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COMPARISON OF FUEL CONSUMPTION AND EMISSION CHARACTERISTICS OF CHINA VI COACH UNDER DIFFERENT TEST CYCLES

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ABSTRACT

As the test cycle used for evaluating the fuel consumption and emission characteristics of the heavy-duty commercial vehicle in China will be replaced from C-WTVC to CHTC in a round 2020, the investigation on the variation of fuel consumption and emission test results after the replacement is well needed for further vehicle's development and calibration. In this paper, the fuel consumption and emission characteristics of a China VI coach under these two test cycles have been discussed and compared. Results showed that fuel consumption, CO, HC and NOx emissions of the test coach all increased after changing the test cycle from C-WTVC to CHTC, which were due to the low rotation speed and low torque operating points, and the aggressive and frequent acceleration under CHTC. In addition, Acceleration driving condition contributed most to the deterioration of fuel consumption, CO, HC and NOx emissions under CHTC, which attention should be especially paid in the further vehicle calibration.

Keywords: heavy-duty commercial vehicle, coach, test cycle, fuel consumption characteristic, emission characteristic

NONMENCLATURE

Abbreviations	
CHTC-C	China Heavy-duty commercial vehicle Test Cycle-Coach
C-WTVC	China-World Transient Vehicle Cycle
CO	Carbon monoxide
HC	Hydrocarbon
NOx	Nitric oxides
SCR	Selective Catalytic Reduction

1. INTRODUCTION

The coach is a kind of heavy-duty commercial vehicle which is used passenger transport among cities, towns and villages. In 2018, sales quantity of coach is up to 84420 units, which accounts for 42.5% of the overall sales quality of coach, public bus and school bus [1]. Furthermore, the fuel consumption and exhaust emitted accounts for a large proportion of the whole vehicle transportation due to its large curb weight and long driving distance. Therefore, the energy conservation and emission reduction of the coach cannot be ignored.

In current Chinese standard (GB/T 27840 and GB 17691), C-WTVC is the test cycle used for evaluating the fuel consumption and emission characteristics of the heavy-duty commercial vehicle [2-3]. Because that C-WTVC was developed according to the diving data in Europe, US and Japan [4], it was difficult to reflect the real driving characteristics of China resulting in the gaps of fuel consumption and emission levels between the real-road and regulation test. To solve this problem, China's Ministry of Industry and IT (MIIT) introduced China automotive test cycle (CATC) series in 2018 which was developed according the three years' real-road driving data of more than 5000 vehicles in 41 Chinses cities.

CATC series is divided into light-duty (CLTC) and heavy-duty commercial vehicle test cycles (CHTC). The CHTC series include 6 test cycles which are defined as bus test cycle (CHTC-B), coach test cycle (CHTC-C), light truck test cycle (CHTC-LT), heavy truck test cycle (CHTC-HT), tractor-trailer test cycle (CHTC-TT) and dumper test cycle (CHTC-D). CHTC series will be replace C-WTVC in GB/T 27840 and GB 17691 in a round 2020.

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The replacement of the test cycle will certainly affect the measuring result of the fuel consumption and emission, so that research on the results comparison under different test cycles is well needed for further vehicle's development and calibration. In this paper, the fuel consumption and emission characteristics of a China VI coach under different test cycles have been discussed and compared.

2. TEST APPARATUS AND METHODS

2.1 Test vehicle

The test vehicle used in this investigation was a 9m coach which reached the China VI emission standard and the specifications have been summarized in Table 1. During the test, the vehicle load was set as 100%, and the total vehicle mass was 13000kg.

Table 1. Vehicle specification

Parameters	Value
Length*width*height(mm)	8995*2500*3410
Curb weight(kg)	9800
Maximum design total mass(kg)	13000
Engine rated power(kW/rpm)	199/2100
Enigne maximum torque(N.m/rpm)	1000/1200~1700
Gear	6 Manual
Gear ratio	6.4/3.7/2.2/1.4/1.0/0.7

2.2 Diving cycle

In this paper, two driving cycles have been used in the tests, one was the C-WTVC and the other was CHTC-C and both cycles were divided into low, medium and high velocity parts, as shown in Fig.1.

