

Real-road Emission and Fuel Economy of Buses using Different Fuel

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Abstract: The real-road emission and the fuel economy of 2 China-VI buses and 2 China-III buses using different fuel are tested using portable emission measurement system. The results show that, compared with Beijing VI diesel buses, China VI buses using B5 biodiesel is 33.1% lower in CO specific emission, 15.6% higher in NO_x specific emission, and 13.1% lower in PN specific emission. The CO emission factors of the four buses using B5 biodiesel decrease by 29.5% averagely compared with Beijing VI diesel buses, while the NO_x emission factors increase by 12.7% and PN emission factors decrease by 9.1%; the CO₂ emission factors increase by 11.3% and thus the fuel consumption per 100km increase by 11.51% which is calculated using carbon-balance method considering the impact by fuel density. The fuel economy difference is high. More research on the impact on fuel economy by fuel heat value or other physical and chemical parameters is necessary in the future.

1.Introduction

As the economy continues to grow in China, the demand for oil product becomes higher and it thus increasing the oil import of China. In 2016, the dependence upon foreign trade of oil increases to 65%. The demand for diesel is the largest among all the oil products and it thus leads to a big gap between the demand and the production of diesel. As a regenerable and clean energy source, the biodiesel is an alternative of diesel^[1-3].

Many researchers studied the emission and the fuel economy of biodiesel using chassis dyno and test bench^[4-6]. The biodiesel can reduce the tailpipe PM, CO and HC while increase NO_x and CO₂; the fuel consumption of vehicles using biodiesel also increases.

While there are many researches on the emission characteristics of vehicles using biodiesel on chassis dyno and test bench, the research on real-road condition is insufficient. This paper tests 4 buses using Beijing VI diesel and B5 biodiesel on real-road by portable emission measurement system (PEMS), and analyzes the emission characteristics and fuel economy comprehensively. The results are helpful to the application of biodiesel.

2.Research Method

2.1 Test equipment and tested vehicles

The PEMS used is Semtech-ECOSTAR produced by Sensor Inc., consisting of a gaseous and particle emissions analyzing system, a sampling system, an exhaust flow meter, a global positioning system (GPS) and a weather station. NO and NO₂ are analyzed by non-dispersible ultra-violet (NDUV), CO



and CO₂ by non-dispersible infrared absorption (NDIR), and particle number by condensed particle counter (CPC). As flame ionization detector shall be used to detect THC, while the tests are done during a sensitive period, the THC is not analyzed due to safety concern.

The tested vehicles are buses in operation. A total of 4 buses are tested, whose parameters are specified in Table 1

Table.1 Vehicle parameters

Parameters	No. 1	No. 2	No. 3	No. 4
Odometer/km	193794	193681	492200	492054
Engine Capacity/L	8.424	8.424	8.4	8.4
Maximum Power/kw	243	243	228	228
Gross mass/kg	18000	18000	17500	17500
Payload/kg	3500	3500	3500	3500
Emission Level	China VI	China VI	China-III	China-III
After-treatment System	DOC+DPF+SCR	DOC+DPF+SCR	None	None

2.2 Fuel

The fuel used is Beijing VI vehicular diesel and B5 biodiesel. The physical and chemical parameters are listed in Table 2.

Table.2 Physical and chemical indicators

Parameters	Beijing VI diesel	Biodiesel 5%
Density/kg.(m ³) ⁻¹	828.6	827.3
Cetane Number	56.5	52.2
Sulfur Content/mg/kg. ⁻¹	6.1	7.5
Viscosity/mm ² .s ⁻¹	4.665	4.644
90% Distillation Temperature/°C	316.1	347.8

2.3 Test Route and Plan

The tests were done during workdays. The vehicles started from Yejinyiju Station of Bus No. 811 in Yanjiao, Sanhe City, Hebei. The normal entry to and exit from the station was followed until the bus service terminates at Bawangfen west station in Beijing. The bus then returned back following the same route.

