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Research on Correlation between Vehicle Cycle and Engine Cycle in Heavy-duty commercial vehicle

Chen lin[1,2], Wang Zhong[1], Liu Shuai[1]

1.School of Automotive and Traffic Engineering, Jiangsu University, Zhenjiang, 212013

2. CATARC Yancheng Automotive Proving Ground Ltd. Yancheng, 224100

Corresponding author's e-mail address：chenlin@catarc.ac.cn

Abstract. In order to study the correlation between vehicle cycle and engine cycle in heavy commercial vehicles, the conversion model of vehicle cycle to engine cycle is constructed based on the vehicle power system theory and shift strategy, which considers the verification on diesel truck. The results show that the model has high rationality and reliability in engine operation. In the acceleration process of high speed, the difference of model gear selection leads to the actual deviation. Compared with the drum test, the engine speed distribution obtained by the model deviates to right, which fits to the lower grade. The grade selection has high influence on the model.

1. Introductions

With the continuous development of China's automobile industry, energy shortage and environmental pollution have become increasingly prominent problems. Heavy diesel vehicles account for only 5% of the total vehicle capacity, but the share of NOx and particulate emissions in motor vehicle emissions is as high as 78% and 82% respectively. It has a direct impact on human health[1]. All countries in the world have formulated strict emission regulations to limit the emission of heavy diesel vehicles and achieved good results[2-5]. In view of the pollution of diesel vehicles in China, when the model is approved according to GB 17691-2005 Limits and measurement methods for exhaust pollutants from compression ignition and gas fuelled positive ignition engine of vehicles，the engine is required to operate under one or more designated test cycles and meet specific emission limits. GB 17691 exposure draft (the six stage of China) which was released nearly adopted World Harmonized Transient Cycle (WHTC) and World Stable Transient Cycle(WHSC). On the basis of the engine reference cycle provided, the engine's proprietary actual test cycle is generated for specific attributes of the test engine. In the light of the correlation between vehicle test cycle and engine test cycle, scholars at home and abroad have carried on relevant research. For example, Ke Jinwu calculates the stable operation conditions of corresponding engine through the decomposition of light-vehicle NEDC cycle and distributes the weight coefficients according to the frequency statistics, thus the better effect is achieved[6]. Tang Bo obtained the correlation degree between the equivalent working condition of engine and the ESC cycle condition as well as the emission situation of the whole vehicle by using engine bench steady state test to simulate vehicle NEDC cycle condition, in order to verify the correctness of the model of the engine equivalent working condition[7]. Liu Jingping et al. calculated the scatter points of engine operating conditions corresponding to vehicle road cycle. According to the simplified principle of the shortest distance zone, the simplified working condition of engine is obtained, and the fuel economy under the condition of vehicle running is predicted[8].

Heavy duty diesel vehicles are complex in terms of fuel consumption and emission certification: the oil consumption is tested and verified on the drum test stand according to GB/T27840-2011 Fuel consumption test methods for medium and heavy-duty commercial vehicles. The emissions are tested with engine dynamometer according to GB 17691-2005. This leads to the measurement of emissions without measuring fuel consumption, while measuring fuel consumption does not test the emissions. In this paper, a calculation method based on vehicle cycle transformation into engine cycle is put forward, and a transmission system model including engine, transmission box and so on is established. The relevant tests were carried out on a freight car, which laid a theoretical foundation for the correlation between the vehicle cycle and the engine cycle.

2. Modeling

According to the theory of automobile, the running state of a car (speed, gear, acceleration, etc.) can determine the operating conditions of an engine. Figure 1 is the cycle transition process of vehicle cycle to engine in the model. The model is composed of input module, gear selection module and output module. The input module obtains the relevant parameters of vehicles required in the test; the gear module tests the gearbox simulation and optimizes the engine performance shift strategy based on generating different gear options. The output module outputs the corresponding rotation speed and load parameter cycle of the vehicle engine under the condition of the input vehicle cycle test.