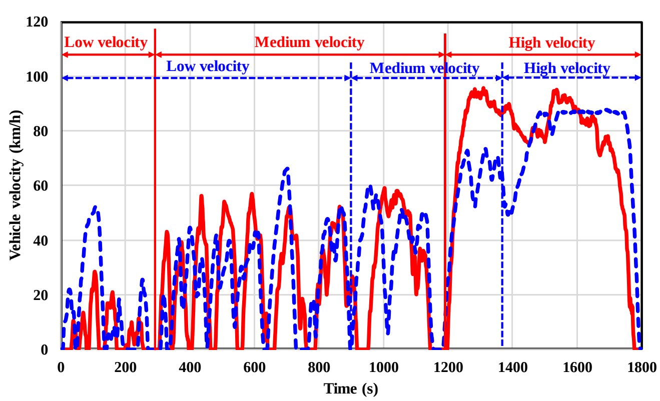

Fig.1.CHTC-C (red solid) and C-WTVC (blue dashed) test cycles

The fuel consumption and emission results of the coach under C-WTVC were calculated by each part's value with weighing coefficients of 0.1 (low), 0.2 (medium), and 0.7 (high). The results of CHTC-C did not need the weighing calculation of each part. In addition, the main parameters of these two test cycles including driving duration, driving distance, average velocity etc. have been listed in Table.2 and of which Idling, constant, acceleration and deceleration driving conditions were defined in Table 3.

Table 2. Comparison of the main parameters of CHTC-C and C-WTVC (coach)

Main Parameters	CHTC-C	C-WTVC (coach)*
Driving Duration (s)	1800	485.5
Driving distance (km)	19.62	8.07
Max. velocity (km/h)	95.70	87.80
Mean velocity (km/h)	39.24	59.79
Max. acceleration (m/s^2)	1.25	0.87
Mean acceleration (m/s^2)	0.43	0.33
Min. deceleration (m/s^2)	-1.28	-1.00
Mean deceleration (m/s^2)	-0.48	-0.46
Iding condition (%)	18.22	5.24
Constant conditon (%)	33.00	59.88
Acceleration condition (%)	26.22	16.29
Deceleration condition (%)	22.56	18.59

* C-WTVC (coach) was the C-WTVC after weighted with weighing coefficients of 0.1 (low), 0.2 (medium), and 0.7 (high).

Table 3. Defination of Idling, constant, acceleration and deceleration driving conditions

Conditon	Acceleration (m/s^2)	Velocity (m/s)
Iding condition	-0.15≤a≤0.15	v<1
Constant conditon	-0.15≤a≤0.15	v≥1
Acceleration condition	a>0.15	-
Deceleration condition	a<-0.15	-

Results showed that the mean velocity of CHTC-C was lower than the C-WTVC (coach) although with a higher maximum velocity. Either the absolute value of maximum or mean acceleration/deceleration of CHTC-C was higher than C-WTVC (coach), which indicated a more aggressive driving style in China.

The proportion of each driving condition presented that the proportions of CHTC-C's idling condition, acceleration and deceleration condition were all higher than C-WTVC (coach) resulting in a nearly 50% decrease of the proportion of constant condition compared to C-WTVC (coach).

2.3 Test system

The test system in this study consisted of heavy-duty chassis dynamometer, fuel consumption instrument, exhaust gas analyzer (HORIBA MEXA-7200DTR) and CAN analyzer. The exhaust gas analyzer was used to measure the vehicle's transient emissions of CO, HC and NOx, and CAN analyzer was used to monitor the rotation speed and output torque ratio of the diesel engine.

3. RESULTS AND DISCUSSION

3.1 Distributions of diesel engine operating points under different test cycles

To clearly explain the variations of fuel consumption and emission characteristics between these two cycles, the diesel engine operating points were compared first as shown in Fig.2.