For each bus, the real-road emission tests were done using both kinds of fuel. The bus was firstly tested used Beijing VI vehicular diesel. After the test finished, the oil tank is emptied and B5 biodiesel was refilled to the tank. The tank clean method is done by refilling the tank using the tested fuel to 20L, and driving the bus for 50km. These operations are done twice until the engine adapts the new fuel. The real-road emission tests were then done using B5 biodiesel. The schematic diagram is shown in Fig. 1.

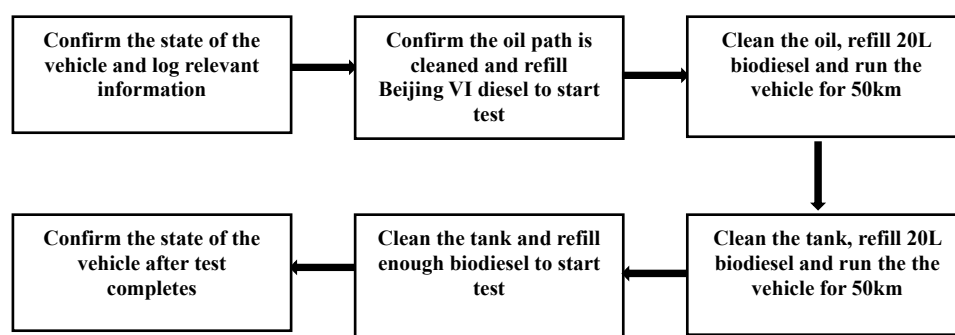


Figure.1 Experimental flow chart

3. Results and Analysis

3.1 Comparing between the PEMS results and the Emission Limit

Both vehicles pass the integrity verification and the validity verification and thus the PEMS results are eligible for comparison with the regulation.

