Investigation on the Development of Fuel Consumption for China’s Gasoline Passenger Car in Recent Years

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Abstract. As the application of several energy saving technologies and the continuous tightening fuel consumption standards, the fuel consumption of China’s gasoline passenger cars is decreasing continuously. In this paper, the development of the standards related to fuel consumption was reviewed firstly, and the development of the fuel consumption for China’s gasoline passenger cars has been investigated based on the declared fuel consumption data of over 4800 vehicle models produced or imported in recent 5 years (2014-2018). Results showed that the average fuel consumption in 2018 decreased 6.4% compared to 2014, about 1.6% per year. In additions, the development of gasoline passenger cars with turbocharge engines and auto transmissions had a more significant effect on the fuel consumption reduction, and the annual decreasing rate reached 2.4% per year and 3.6% per year, respectively.

1. Introduction
China, the world’s largest auto market, produced more than 25.72 million automobiles in 2019, which contained 21.36 million passenger cars with a share of 83.0%, and the China's passenger car ownership reached 221 million by the end of 2019 [1-2]. As a result, the contribution of the passenger cars to the nation’s transportation fuel consumption is increasing significantly, and caused the problems of air quality and congestion in many large cities. Facing the increasing pressure on the nation’s goals of oil independence and climate change mitigation, documents of Energy saving and New Energy Vehicles Industry Strategic Planning (2012-2020) has been published in 2012. According to the documents, the average fuel consumption of the new passenger car should obtain 5.0 L/100km in 2020 and 4.0L/100km in 2025 [3]. In order to achieve these targets, the per-vehicle fuel consumption limits (GB 19578) and the corporate average fuel consumption (CAFC) targets (GB 27999) are strengthening simultaneously [4-5]. In recent years, the fuel consumption of China’s gasoline passenger cars decreased continuously by using the advanced technologies including engine and transmission technologies [6-7]. In this paper, the development of fuel consumption of China’s gasoline passenger cars in recent years has been investigated. The development of the related standards was introduced firstly, and the development trend of the fuel consumption has been quantified based on the declared fuel consumption data of over 4800 gasoline passenger car models produced or imported in recent 5 years (2014-2018). Finally, the effects of typical energy saving technologies including turbocharge and advanced transmission on the fuel consumption reduction have also been discussed.

2. China’s passenger car fuel consumption standards in various phases
China’s fuel consumption standards for passenger car was first adopted in 2004, which established Phase I and Phase II per-vehicle fuel consumption limits. Since that, the standards went through five phases including the update of the per-vehicle fuel consumption limits and CAFC targets, as shown in Figure 1.
In Phases I (2005-2007) and Phase II (2008-2011), the per-vehicle fuel consumption limits were divided into regular vehicles and special featured vehicles (vehicles with three or more rows of seating and vehicles with automatic transmissions), and both were set based on different curb mass bins. In Phase III (2012-2015), the CAFC targets from 2012 to 2015 of each passenger car model for auto manufactures was first introduced, the set of target value was based on the same curb mass bin of Phase I and II, and the passenger cars were also divided into regular vehicles and special featured vehicles same as Phase I and II. The addition of CAFC target was supposed to further decrease the fleet-average fuel consumption.

In Phase IV (2016-2020), both the standards of per-vehicle fuel consumption limits and CAFC targets were updated. The per-vehicle fuel consumption limits were modified according to the CAFC targets in Phase III, and the CAFC targets from 2016 to 2020 were further strengthened. In addition, the preferential policy to vehicles with automatic transmissions were eliminated, the special featured vehicles was only defined as vehicles with three or more rows of seating.

In Phase V (2021-), the CAFC targets from 2021 to 2025 and after were strengthened continuously according to the lasted standard of GB 27999-2019, and it worth noting that, instead of the step curve used to calculate CAFC target of each vehicle model in the former standards, linear curve related to the curb mass was used in order to evaluate the fuel consumption more accurate. Besides, the standard related to the per-vehicle fuel consumption limits (GB 19578) would be published officially in the first half of 2020. Except for the variations of per-vehicle fuel consumption limits and CAFC targets, the fuel...
consumption measurement methods had also been updated, the test cycle was varied from NEDC (New European Driving Cycle) to WLTC (Worldwide Harmonized Light Vehicles Test Cycle). The variations of per-vehicle fuel consumption limits and CAFC targets of these five phases are shown in Figure 2.