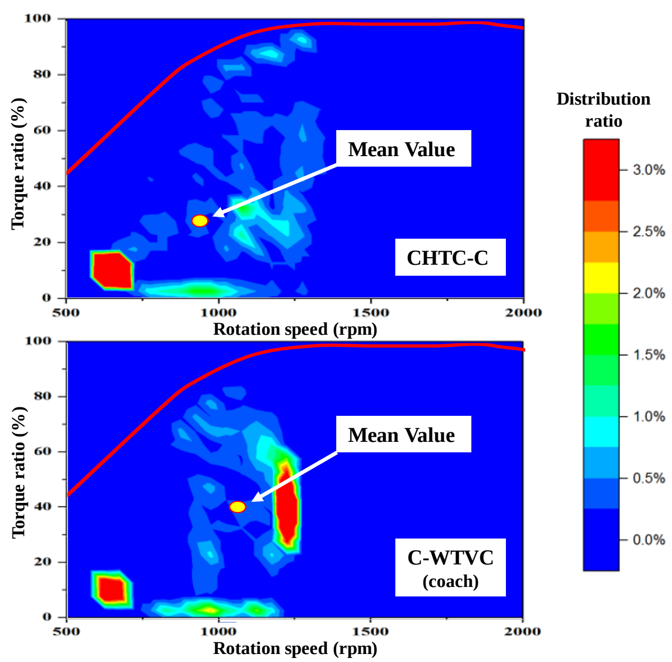

Fig.2. Diesel engine operating points under CHTC-C and C-WTVC (coach) test cycles

Results showed that most of the operating points under CHTC-C were concentrated in the low rotation speed and low torque region (35.61%). While operating points under C-WTVC (coach) were concentrated not only in low rotation speed and low torque region (14.93%) but also the high rotation speed region (34.22%). The mean values of rotation speed and torque ratio under these two test cycles, as the yellow pots shown, also indicated that the distribution of the operating points under CHTC-C tend to the low rotation speed and low torque ratio region. This was mainly due to the higher idling condition proportion and lower mean velocity of the CHTC-C. It worth noting that operating points with high torque ratio (>80%) only appeared under CHTC-C, which was because of the higher output torque requirement due to both higher velocity and acceleration values.

3.2 Fuel consumption and emission characteristics under different test cycles

Fig.3 showed the fuel consumption and emission characteristics of the test coach under different test cycles. Results indicated that fuel consumption rate under CHTC-C were higher than C-WTVC (coach), 7.71%. For emission characteristics, all kinds of the emissions were higher under CHTC-C. The values of CO, HC and NOx emissions under CHTC-C increased 9.88%, 39.01% and 23.41% than C-WTVC's results, respectively.

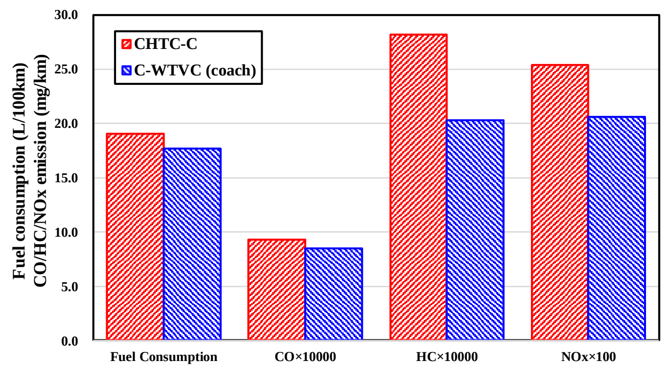

Fig.3. CHTC-C and C-WTVC (coach) test cycles

The higher fuel consumption rate under CHTC-C could be attributed to the low rotation speed and low torque ratio distribution of the diesel engine operating points, which was away from the high efficiency region. Besides, higher acceleration value and proportion also caused more incomplete combustion of the injected fuel resulting in higher fuel consumption.

The mass generation of CO was due to either low combustion temperature or rich fuel-air mixture. The low rotation speed and low torque ratio distribution resulted in lower combustion temperature, and higher acceleration value and proportion led the rich fuel-air mixture distributed in the cylinder. These all increased the CO emissions under CHTC-C.

HC emissions was generated because of the insufficient fuel-air mixing and quenching, which was often occurred when vehicle accelerating. So, the higher acceleration value and proportion of CHTC-C were the main reasons caused the increase of HC emissions.

The increase of NOx emission under CHTC-C was mainly attributed to two reasons, one is the higher in-cylinder caused for the frequent acceleration, the other was the low convert efficiency of the SCR system due to the lower exhaust temperature which was related to the low rotation speed and low torque ratio operating point distribution.