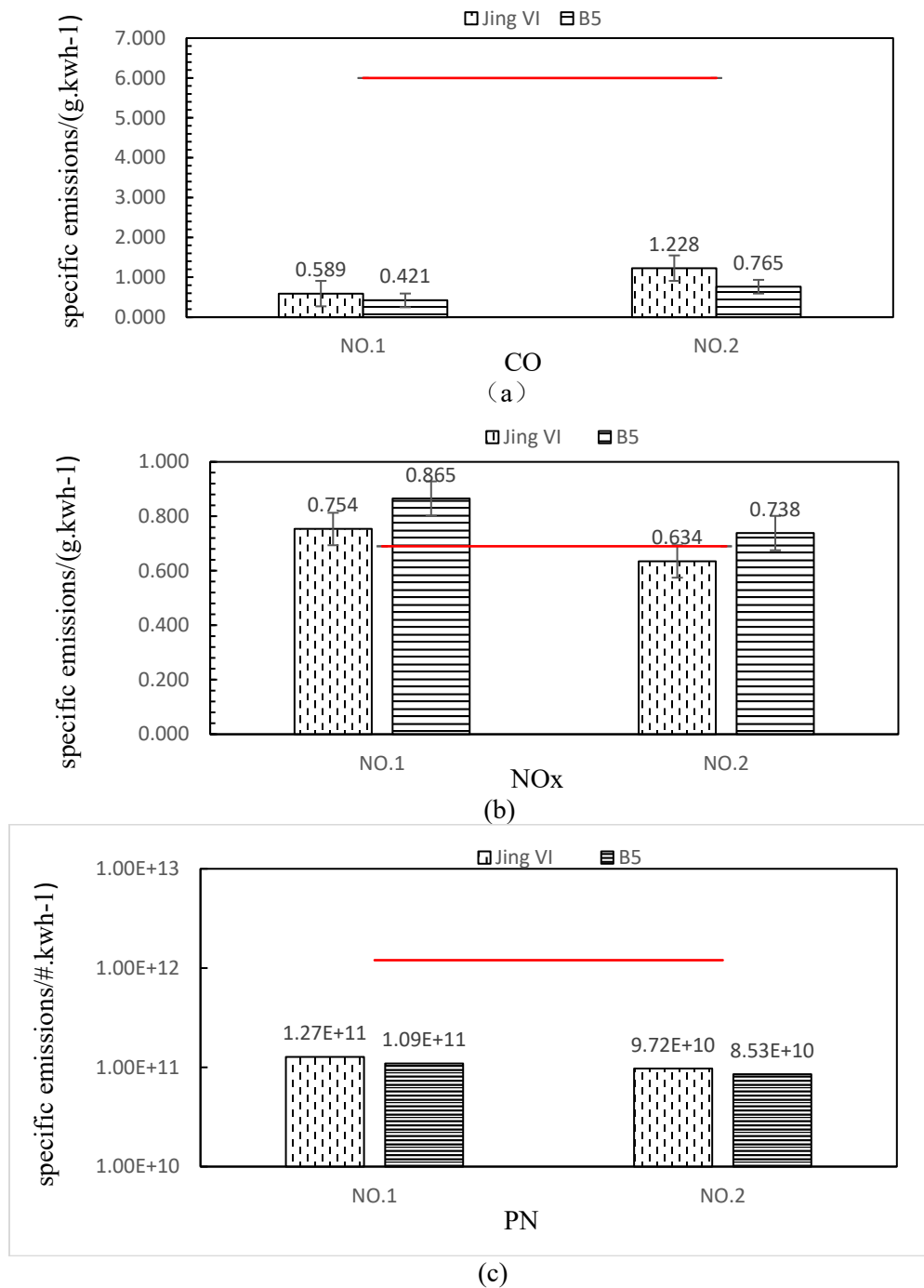


Figure.2 Contaminant analysis

As shown in the results, the vehicles using both Beijing VI diesel and B5 biodiesel emit far less CO than the 6 g/kWh limit of the regulation. For each vehicle, the B5 biodiesel reduces CO emissions compared with Beijing VI diesel by respectively 28.5% and 37.7%. Vehicle No. 1 fails to meet the

regulation limit of 0.69 g/kWh for NO_x. The B5 biodiesel increases the NO_x emissions by 14.8% compared with Beijing VI diesel. Vehicle No. 2 meets the regulation limit using Beijing VI diesel while exceeds the limit when the fuel is switched to biodiesel and is 16.4% higher, for NO_x emission. For PN, the vehicles using both fuel meet the regulation limit. The B5 biodiesel decrease the PN emissions by 13.8% and 12.3% respectively for vehicle No.1 and vehicle No.2 compared with Beijing VI diesel.

3.2 Emission factors

As the vehicles are similar in gross mass, and their payloads are also similar, the emissions factors (g/km) are able to be used to evaluate the emission of the vehicles, using the calculation equation in Formula (1). To increase the confidence of the comparison, the results are averaged every 10km/h in the same speed range of the 4 vehicles.

Emission factor = Cumulative emissions during the test/ Cumulative distance during the tests (1)

Where the unit of emission factor is g/km

The unit of cumulative emissions is g

The unit of cumulative distance is km

Table.3 Driving Conditions

Conditions	NO.1		NO.2		NO.3		NO.4	
	Jing VI	B5	Jing VI	B5	Jing VI	B5	Jing VI	B5
Distance/km	79.5	79.1	79.1	78.8	79.4	79.1	73.8	74.1
Average Speed/km.h ⁻¹	30.74	28.82	31.24	25.80	27.77	30.44	28.74	26.02
Idling time percentage/%	18.6	23.4	17.7	23.4	23.2	21.6	19.3	23.6
non-idling time percentage/%	19.8	16.3	21	9.8	13.7	21.9	22.3	14.1
Acceleration time percentage/%	29.7	28.7	28.9	33.5	28.2	24.6	28.5	29.8
deceleration time percentage/%	31.9	31.6	32.5	33.3	34.9	31.9	29.9	32.4
Average Acceleration/m.(s ²) ⁻¹	1.15	1.11	1.26	1.15	1.24	1.21	1.04	1.04
Average Deceleration/m.(s ²) ⁻¹	-0.91	-0.87	-1.00	-1.01	-0.90	-0.85	-0.84	-0.85

