FUEL, LUBRICANT AND GREASE

1 Introduction

The price of West Texas Intermediate (WTI) crude oil started 2019 below 50 USD per barrel, but quickly climbed back to the mid-50 USD range per barrel in the early weeks of January following expectations of progress stirred by the agreement to reduce production reached at the end of 2018 by the OPEC nations. In late March, the price recovered to 60 USD for the first time in about four months. After that, the intermingling factors causing the price to drop, such as the trade friction between China and the U. S. and increased oil production by the latter with factors causing the price to rise such as growing concerns over the political instability in Libya and the progress of the agreement to reduce production led the price to fluctuate between the mid 50 USD range and 60 USD per barrel. The higher risk to oil supply stemming from concerns over a global economic slowdown spurred by the intensification of the U. S.-China trade friction in early August, followed by the attack on a Saudi Arabian oil facility in September, caused the price to surge up to the mid-60 USD per barrel range. Projections of a rapid recovery of the attacked facility then led the price to fluctuate around 50 USD per barrel. In November, the price started to rise on expectations of progress in U. S.-China trade talks, reaching the 60 USD per barrel level in mid-December(1).

The amount of crude oil imported into Japan in 2017 was 175.49 million kL, a decrease of 1.1% from the previous year, and the amount of crude oil processed in Japan was 177.05 million kL, a decrease of 0.4% from the previous year. The statistics fall short of the values for the previous year. However, the rate of decrease, which was 5.4% for imported and 4.8% for processed oil, is smaller than that of the previous year.

Figure 1 shows the monthly changes in fuel oil sales volume in Japan. The amount of fuel oil sold was lower than in the preceding year for most months, and the total sales volume in Japan in 2019 was 165.13 million kL, a 2.9% decrease over the previous year. The sales volume for gasoline was 49.59 million kL, a 2.9% decrease, while the diesel sales volume reached 33.90 million kL, a 0.1% increase. The domestic sales volume of diesel oil in 2019 increased slightly, matching the prediction in the (draft) petroleum product demand forecast for 2019 to 2023(3) published on the website of the Ministry of Economy, Trade and Industry (METI).

Figure 2 shows the predicted demand for fuel oil in Japan from fiscal 2019 to fiscal 2023(3). For the period between fiscal 2018 and fiscal 2023, the demand for gasoline is expected to maintain an average annual rate of −2.2%

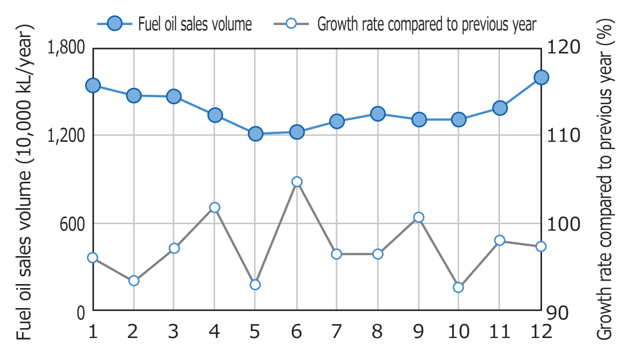

Fig. 1 Monthly Changes in Japanese Fuel Oil Sales Volume (2019)

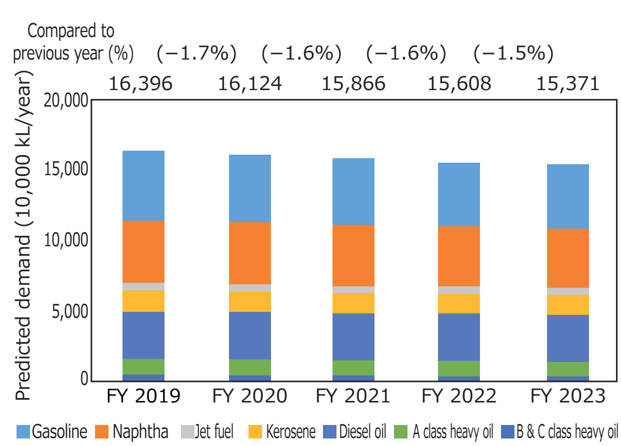

Fig. 2 Predicted Demand for Petroleum Products

due to the shorter driving distances and greater fuel efficiency of passenger vehicles. Demand for diesel fuel is anticipated to maintain an average annual rate of 0.0% on the assumption that solid economic growth will support a steady level freight transportation despite the continuing shift toward a service economy and higher added value.

