THE ENVIRONMENT SITUATION AND TECHNOLOGIES FOR THE AUTOMOBILES

1 Introduction

This article presents the environmental performance of the achievement status of environmental standards, overall trends throughout the year for emissions regulations and fuel economy standards (CO_2), and some new cars released in FY2019 (including partial improvements).

2 Overview and Regulatory Trends

For air pollution conditions[1], the 2018 environmental standard sets a nitrogen dioxide (NO_2) achievement rate of 100% for ambient air monitoring stations and 99.7% for roadside air pollution monitoring stations (in 2017, 100% and 99.7%, respectively). For suspended particulate matter (SPM), the achievement rate is set to 99.8% for ambient air monitoring stations and 100% for roadside air pollution monitoring stations (in 2017, 99.8% and 100%, respectively). Over the last few years, these environmental standards have largely been met nationwide. The annual average concentration of both NO_2 and SPM has been decreasing, and in terms of air pollution, automobiles has come to have a limited impact.

At 93.5% for ambient air monitoring stations and 93.1% for roadside air pollution monitoring stations, the lower achievement rate observed for particulate matter (PM 2.5), represents an improvement over 2017 (89.9% and 86.2%, respectively. The shift in the achievement rate is shown in Fig. 1). Despite rising overall nationwide achievement levels, some regions, namely major cities in the Kanto and Kansai areas, as well as ambient air monitoring stations in northern Kyushu and the area of Shikoku facing the Seto Inland Sea, have low environmental standard achievement rates (by prefecture). The standard achievement rate remains extremely low for photochemical oxidant (Ox), at 0.1% for ambient air monitoring stations and 0% for roadside air pollution monitoring stations (0% for both in 2017). Claims for damages attributed to that substance were filed by 13 people. While continued efforts are still required, the situation has improved compared to the over 40,000 people filing damage claims in the 1970s and the 1,000 to 2,000 people doing so during some of the years in the 2000s.

The introduction of the WHTC and WHSC for most heavy-duty vehicles, with exception of some heavy-duty gasoline vehicles, and of the WLTC for passenger cars by 2019 has closed a chapter in the major changes in emissions regulations carried out over the last several years.

New regulations scheduled for adoption in 2020 include the introduction of Euro 5-equivalent regulation values for motorcycle tailpipe emissions and regulations concerning PM emissions in direct injection gasoline vehicles.

As of May 7, 2020, no information has been released on the 2018 road traffic noise situation, which constitutes another regional environmental issue.

In contrast, in terms of global environmental issues, the CO_2 emissions from the transportation sector in 2018 were 210 megatons (Mt), a 1.4% decrease over the previous year[2]. This represents a reduction of 1.39 million tons (6.2%) compared to 2013. Automobiles, which accounted for approximately 86%, are the main source of emissions. The main reason for the decrease is the reduction in CO_2 in the passenger segment, where despite