3.2.1 CO emissions

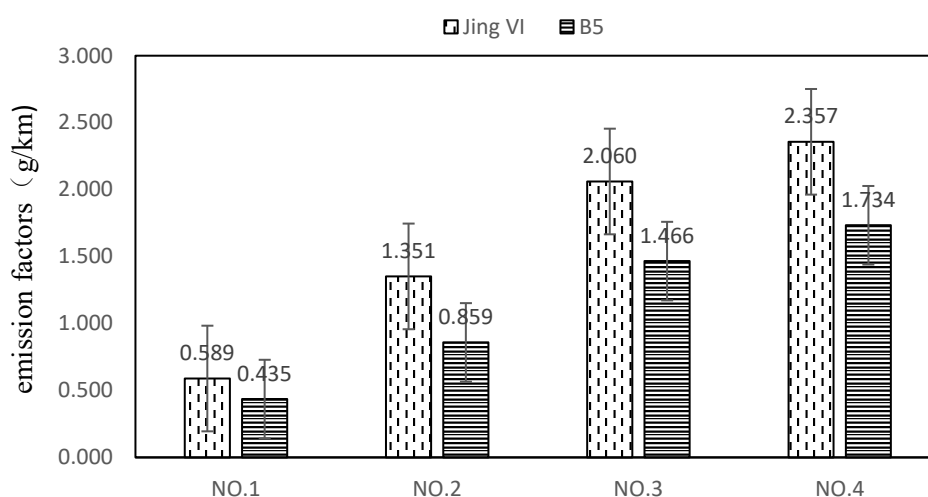


Figure.3 The overall CO emission factor of different fuels used in different vehicles CO Analysis

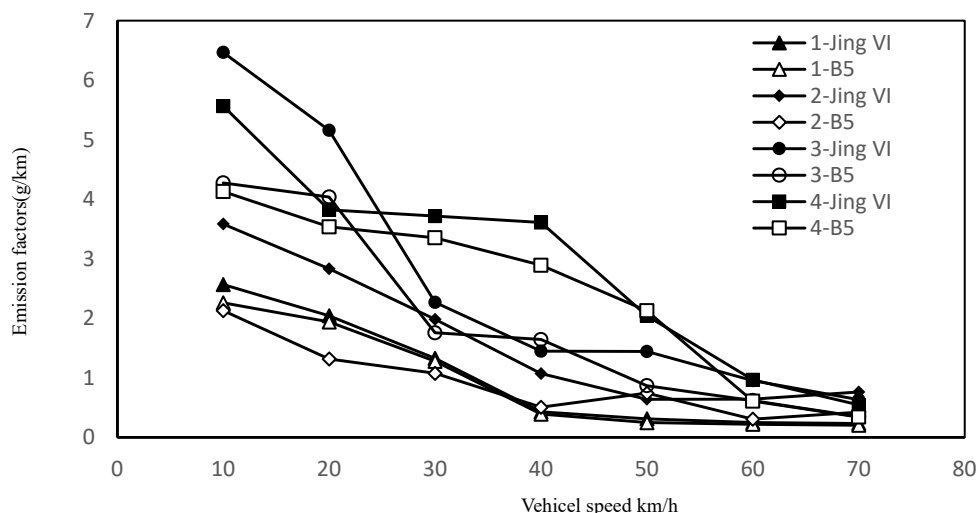


Figure.4 The relationship between CO emission factors of different vehicles and vehicle speed

As shown in Fig.3, the four buses are averagely lower in the emission factors of CO when using B5 biodiesel, respectively by 26.1%, 36.4%, 28.9% and 26.4% and averagely by 29.5%. The reason is that the biodiesel contains oxygen which can promote the combustion, and can oxidize CO.

As is shown in Fig.4, during the cycle, the CO emissions of the vehicles using biodiesel are lower than those using Beijing VI diesel in most time, and thus leads to the decrease of CO emission factors.

