing engine oil to scatter is collision of droplets of sprayed oil with engine oil during post injection. Accordingly, methods to quantify the engine oil scattered during post injection are being studied.

3. 3. Gear Oil

(1) Regulatory Trends

There were no major trends related to gear oil in 2021.

(2) Technological Trends

Achieving low viscosity remains an important issue in gear oils to address the challenge of automobile fuel efficiency. New viscosity index improvers (VIIs) are being developed to reduce the viscosity of gear oil at 40℃ while maintaining a constant viscosity at 100℃. It has been reported that the viscosity index of a new VI is improved by 20% as compared to conventional VIIs. Since differential gear oil used in final differential gears receive extremely high contact pressure, wear and seizure caused by reduced viscosity are of concern. Technologies to ensure both reduced viscosity and wear resistance are required. One example involves studying the addition of MoTDC to reduce wear.

3. 4. Automatic Transmission Fluid (ATF)

(1) Regulatory Trends

There were no major trends related to transmission fluid in 2021.

(2) Technological Trends

As with gear oil, the viscosity of ATF is being reduced to achieve better fuel efficiency. It has been reported that the use of a special base oil having a linear molecule structure and a polar ester base oil, specifically for the purpose of reducing wear in the state of elastic fluid lubrication, reduces loss torque by a little over 10% in automatic transmission units as compared to conventional oil.

Japan aims to achieve carbon neutrality by 2050 to reduce CO_2 emissions. Hybrid electric vehicles (HEVs) and electric vehicles (EVs) are likely to become the main products as they produce few CO_2 emissions during driving. Manufacturers are actively developing fluids for EV transaxles (e-Axles) in particular. The e-Axle fluids are required to exhibit performance different from that of existing fluids in the area of motor cooling, insulation, and material compatibility. Reduced viscosity is considered effective at achieving cooling performance in particular. As with gear oil, it has been reported that VII optimization can realize both durability and reduced gear and bearing viscosity.

4 Grease

Environmental regulations are becoming stricter worldwide to address environmental problems such as global warming and air pollution, and achieve a decarbonized society. This trend is especially noticeable in the automotive and related industries. Europe and China are leading a fast-paced transition from conventional gasoline and diesel vehicles to electric automobiles including EVs and HEVs.

As with internal combustion engine vehicles, improving power consumption efficiency is major development challenge in electric vehicles. The motors in electric propulsion systems must exhibit high levels of speed and efficiency, and the performance of the greases used as lubricants has also increased significantly. Grease lubrication is notably more prone to trapping heat than oil lubrication. Therefore, manufacturers are developing various measures to meet the essential high speed requirement. For example, reports have described altering grease for harder consistency to suppress the spattering of grease by centrifugal force and keep it on the transfer surface even during the high-speed rotation of bearings, as well as of grease that uses urea as a thickener with excellent service life at high temperature.

Grease thickeners must also tackle issues other than performance. Due to increasing demand of lithium ion batteries associated with increased EV production, the grease industry faces the issues of a hike in prices and unavailability of the lithium hydroxide used as a raw material in lithium-based greases, which are likely to be replaced with non lithium-based greases in the future.

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