3.3 *Fuel consumption and emission share ratios of each driving condition under different test cycles*

In this paper, the concept of share ratio was introduced to investigate the contribution of each driving conditions to the overall fuel consumption and emission, which was defined as the percentage of fuel consumption or emission gross under one driving condition (idling, constant, acceleration or deceleration condition) to the gross under the whole test cycle. The comparison of the share ratio of each driving condition under different test cycles was given in Fig.4

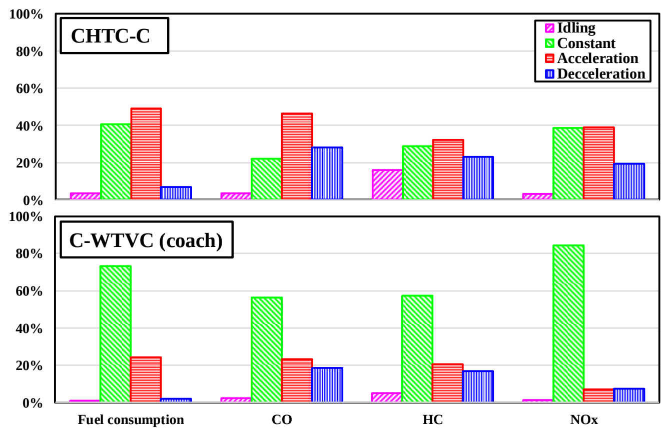

Fig.4. Fuel consumption and emission share ratios of each driving condition under different test cycles

Results showed that the share ratio of acceleration condition to the fuel consumption and overall emissions was the highest under CHTC-C, while was the constant condition under C-WTVC (coach). This was mainly attributed the difference of the driving condition proportions between these two cycles. To eliminate this effect, the share ratios were divided by duration of each corresponding driving condition, as shown in Fig.5.

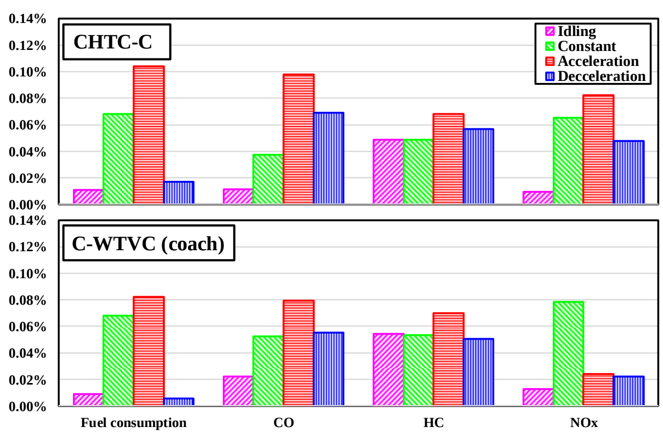

Fig.5. Fuel consumption and emission share ratios per second of each driving condition under different test cycles

From the values of fuel consumption and emission share ratio per second, it indicated that acceleration condition contributed most to the fuel consumption, CO emission and HC emission under both CHTC-C and C-WTVC (coach). Moreover, the values under CHTC-C were generally higher than C-WTVC (coach), which was because of the more aggressive acceleration driving styles of CHTC-C. The difference of the most contribution driving condition to NOx emission between these two cycles showed that higher acceleration was the main reason caused NOx generation under CHTC-C, while higher in-cylinder temperature caused by higher average velocity of the constant condition was the reason under C-WTVC (coach).

4. CONCLUSION

In this paper, the fuel consumption and emission characteristics of a China VI coach under CHTC-C and C-WTVC (coach) have been discussed and compared. The conclusion can be reached as the following.

The distribution of the diesel engine operating points under CHTC-C tend to the low rotation speed and low torque ratio region compared with C-WTVC (coach), and the operating points with high torque ratio (>80%) only appeared under CHTC-C.

The higher fuel consumption, CO, HC, and NOx emissions was obtained under CHTC-C, which were due to the low rotation speed and low torque operating points, and the aggressive and frequent acceleration.

Acceleration driving condition contributed most to the deterioration of fuel consumption, CO, HC and NOx emissions under CHTC, which attention should be especially paid in the further vehicle calibration

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