While the vehicle speed is low, the CO emission factors of vehicle No.1 and No.2 are far less than vehicle No.3 and No.4. As the speed increases, the difference between the vehicles certificated to different emission standards becomes smaller. The reason is that vehicle No.3 and No.4 are China-III vehicles without any after-treatment device while vehicle No.1 and No.2 are China-VI vehicles with DOC that can control the CO emissions in low level. As is shown in the figure, the emissions are similar when the speed is low for vehicle No.3 and No.4 using biodiesel and vehicle No.1 and No.2 using Beijing VI diesel. As most urban buses run at low speed, the use of biodiesel is helpful to reduce CO emissions.

3.2.2 NOx Emissions

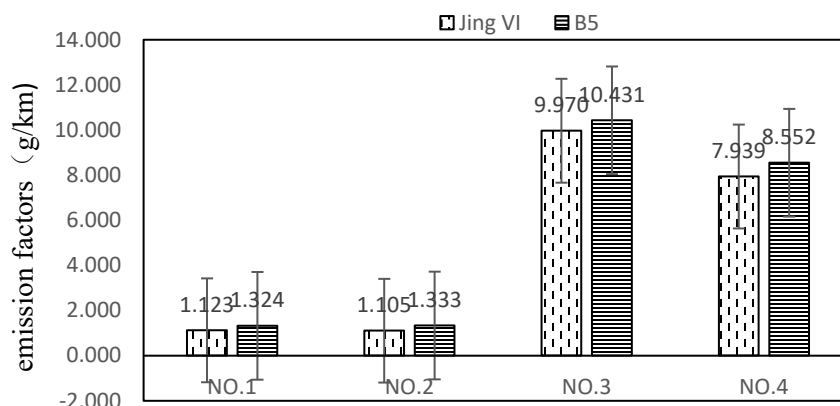


Figure.5 The overall NO_x emission factor of different fuels used in different vehicles

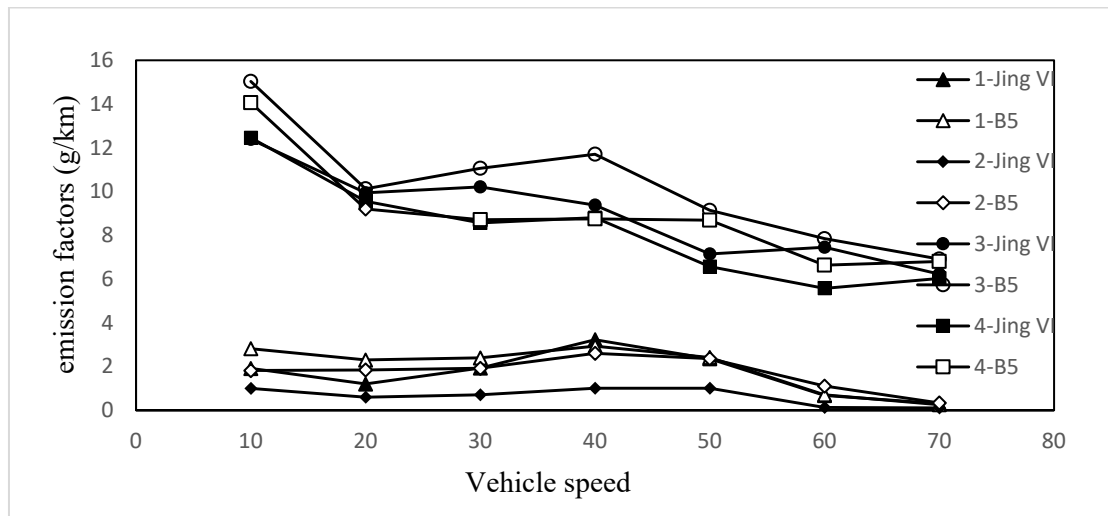


Figure.6 The relationship between NO_x emission factors of different vehicles and vehicle speed

As is shown in Fig.5, the four buses using B5 biodiesel are all high in NO_x emission factors compared with those using Beijing VI diesel, respectively by 17.9%, 20.6%, 4.6% and 7.7%, and averagely by 12.7%. The reason is that the biodiesel contains oxygen which promotes the combustion and thus increases the in-cylinder temperature leading to the increase of NO_x emissions.