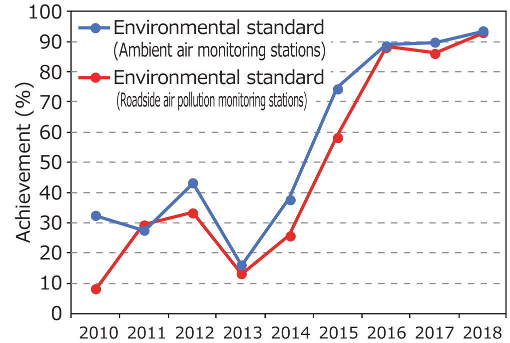

Fig. 1 Shift in PM 2.5 Environmental Standard Achievement

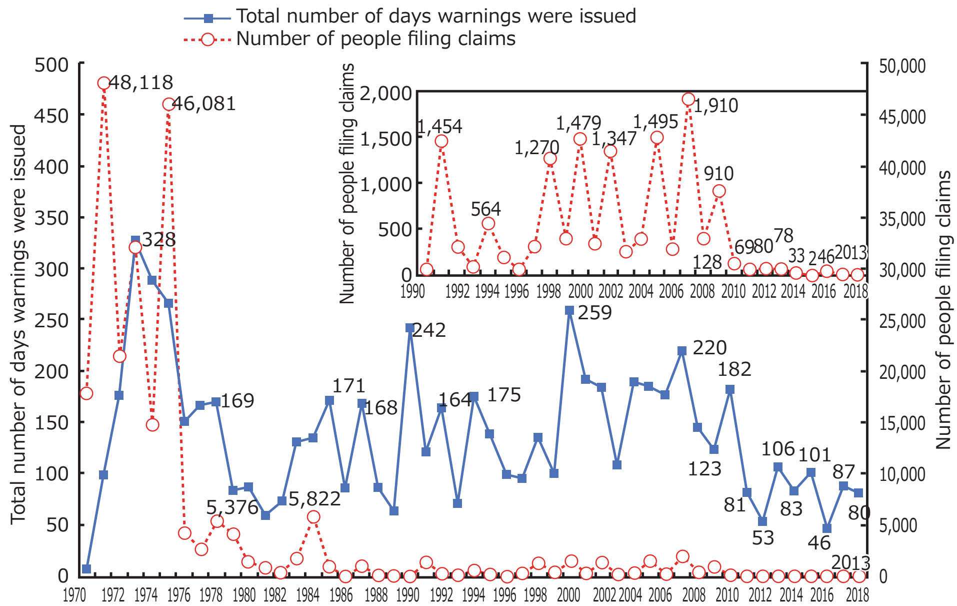

Fig. 2 Shift in the Total Number of Days Photochemical Oxidant Warnings Were Issued and the Number Of People Filing Damage Claims

an increase in the amount of activity, better fuel economy has decreased the energy consumption per unit of transportation. This shows that the spread of fuel-efficient vehicles over the last several years is contributing to the reduction of CO_2 emissions[3].

The passenger car fuel economy standards for standard emissions defined in June 2019, which directly affect CO_2 emissions and represent the next stage of Japanese standards, have been announced[4]. They contain three key points. The first is the introduction of the well-to-wheel (WTW) concept, which traces energy consumption back to the electricity generation stage. The calculation of power generation efficiency is based on the power source mix of the Long-Term Energy Supply and Demand Outlook (Ministry of Economy, Trade and Industry, July 2015), which takes into account the WTW viewpoints expressed in the power supply industry thermal power generation criteria outlined in the business operator criteria concerning the rationalization of energy use in plants or other facilities stipulated in the Act on the Rationalization etc. of Energy Use, as well as in the interim report of the Strategy Meeting for the New Era of Automobiles (July 24, 2018). The second is the switch from the JC08 test cycle to the WLTC for evaluation tests. The third is the establishment of fuel economy standard values based on vehicle weight. Although having standard values differ by vehicle weight is a continuation of past practice, implementing it in the context of

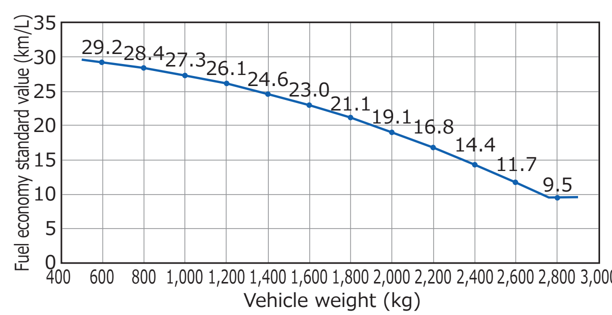

Fig. 3 FY 2030 Fuel Economy Standard Values by Vehicle Weight

the WLTC, which does not include vehicle weight categories, has defined an equation for the relationship between vehicle weight and the fuel economy standard value. The equation for vehicles weighing less than 2,759 kg is shown below.

$$FE = -2.47 \times 10^{-6} \times M^2 - 8.52 \times 10^{-4} \times M + 30.65$$

M: vehicle weight (kg)

This equation is illustrated in Fig. 3. Looking at the relationship between vehicle weight and fuel economy based on driving work should yield a curve approaching a convex hyperbola relative to vehicle weight, but that is not the case. This is attributed to top-runner approach used to determine the standard values. In that approach, the use of further fuel-efficiency enhancing technologies and anticipated market penetration is factored in for the top runners in each weight class to determine the values. For example, the 800 kg or so class mainly consists of mini-vehicles, and since they can hardly be expected to

Fig. 4 Tesla Model 3

Fig. 5 Toyota Corolla (Touring model in picture)

Fig. 6 Daihatsu Rocky

be equipped with full hybrid systems, it is unrealistic to assign them a much larger value than the 1,200 kg or so class, which includes many fuel-efficient compact hybrid vehicles. In light of these factors, the standard value is set to 25.4 km/L when the proportion of shipments by vehicle weight is taken into consideration. At first glance, the European CO_2 regulations of 95 g/km for 2020 and later (corresponding to approximately 24.4 km/L for gasoline vehicles) may seem lax for standards applying ten years down the road. However, the European regulations also stipulate effectively zero CO_2 for electricity. In the context of the accelerating shift to EVs and PHEVs, this means that the next-stage Japanese fuel economy standards will have to call for superior fuel economy performance even for EVs and similar vehicles. Consequently, the regulations can be described as a highly efficient measure to reduce energy consumption and CO_2 emissions.