2 Fuels

2. 1. Fuel Trends

The Fifth Strategic Energy Plan approved by the Cabinet in July 2018 stipulates long-term energy policies that encompass fuels. In general terms, it outlines challenging scenarios to achieve the originally planned energy mix for 2030, as well as energy conversion and decarbonization by 2050.

Similarly, the Petroleum Association of Japan formulated the Petroleum Industry Long-Term Low Carbon Vision for 2050, which defines the industry's resolve to find solutions to the issue of global warming from the perspectives of both supply and consumption of energy. Example initiatives include reducing the carbon footprint of petroleum fuels by reducing the energy consumed in the refining process and introducing next-generation biofuels, as well as improving internal combustion engine thermal efficiency through higher fuel quality[5].

Regulations concerning petroleum refiners have defined the goal of raising the processing efficiency of vacuum distillation residue, as stipulated in the third official announcements of the Act on Sophisticated Methods of Energy Supply Structures[6]. With respect to biofuels, the target of 500,000 kL/year in crude oil equivalent set for the introduction of ETBE in 2022 has been maintained, and a revision of the official notice concerning next-generation bioethanol targeted at substances such as inedible cellulose, as well as the introduction of bio-jet fuels, is scheduled in fiscal 2019[7].

Another change in the environment surrounding fuel oils is the strengthening of regulations on the sulfur content of marine fuels used in general ocean areas by the International Maritime Organization (IMO), lowering the permitted content from 3.5 wt% or less to 0.5 wt% or less. In light of the petroleum product characteristic of being a co-product of crude oil, it is possible that changes to marine fuel production methods instituted by petroleum refiners to comply with that regulation will have a significant impact on the manufacturing methods and properties of automotive fuels (gasoline and diesel)[8].

In response to the need for a total quality assessment of transportation fuel oils based on adapting to advanced methods and complying with the IMO regulations, the Japan Petroleum Energy Center (JPEC) initiated the two-year Japan Marine and Auto Petroleum Program (J-MAP) project, which consists of joint research ventures between the petroleum industry on the one hand, and the automotive and marine industries on the other, in fiscal 2018.

2. 2. Gasoline for Automobiles

With respect to fuels using cracked gasoline (gasoline fraction obtained from FCC devices), the above-mentioned J-MAP has started studying the potential of measures based on fuel composition[8] to address the issue of PN emissions concerns if the heavy aromatic content increases identified in past studies (Japan Auto Oil Program (JATOP) III)[9].

The growing number of gasoline vehicles that use direct injection has also been leading to research on gasoline PM emissions. More specifically, combustion devices are being used to investigate the soot generation characteristics and reduction effectiveness of compounds consisting of butanol isomers blended with isooctane or toluene during liquid surface combustion in engine cylinders. That research has demonstrated that soot generation is more likely under lean premixed gas ratios[10]. Moreover, since gasoline now also requires lubricity due to the increased fuel injection pressure from direct injection, research on gasoline lubricity is also being carried out. One paper on how fuel compositions that use paraffin and aromatic fuels affect lubricity has been published[11].

Other research is looking into how modifying the fuel composition affects combustion and has demonstrated that altering the molecular structure of fuel changes the speed of combustion in lean burn conditions, and substances such as furan or nitromethane have been reported to accelerate combustion[12].

Research focusing on combustion characteristics when waste plastic decomposition oil is added to commercial gasoline is also shedding light on the effect of increasing waste plastic content on emissions (CO, CO_2, HC, and NO_x)[13].

2. 3. Diesel Fuel for Automobiles

The study concerning diesel by the above mentioned J-MAP explored the potential of fuel-oriented measures such as optimizing the amount of blended cracked base material, amount of additive that raises the cetane number, or the level of lightening[8] to solve issues highlighted in past research (JATOP II, III), including the higher diesel particulate filter (DPF) loads caused by increasing the mixture of cracked diesel and the rise in NO_x resulting from increasing the amount of additive that raises the cetane number[14].