As is shown in Fig.6, during the cycle, the NO_x emissions of the vehicles using biodiesel are higher than those using Beijing VI diesel in most time, and thus leads to the increase of NO_x emission factors. The NO_x emissions of the four vehicles are similar, and they are all high in the initial stage and in the period when the speed reaches 40km/h. This is because the air-fuel ratio and the combustion temperature promote the formation of NO_x at these points, and thus leads to a high emission of NO_x. These points are important for vehicle calibration.

3.2.3 PN Emissions

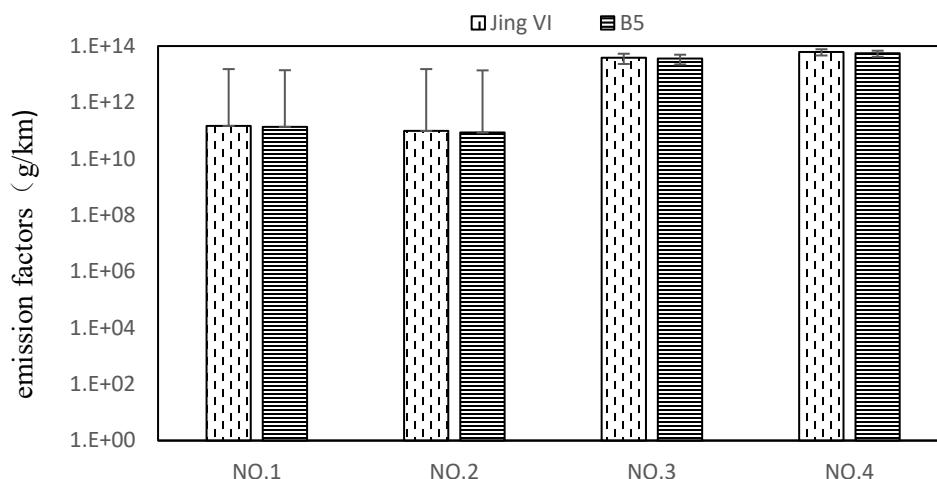


Figure.7 The overall PN emission factor of different fuels used in different vehicles

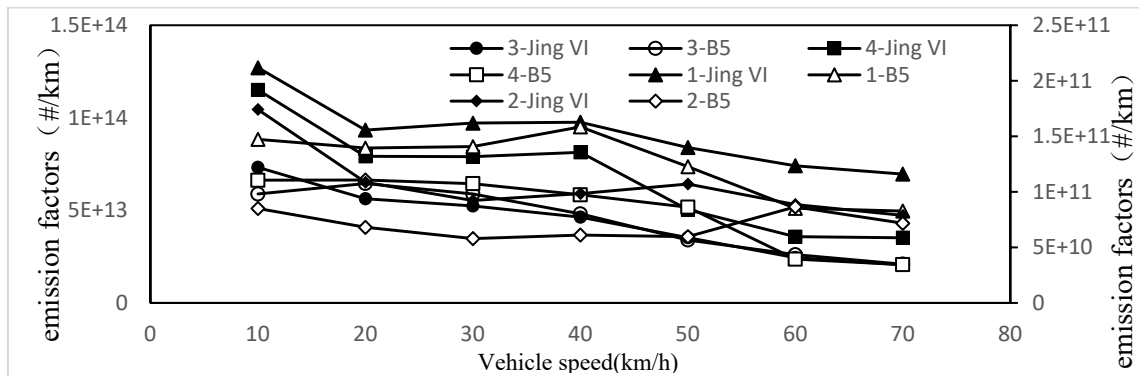


Figure.8 The relationship between PN emission factors of different vehicles and vehicle speed

As shown in Fig.7, the four buses using B5 biodiesel are all low in PN emission factors compared with those using Beijing VI diesel, respectively by 7.5%, 12.3%, 6.1% and 10.6%, and averagely by 9.1%. The reason is that the biodiesel contains oxygen which promotes the combustion and thus lessens the area where insufficient combustion occurs. As is shown in Fig.8, during the cycle, the PN emissions of the vehicles using biodiesel are lower than those using Beijing VI diesel in most time, and thus leads to the decrease of PN emission factors. The biodiesel is beneficial for reducing particle emissions.