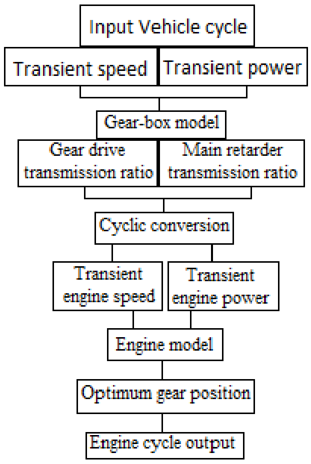

Figure 1 Cycle conversion flow chart

According to the comprehensive drive ratio between transmission and main driver, and the related information of test tire, vehicle speed will be converted to the actual value of the engine speed. According to the rated speed and idle speed of engine calibration, it is standardized.

$$\mathrm{Ne(t)} = \frac{\mathrm{V(t)}}{2\pi \mathrm{r}} \times \frac{1000}{60} \times \mathrm{i_m} \times \mathrm{i_f}$$

$\frac{\mathrm{V(t)}}{2\pi\mathrm{r}}$ converts the vehicle speed to the angular speed through the rolling radius r of tire; im is the drive ratio of transmission, which is determined by the gear selected by the model; if is the drive ratio of main reducer.

The transient load of the engine Le(t) can be obtained by dividing the transient power of the vehicle by the maximum power of the engine under the gear transient speed. The formula is shown as follows:

$$\mathrm{Le(t)} = \frac{\mathrm{P_{norm}(t)}}{\mathrm{P_{max}(Ne(t)) \; / P_e}}$$

Wherein, the rated power Pe is the maximum power specified by the manufacturer; Standardized transient power Pnorm (t)of vehicle is the cycle parameter of the vehicle. It is the result that the transient power of the vehicle cycle is standardized according to the rated power of the vehicle. It has nothing to do with the characteristics of the engine.

Pmax(Ne(t) is obtained according to external characteristic curve, namely the maximum output power of engine under the transient rotative speed Ne(t)at t second. It is standardized by dividing P_e

3. Test comparison analysis

In order to verify the rationality and reliability of the model results, the engine cycle of the model output is compared with the actual engine cycle and drum cycle.

3.1. Bench test analysis

Engine performance and power supply are important benchmark conditions in the cycle of the model obtained from the model calculations. The rationality of the model can be verified by comparing it with the actual cycle of the platform. Figure 2-4 is the Engine speed cycle results generated in low-speed section, middle-speed section and high-speed section under C-WTVC conditions. The blue color is model cycle; the red is engine cycle.