The evaluation of whether the 2020 fuel economy standards are achieved began in April. This led to halting the production or sale of more than a few models in late 2019 and early 2020. The main examples are the Toyota Estima and Mark X, the Nissan Cube and Juke, and the Subaru WRX STI. Those models have all been on the market for several years, and exhibit a fuel economy performance in line with the previous generation of standards (although the Estima notably offers a hybrid version). Each of them was once a popular model with a strong market presence, and many sold well until the very end. However, strong sales of those models results in lowering the corporate average fuel economy (CAFE) score of their respective manufacturers. Although it was probably not the only cause, that likely played an important part in the decision to shelve those models.

Until the 2015 fuel economy standards, even gasoline vehicles without a hybrid system could achieve the standard through the introduction of various technologies to improve fuel economy, leading to the rapid spread of direct injection, start-stop mechanisms, electric power steering, and other systems that raised the overall level of fuel economy. The even stricter values introduced in the 2020 fuel economy standards has led to polarization of models in which greater funding and work hours were invested to achieve compliance by the time the standards came into effect, and models that were essentially discarded. The fuel economy standards have become an extra factor differing from user needs in determining product configuration, and that situation is likely to continue for some time.

3 Trends in Environmentally Friendly Technologies for Individual Vehicles Seen in Models Released in FY2019

Among the models released in FY2019, this section presents those most likely to attract attention in terms of technologies that improve fuel economy and reduce emissions. Unless noted otherwise, the specifications for fuel economy values and the figures are based on manufacturer press releases, as well as catalog information, including information released on the Web.

In May 2019, Tesla announced it would start taking orders for the Model 3 in Japan (Fig. 4). This is a high performance, 4WD model said to have a cruising range of 530 km (WLTC) on a single charge and accelerate from 0 to 100 km/h in 3.4 seconds. Despite a performance in no way inferior to that of the premium European EV brands, this model is clearly less expensive. In terms of quality, issues such as the supply structure and the frequency of breakdowns remain unknown factors, but this vehicle will undoubtedly have a strong impact on the EV market.

In September 2019, ALL New the Toyota Corolla models (including the Touring station wagon) were fully redesigned (Fig. 5). The line offers three powertrain variations: a hybrid model with a 1.8-liter engine, and two gasoline engine models respectively featuring a 1.2-liter

Fig. 7 Mazda SKYACTIV-X Engine

Fig. 8 Porsche Taycan

Fig. 9 Toyota Yaris

with turbocharging and 1.8-liter engine. Of those, the hybrid models (S, GX) have a WLTC fuel economy of 29.0 km. This model is also sold in Europe, where its CO_2 emissions of 76 g/km (European catalog value converted to EU mode) are well below the European CO_2 regulation value of 95 g/km starting in 2020. In today's European market, excluding EVs or PHEVs, only an extremely limited number of vehicles powered by gasoline or diesel energy achieve CO_2 emissions of 95 g/km or less, demonstrating the world-class superior environmental performance of this particular model.

November 2019 marked the launch of the new Toyota Raize and Daihatsu Rocky (Fig. 6). It is one of the rare 5-series license plate compact SUVs. Sporting a 1-liter turbo gasoline engine combined with the new D-CVT that uses split gears to achieve a add on wide gear ratio, it achieves a WLTC mode fuel economy of 18.6 km/L in the 2WD version.

In November 2019, ALL New the Mazda 3 line that had been fully redesigned in May was expanded with the addition of a model equipped with the SKYACTIV-X engine (Fig. 7). The core of the SKYACTIV-X technology is Spark Controlled Compression Ignition (SPCCI) combustion. Extensive research showing that burning a uniform lean premixed gas combust through auto-ignition would achieve low NOx, low PM, highly efficient combustion has been conducted in the past. However, it have never been commercialized before due to the difficulty of guaranteeing ignition and stable combustion under transient operation or in other fluctuating conditions, the need for balance with normal combustion imposed by the restricted operating range, and the complexity of the attendant mechanisms, control, and related systems. Achieving commercialization through advanced control and the technique of varying the pressure to induce auto-ignition in spark ignition therefore deserves a high de-

Fig. 10 Suzuki Hustler

gree of recognition. At the same time, mitigating the above issues appears to have been considered by combining the approach with mild hybrid mechanisms and superchargers. In the closely monitored area of fuel economy, the 6-speed automatic transmission X-PROACTIVE model achieves a WLTC value of 17.2 km/L, placing it roughly midway between the standard gasoline and the diesel vehicles in the same Mazda 3 line. The automaker subsequently installed the same system on its CX-30 model.