3.3 Fuel Economy

3.3.1 CO₂ Emissions

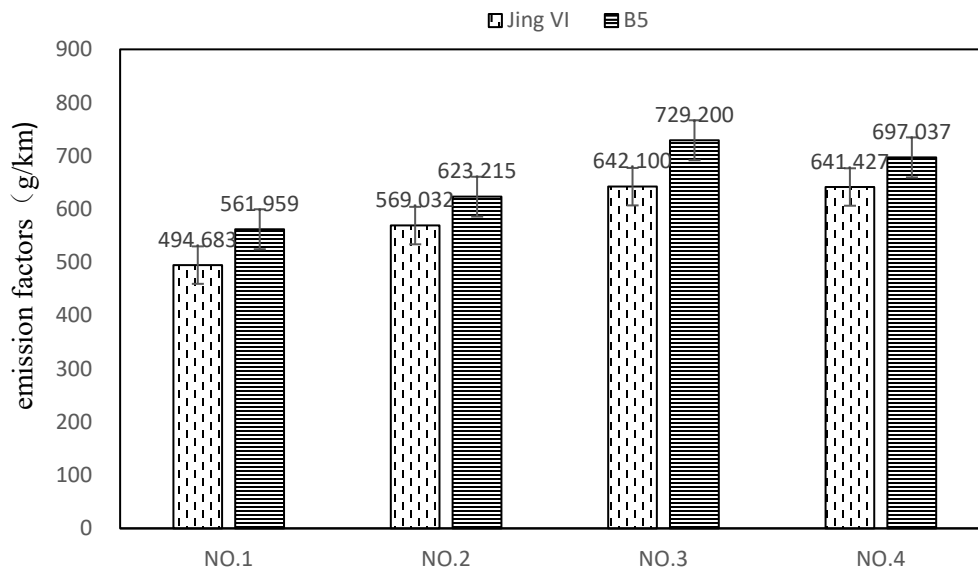


Figure.9 The overall CO₂ emission factor of different fuels used in different vehicles

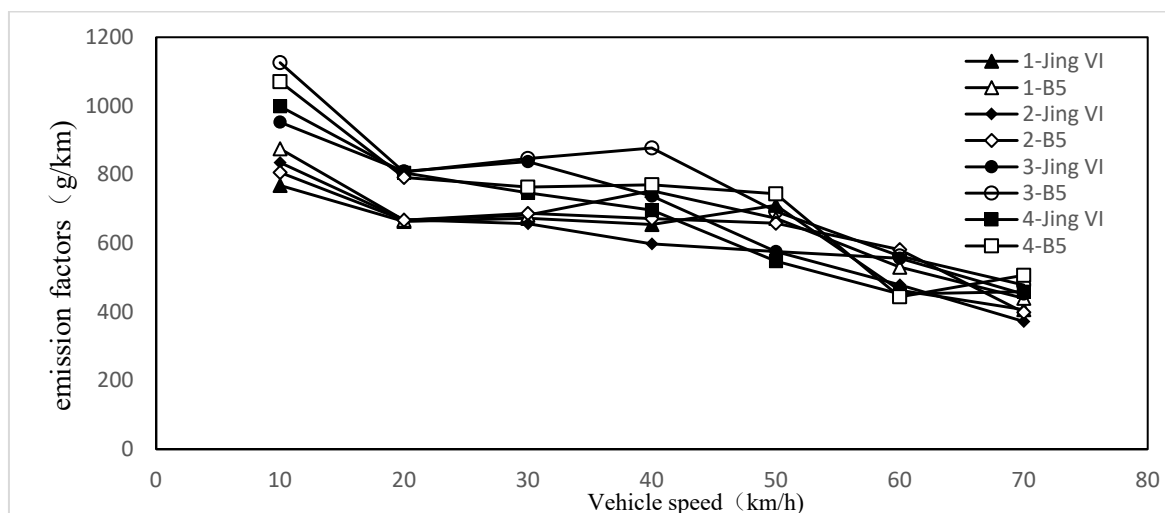


Figure.10 The relationship between CO₂ emission factors of different vehicles and vehicle speed

As is shown in Fig.9 and Fig.10, for both integrating conditions and speed-dependent conditions, the four buses using B5 biodiesel are all high in CO₂ emission factors compared with those using Beijing VI diesel, respectively by 13.6%, 9.5%, 13.6% and 8.7%, and averagely by 11.3%.