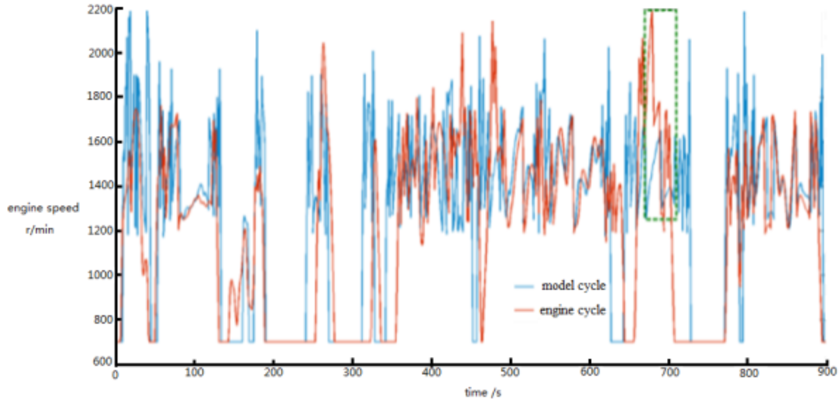

Figure 2 Engine cycle in low speed

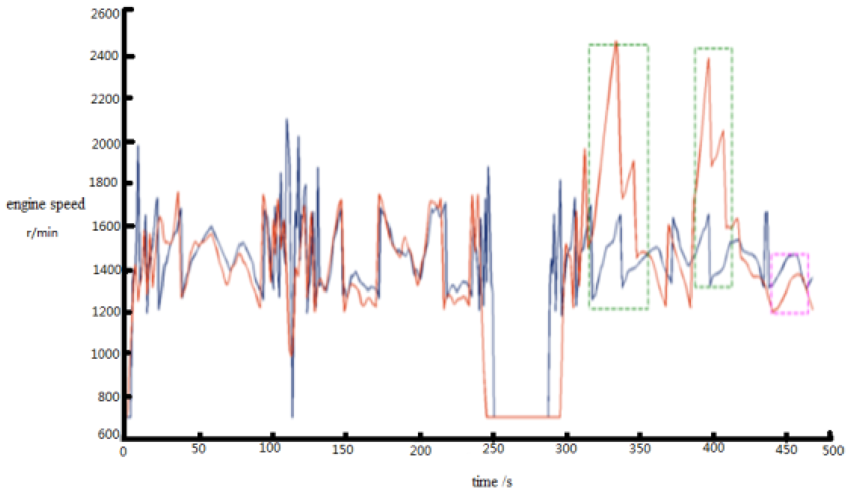

Figure 3 Engine cycle in middle speed

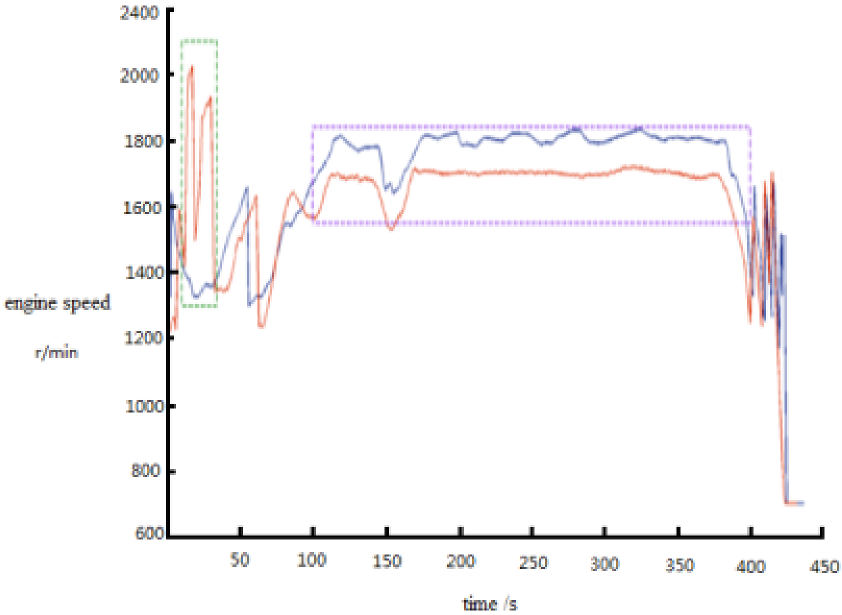

Figure 4 Engine cycle in high speed

As shown in figure 2, there is a considerable degree of consistency between the speed of the model cycle and the speed of the bench cycle, which shows that the model cycle and the platform cycle have a considerable degree of rationality and reliability in reflecting the operation of the engine.

In the section 670s-710s (figure 2), 400s-420s(figure 3), and 10s-30s (figure 4), It can be seen that there is a big difference between the model cycle and the bench cycle. The speed of former is lower than the latter. Comparing with C-WTVC speed cycle, it can be seen that these differences occur in the acceleration process with higher speed, and the model chooses the gear at high speed acceleration. Low driving ratio under high gear caused high fall in the speed. There is a sustained structural difference between the speed of model cycle and the bench cycle. This means that in the same whole vehicle running state, there is an essential difference between the corresponding engine speed and vehicle speed at the same time period. The difference in gear selection is the root cause of this difference.

In the section 440s-480s (figure 3) and 100s-400s (figure 4), there is obvious difference in speed between model cycle and bench cycle, but the change trend is the same. This is mainly because the actual calibration parameter of the transmission system is the information source for gear selection. The speed and speed parameters of the engine generated in the conversion process are in perfect agreement with the actual driving situation of the vehicle equipped with the transmission system. When generating the platform cycle, because the characteristic parameters of testing engine is inputted, lacking other information sources including the driving system calibration, there will be deviation between the generated cycle and actual cycle.