In November 2019, Porsche's first EV, the Taycan, became available in Japan (Fig. 8). If features a body size similar to that of the automaker's Panamera model, and has a vehicle weight of 2,300 kg. Nevertheless, in 4WD, it combines the impressive power of a maximum momentary output of 560 kW (Turbo S) with a drivetrain featuring a gear changing mechanism, accelerates from 0 to 100 km/h in 2.9 seconds (European catalog value), and exhibits a cruising performance of 412 km in the WLTC. This makes the Taycan a roll model for others under European CO_2 regulations that expect zero CO_2 emissions from electricity. While the electrification of vehicles is a suitable step toward a recycling-oriented society, it is even more important to reduce the actual consumption of energy, a fact that casts doubt over whether an EV weighing 2.3 t really represents a way to comply with

Fig. 11 Honda Fit (Basic model in picture)

the CO_2 regulations.

In December 2019, Toyota announced the Yaris as the model succeeding the Vitz (Fig. 9). The remarkable topic in discussing the environmental performance of the Yaris is the 36.0 km/L WLTC fuel economy offered by the hybrid versions (Hybrid X, 2WD model). This currently makes it the world leader outside the EV class, with the caveat that the WLTC fuel economy of the Prius and other models has not yet been released. It combines a refined version of the proven THS-II system with a newly developed 1.5-liter 3 cylinder engine. In contrast, the 1.5-liter (CVT) model has a fuel economy of 21.6 km/L. While the new long-stroke engine dubbed Dynamic Stroke offers superior fuel economy, it does not make use of a start-stop system. This is attributed to the exclusion of such systems from the WLTC due to issues such as cost/performance, as well as the shorter idle time than in the JC08 test cycle downplaying the effectiveness of start-stop systems. Start-stop has clearly proven effective in urban driving, and its removal from the test cycle may mark the beginning of discrepancies between internationally harmonized standards and actual common use conditions in Japan affecting the choice of adopted technologies.

In December 2019, the Suzuki Hustler was completely redesigned (Fig. 10). Its new engine and mild hybrid mechanism combine to achieve a WLTC fuel economy of 25.0 km (Hybrid X and G). This figure sets it alongside the Daihatsu Mira e:S as the co-leader in Small-car fuel economy (limited to the WLTC). Achieving that level in an SUV model with a high vehicle height demonstrates impressive technical ability.

In February 2020, the Honda Fit was completely redesigned (Fig. 11). The fuel-efficient model of Basic has a fuel economy of 29.4 km/L for the hybrid model and 20.4 km/L for the gasoline model (WLTC values in both cases). With each refinement, previous generations of the Fit Hybrid had remained a neck-and-neck rival with the Toyota Aqua for the top spot in fuel economy, but this latest version does not establish a similar rivalry with the aforementioned Yaris Hybrid. The hybrid mechanism consists of a two-motor system known as e:HEV, which exhibits significantly higher potential for improving fuel consumption than the previous generation IMA system. Despite this, it only achieves a modest improvement in the JC08 test cycle (from 37.2 to 38.6 km/L), and that potential is assumed to have been distributed to elements other than test cycle fuel economy, such as cost, safety, and comfort.

For heavy-duty vehicles, the finalization in 2019 of the compact class lineup described below brings three years of expanding the number of models compliant with the 2016 emissions regulations to a close. While there were some examples of upgrading vehicles already compliant with the 2016 emissions regulations, most of those consisted of strengthening safety systems, and there were few cases of modifications to the engine system. However, the upgrades did trigger the introduction of advanced OBD (the WWH-OBD based on international standards).

In August 2019, Hino launched an upgraded Liesse II small bus model. In addition to adding a urea SCR not found in the previous model to make the vehicle compliant with the 2016 emissions regulations, all manual and automatic transmission models have been made compliant with the 2015 fuel economy standards.

Also in August, Mitsubishi Fuso announced the 2019 Rosa small bus model. It was made compliant with the 2016 emissions regulations, and now also exceeds the 2015 fuel economy standards by 10%.

These descriptions alone can hardly be described as notable. Nevertheless, the manufacturers should be commended for responding to society and user needs with respect to models viewed as putting a strain on profitability by achieving (and sometimes exceeding) the 2015 fuel economy standards in all models in the extremely small light-duty bus market as well as making them compliant with stricter emissions regulations.

4 Conclusion

In 2019, the next-stage fuel economy standards, including the WTW energy evaluation concept, were established. The aforementioned compilation of the standards also discusses flexibility in terms of determining achievement. This flexibility seems likely to apply to evaluating technologies that are not reflected in test cycle fuel economy, such as the U.S. off-cycle credits. Discussions on the evaluation and determination of achievement for the 2030 fuel economy standards are set to continue for some time.

Although the economy is expected to stagnate and shrink in 2020 due to the COVID-19 pandemic and other related issues, it is also possible that economic stagnation and the slowdown in air freight and other parts of the transportation sector slowdown the spread of air pollution and global warming. Hoping for a radical and major change of course in ongoing environmental policies, or their attendant technological advances would not be realistic, but there is a strong possibility that discussions on the speed of those advances and modifying timetables will be held.