3. Results and discussion
In this part, the declared fuel consumption data of over 4800 gasoline passenger car models produced or imported in recent 5 years (2014-2018) has been analyzed. The database includes vehicle’s information such as vehicle mass, gasoline engine, transmission and fuel consumption as shown in Table 1. Based on these data, the development trends of the fuel consumption for China’s gasoline passenger car in recent years have been investigated first, and the effects of typical energy saving technologies including turbocharge and advanced transmission on the fuel consumption reduction have also been discussed.

| Information type | Details |
|------------------|---------|
| Vehicle mass (kg) | Curb mass/Maximum design mass |
| Gasoline engine | Engine type (Naturally aspirated/ turbocharge) |
| | Displacement (L) |
| | Rated power (kW) |
| Transmission | Transmission type (Manual transmission MT/Auto transmission AT/ Continuously Variable Transmission CVT/ Dual Clutch Transmission DCT) |
| Fuel consumption | Unban, suburb and combined cycles under NEDC |

3.1. Development trends of the fuel consumption for gasoline passenger car
As we all known that NEDC contains an urban cycle and a suburb cycle used to simulate the real-road driving. The declare fuel consumption of a gasoline passenger car in china includes the fuel consumption of urban cycle, suburb cycle and the combination of both. The variations of these three fuel consumption average values from 2014 to 2018 have been calculated as shown in Figure 3. Results showed that the average fuel consumption of NEDC in 2018 was 7.13 L/100km, which was 6.4% lower than 2014, and the annual decreasing rate was about 1.6% per year. It also indicated that the fuel consumption decreasing under the urban cycle was the most obvious whose annual decreasing rate reached 2.0% per year, and the decreasing rate under suburb cycle was smaller, only 1.1% per year.

![Figure 3. Variations of average fuel consumption under unban cycle, suburb cycle and NEDC](image-url)

Because that the cub mass of the passenger car directly affected the fuel consumption cycle results, and the standard limits of the fuel consumption were also set based on different curb mass bins, the variations
of the average fuel consumption under each curb mass bin have been giving in Figure 4. For either cycle, the fuel consumption increased linearly with the increase of curb mass. The annual decreasing trends of the fuel consumption were also observed, and the gap between the fuel consumption of each year enlarged as the increase of the curb mass especially under urban cycle whose largest gap reached 4.13 L/100km and the annual decreasing rate was about 5.38% per year. The results also indicated that the fuel consumption reduction was more apparent for the gasoline passenger cars with higher curb mass.

Figure 4. Variations of the average fuel consumption under each curb mass bin (Unban cycle, suburb cycle and NEDC)

3.2. Effects of turbocharge on fuel consumption reduction
As one of the main energy saving technologies, the main function of turbocharge is to compress the inlet charge before entering into the cylinder resulting in the increase of the output power and torque in order to realize the downsizing of the gasoline engine. Due to this advantage, turbocharge engines have been widely used in the gasoline passenger cars as shown in Figure 5. The model proportion of the gasoline passenger cars with turbocharge engines have more than doubled since 2014, and accounts for 67.8% in 2018.

Figure 5. Model proportion of gasoline passenger car with turbocharge engines (green) and naturally aspirated engines (red)

In order to estimate the effect of curb mass on the fuel consumption, the fuel consumption per ton (L/(100km·t)) has been introduced which is the ratio between fuel consumption and the curb mass. Figure 6 showed the variations of the fuel consumption for the gasoline passenger cars with and without turbocharge engines. Results showed that the reduction of the average fuel consumption were 7.9% and 9.6% under NEDC for naturally aspirated engines and turbocharge engines in 2018 compared to 2014, and the annual decreasing rates were 2.0% per year and 2.4% per year respectively. It worth noting that
the turbocharge engines’ decreasing trend in fuel consumption was more obvious under urban cycle, and the annual decreasing rate reached 2.9% per year. This indicated development of passenger cars with turbocharge engines had a more significant effect on the fuel consumption reduction especially under urban cycle. Besides, the average fuel consumption of vehicles with turbocharge engines was 9.2% lower than naturally aspirated engines under NEDC cycle.