Research on diesel conducted outside the J-MAP project includes studies on deposit accumulation in exhaust gas recirculation (EGR) systems. One example seeks to clarify the deposit generation mechanism by evaluating how the THC concentration in exhaust gas and the post injection timing correlate with deposit generation. That research has identified that deposits can be soft gel-like soft deposits or solid hard deposits, and that the later contain a large amount of polycyclic aromatic hydrocarbons (PAH) originating in exhaust gas. Research on predicting the amount of EGR deposit accumulation is also being conducted. Although actual deposits are believed to accumulate in the EGR system as a result of the combination of a large number of chemical species and complex reaction paths, one study developed a simplified model using the main PAH originating in exhaust gas and predictions using that model demonstrated a correlation with experimental results[16].

Biodiesel has also been the object of many studies. One example accelerated degradation using fatty acid methyl ester (FAME) and FAME blended diesel and focused on the extent of decrease in the amount of degradation products and the induction period. Another study has shown that the degradation speed of FAME blended diesel correlates with the number of double bonds in the FAMEs and that FAME constituents are preferentially oxidized[17]. Other examples include research that used commercial diesel blended with biodiesel fuel (BDF) to look at how the grain size and quantity of nanoparticles in the exhaust gas affects aftertreatment devices(18), and research using fuel that blended isobutanol or isopentanol with FAMEs to determine their effects on combustion and exhaust gas characteristics when a mechanical turbocharger and an EGR system are employed concurrently[19].

3 Lubricants

3. 1. Gasoline engine oil

(1) Regulatory Trends: Various countries have been setting CO_2 emissions reduction targets to cut down on greenhouse gas emissions on a global scale. Automobiles, which are said to account for approximately 20% of all emissions, are also subject to strict regulations. Efforts to comply with such regulations have led to an increase in the number of vehicles with downsized direct injection engines equipped with a turbocharger. However, there are concerns about the irregular combustion known as low speed pre-ignition (LSPI) that occurs in such engines in the low speed high load range. Engine oil has been found to contribute significantly to that phenomenon[20]-[22], and there have been strong calls to find solutions. In response, the American Petroleum Institute (API)/International Lubricant Standardization and Approval Committee (ILSAC) SP/GF-6 standard with LSPI protection requirements, licensed starting on May 1, 2020[23]. Within GF-6, two standards, GF-6A and GF-6B, have been established for the different SAE viscosity grades. The 0W-20, 5W-20, 0W-30, 5W-30, and 10W-30 viscosity grades have been designated as falling under GF-6A, while the 0W-16 grade falls under GF-6B. In addition, the standard modifies some engine tests to accord with the latest engine mechanisms, updating Sequence IIIH to include high temperature oxidation stability, Sequence IVB to cover low temperature valve wear protection, Sequence VH to evaluate low temperature sludge protection, and Sequence VIE (GF-6A) and VIF (GF-6B) to measure fuel economy. Similarly, a new Sequence IX engine test to evaluate LSPI protection and Sequence X test to evaluate timing chain wear protection were added.

One study has shown that using engine oils with a viscosity grade below 0W-16 can improve fuel economy[24], and some Japanese automakers use an engine oil with a viscosity equivalent to 0W-8[25]. However, the fuel economy evaluation used for engines in the U.S., which adopts the API/ILSAC standard, made it difficult to evaluate engine oils with lower viscosity than 0W-16. Consequently, JASO released its M364 standard for 0W-12 and 0W-8 engine oils in April 2019[25], making it available in its on-file system the following October. This standard covers previously non-existent ultra-low viscosity engine oils and therefore uses new test methods to evaluate fuel economy. Two test methods, a motoring test called JASO M365 and a firing test called JASO M366, have been established. Fuel economy targets must be met according to one of those methods. The ILSAC GF-6B standard, excluding the Sequence IX evaluation of LSPI protection, remains the basis for evaluating items other than fuel economy.

The current ACEA standard for European vehicles was scheduled to be updated in 2018, but its issuance is expected to be delayed until the latter half of 2020[26]. Information on discussions held to date suggests that the A3/B3 and A5/B5 categories of the high ash grade A/B classification will be eliminated in favor of a new A7/B7 category. Similarly, the low ash grade C1 category will be eliminated, and a new C6 category will be established for oils with an SAE XW-20 SAE viscosity grade.