3.2. Drum test analysis

Unlike the theoretical cycle of gear selection in engine bench tests, the test driver usually comes from the main selection gear in accordance with driving habits during the test of heavy duty vehicle drum trials. The difference in gear selection has a major impact on engine cycle output. The test analyzes the middle-speed section in C-WTVC cycle. The result is shown in Figure 5. Green line is the Vehicle test speed (km/h); the blue line is the bench gear; the red line is model gear; the yellow line is drum gear.

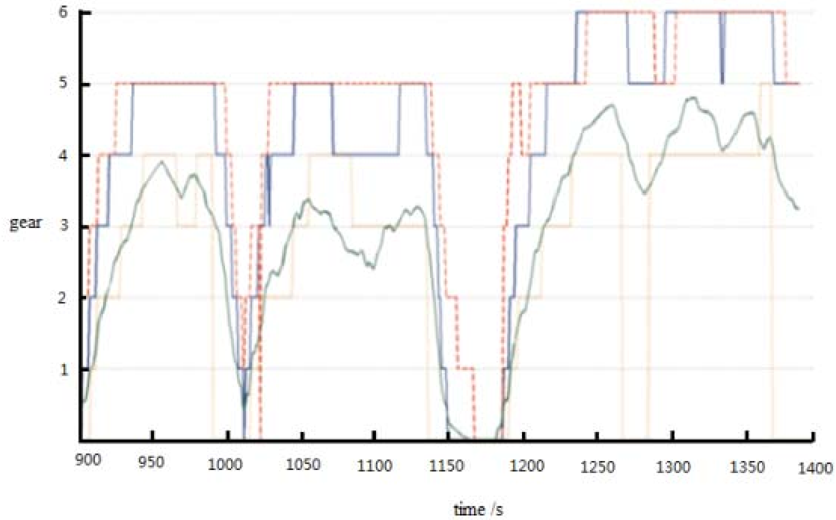

Figure 5 Gear contrast in middle speed

As can be seen from the figure, the theoretical differences between the actual gear and the model are obvious: In the same vehicle test scenario, the driver tends to choose the lower gear in the drum test. In the medium speed range, the top 6 gear is not used. The difference of shift selection has a great influence on engine cycle output. Figures 6 and 7 show the engine cycle parameter distribution of drum cycle and model cycle. It can be seen that in the drum test, the engine speed distribution is right, and it coincides with the lower gear selection. The engine load of model cycle distributes highly in the section 80~100%.This is related to the gear selection criteria for engine dynamics in the model line.