**Figure 6.** Variations of fuel consumption of gasoline passenger car with turbocharge engines and naturally aspirated engines under urban cycle, suburb cycle and NEDC

### 3.3. Effects of advanced transmission on fuel consumption reduction

In general, there are mainly 4 types of transmission used in China’s gasoline passenger cars including MT, AT, CVT and DCT, and the model proportion of each transmission is shown in Figure 7. It could be seen that the proportions of the CVT and DCT increased sharply in recent years, especially DCT which have more than doubled since 2014. On the contrary, the proportions of MT and AT declined, but were still the mainstream. Since there was no fixed gear for CVT compared to other transmissions, this ensured the gasoline engines could always operate in the low fuel consumption region resulting in low fuel consumption. The energy saving advantage of DCT was mainly attributed to the application of 2 clutch discs sets instead of the hydraulic torque converter for shifting resulting in the continuous power and torque output of the gasoline engine.

**Figure 7.** Model proportion of gasoline passenger car with MT, AT, CVT and DCT

Figure 8 showed the variations of the fuel consumption for the gasoline passenger cars with different transmission types. Results showed that the reductions of the average fuel consumption were 7.9%, 14.2%, 5.3% and 5.3% under NEDC for MT, AT, CVT and DCT in 2018 compared to 2014 respectively, the annual decreasing rate were 1.98% per year, 3.55% per year, 1.33% per year and 1.33% per year. It worth noting that the AT’s decreasing trend in fuel consumption was more obvious under urban cycle, and the annual decreasing rate reached 4.1% per year. This indicated that the development of passenger cars with AT had the most significant effect on the fuel consumption reduction especially under urban
cycle. The reason for the fuel consumption improvement was mainly contributed to the wide applications of AT with 7, 8 and even 9 gears. Besides, vehicles with DCT obtained the lowest fuel consumption under either cycle compared to other transmissions. For other transmissions, the average fuel consumption of CVT was 4.0% lower than MT and 3.2% lower than AT under urban cycle, which was due to the higher engine operating efficiency under the low speed and low load operating points. However, this advantage in fuel consumption weakened or even disappeared under suburb cycle, and the average fuel consumption of CVT was 2.6% lower than MT and 4.3% higher than AT. This was because that gasoline engines always operating in high efficiency region under the high speed and high load operating points no matter what the transmission type was, but the disadvantage of low transmission efficiency for CVT became prominent resulting in higher fuel consumption.

![Fuel consumption variations](image)

**Figure 8.** Variations of fuel consumption of gasoline passenger car with MT, AT, CVT and DCT under urban cycle, suburb cycle and NEDC

4. Conclusion
In this paper, the development of China’s gasoline passenger car fuel consumption standards has been introduced. Moreover, the declared fuel consumption data of over 4800 gasoline passenger car models produced or imported in recent 5 years (2014-2018) has been analyzed. The development trends of the fuel consumption have been investigated first, and the effects of typical energy saving technologies including turbocharge and advanced transmission on the fuel consumption reduction have also been discussed. The conclusions can be reached as the following.
1. China’s standards related to the fuel consumption of passenger cars went through five phases from 2004 to 2019 including the update of the per-vehicle fuel consumption limits and CAFC targets.
2. The average fuel consumption of China’s passenger cars in 2018 was 7.13 L/100km, which was 6.4% lower than 2014, and the annual decreasing rate was about 1.6% per year. In addition, fuel consumption
decreasing under the urban cycle was the most obvious whose annual decreasing rate reached 1.98% per year.

3. The fuel consumption of the passenger cars increased linearly with the increase of curb mass, and the fuel consumption reduction of each year was more apparent for the gasoline passenger cars with higher curb mass.

4. The average fuel consumption of vehicles with turbocharge engines was 9.2% lower than naturally aspirated engines. The annual decreasing rate of fuel consumption of the turbocharge engines were also higher, about 2.4% per year, which indicated the development of passenger cars with turbocharge engines had a more significant effect on the fuel consumption reduction.

5. The average fuel consumption of vehicles with DCT was the lowest among 4 types transmission. The annual decreasing rate of the fuel consumption of AT was the highest, about 3.6% per year, which indicated that the development of passenger cars with AT had a more significant effect on the fuel consumption reduction.

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