(2) Technological Trends: Reducing friction is known to improve engine oil fuel economy, and blending molybdenum dialkyldithiocarbamate (MoDTC) has been proven important to improving fuel economy in low viscosity grade engine oils[27]. There have also been reports on improving fuel economy by blending a new viscosity index improver that reduces viscosity at low temperatures and increases it to the limit at high temperatures[28], as well as be blending PAG base oil[29].

Concerns over the impact of micro-particles on human health have led Europe and China to impose regulations on particle number (PN) emissions. An increasing number of vehicles are equipped with gasoline particulate filters (GPF) to comply with those regulations, and higher levels of ash content in the engine have been shown to increase back pressure in the GPF[30].

3. 2. Diesel engine oil

(1) Regulatory Trends: As regulations on CO_2 emissions become more stringent worldwide, lower fuel consumption is playing an increasingly important role in reducing such emissions. The DH-2F JASO standard (Japan) and FA-4 API standard (U.S.) have been established. The F8 and F11 categories fuel economy standards will be added to the ACEA standards (Europe) in mid-2020[31].

(2) Technological Trends: Biodiesel is being used in fuel as part of CO_2 reduction measures based on a carbon neutral approach. The notable recent rise in the proportion of biodiesel fuel blended into diesel in Southeast Asia is having a significant impact on diesel engine oils. For example, Thailand, Malaysia and Indonesia have respectively introduced B10, B20 and B30 fuel, which use rapeseed oil and palm oil as raw material. Research on oil performance when biodiesel fuel is blended into diesel engine oil includes a study and a simulation of oil degradation[32][33], a study on how degraded oil properties relate to friction and wear[34], and a study on the effect of ZnDTP on degradation behavior and wear resistance[35].

3. 3. ATF & CVTF

(1) Regulatory Trends: A shorter test duration for the automatic transmission fluid shudder prevention performance test method (JASO M349:2012) is under consideration Past technological refinements have extended the anti-shudder life of ATF, leading to prolonged test durations for a single cycle under existing test conditions. New and more severe test conditions were therefore added to shorten the test duration[36].

(2) Technological Trends: With the electrification of automobiles decreasing the frequency of engine operation, transmission noises previously masked by the sound of the engine have begun to stand out. In chain CVTs, noise is produced by the sliding of the chain and pulley, and improving the friction characteristics of chain CVTF has been shown to reduce that noise[37].

3. 4. Gear oils

(1) Regulatory Trends: There was no notable activity related to gear oil regulations in 2019.

(2) Technological Trends: For ATF and other automatic transmission fluids, fuel consumption is reduced by lowering the viscosity grade. However, the differential oil in final-drive reduction gears is used under severe high interface pressure and high sliding velocity conditions, and simply reducing the viscosity of the oil presents the risk of decreasing durability factors such as extreme pressure properties and fatigue life. Adding MoDTC to differential oil to enhance durability has been shown to improve wear resistance and mitigate the rise in oil temperature compared to conventional oils[38].

4 Grease

Year after year, automobile fuel economy regulations become stricter in response to environmental protection concerns, and technologies to reduce CO_2 emissions and increase fuel efficiency through downsizing, weight reduction, and electrification are being applied to all automotive parts and units. Grease technology that contributes to decreasing CO_2 emissions and improving fuel economy are also being developed.

Lowering torque to enhance fuel efficiency is the subject of intense study that has resulted in the development of greases adapted to the lower motor bearing torque made more important by the spread of electrification[39], as well as the introduction of low-torque technology in the hub bearings of both passenger vehicles and heavy-duty SUVs.

The downsized, higher power drive motors are being studied in response to the major trend of electrification. Reducing motor size while boosting its power requires increasing rotation speed. The higher bearing rotation speed releases a greater amount of heat, exposing grease to high temperature environments more than ever before. In one study, this issue was addressed by developing a grease that uses a urea thickener exhibiting excellent longevity at high temperatures[41]. The greater number of motor drive modes is also sparking greater demand than ever for quietness in the vehicle interior. Grease that enhances bearing quietness to mitigate vibration and rattling noises[42] has also been developed.

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