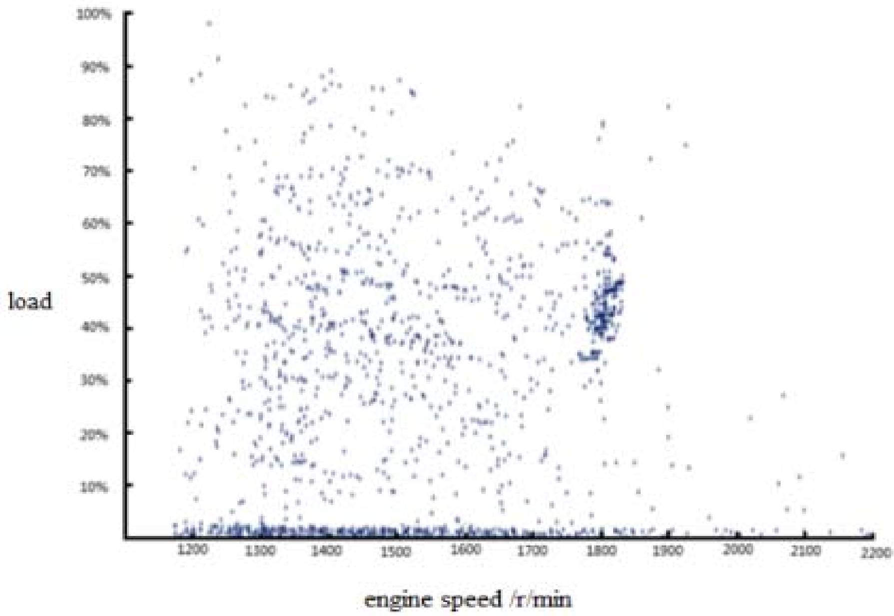

Figure 6 Speed of drum cycle engine

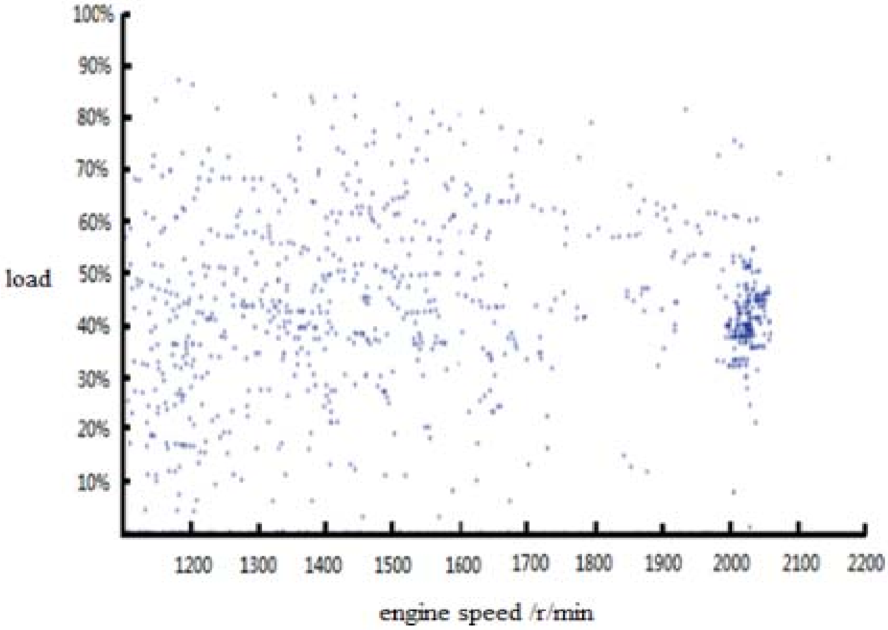

Figure 7 Speed of model cycle engine

As shown in figure 5, 6 and 7, because of the difference of gear conversion method, under the same setting parameters, there is large deviation between the engine parameter distribution generated by C-WTVC vehicle cycle and the output results of drum test. This would have a negative impact on the consistency of their test results.

4. Conclusions

Establish a cycle conversion model from vehicle to engine including input module, gear selection module and output module and investigate the correlation between the vehicle and the engine cycle.

The correctness of the model is verified by comparing the cycle of engine with engine, and the speed of the two loops is consistent with the trend. There is a sustained structural difference in gear selection during higher speed acceleration process.

Under the same test parameters, the difference of the shift method will lead to a great deviation between the engine parameters distribution and the output results of the drum test, which will affect the test results.

References

[1]Du X, Wu Y, Fu L, et al. Intake fraction of PM 2.5, and NOx, from vehicle emissions in Beijing based on personal exposure data[J]. Atmospheric Environment, 2012, 57(57):233-243.

[2] DIESELNET. Heavy-Duty Truck and Bus Engines-European Union[DB/OL].2013.

[3]DIESELNET. Emission Test Cycles-ECE R49 [DB/OL].2013.

[4]DIESELNET. Heavy-duty Truck and Bus Engines-United States[DB/OL].2013

[5] EPA U. Emission Regulations for New Otto-Cycle and Diesel Heavy-Duty Engines; Gaseous and Particulate Exhaust Test Procedures[S]. US government printing office. 2013.

[6] Ke J W, Lan Q, Zhu W Q, Chen L. Research on Light Vehicle Emission Based on Steady Working Condition of Diesel Engine[J]. Internal Combustion Engines ,2015(1):21-25.

[7]Tang B. Bench simulation test research on light diesel vehicle emission [D]. Nanjing University of Science ＆Technolongy, 2015.

[8] Liu J P ，Li Y C，Xia X L，, et al. A Study on the Determination of Simplified Engine Operation Points Corresponding to Vehicle Driving Cycle[J]. Automotive Engineering, 2011, 33(7):563-568.