3.3.2 Fuel Consumption

To appropriately evaluate the fuel economy, the fuel consumption per 100km is calculated using the parameters in Table 2 such as the density, etc. The calculation equation is Formula (2), and the results are shown in Fig. 11.

$$Q = \frac{0.1155}{\rho} [(0.866*HC) + (0.429*CO) + (0.273*CO_2)] \tag{2}$$

Where Q-Fuel consumption

HC- measured THC emissions (g/km)

CO- measured CO emissions (g/km)

CO₂- measured CO₂ emissions (g/km)

ρ - Fuel density (g/cm³)

The difference of the two kinds of fuel is in fuel density. As the emission factors of CO and HC are small, their difference is ignorable during the calculation.

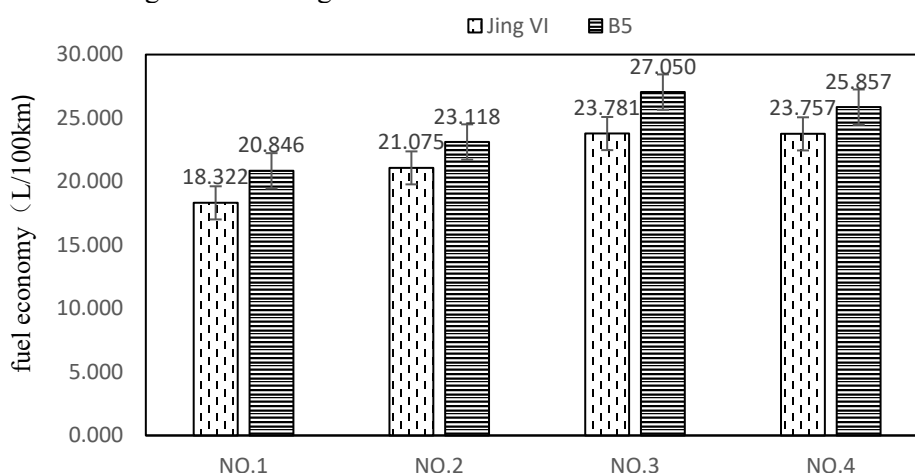


Figure.11 Economic comparison between two fuels

As is shown in Fig.9 and Fig.11, compared with the difference of the two kinds of fuel in CO₂

emission factors, the difference in fuel consumption is smaller. The four buses using B5 biodiesel are all high in fuel consumption compared with those using Beijing VI diesel, respectively by 13.8%, 9.69%, 13.7% and 8.84%, and averagely by 11.51%. This is because the density and the heat value of the biodiesel are smaller than that of diesel. Therefore, to generate the same amount heat, more biodiesel is needed. In general, the Beijing VI diesel is efficient in fuel economy than B5 biodiesel, but due to the impact of not considering cetane number and fuel heat value during the conversion, and the regenerable characteristic of biodiesel, the CO₂ produced is in regenerable cycle, and can be extinguished in biology cycle. Therefore, the carbon balance method can not fully evaluate the fuel economy and can only illustrate its outline. It is also not sure if 5% is the best portion. In future research, how the percentage of biodiesel impacts the fuel economy can be further studied.

4. Conclusion

- 1) For specific emissions, the B5 biodiesel decreases CO by 33.1%, increases NO_x by 15.6% and decreases PN by 13.1% compared with Beijing VI diesel;
- 2) For emission factors, the B5 biodiesel decreases CO by 29.5%, increases NO_x by 12.7% and decreases PN by 9.1% compared with Beijing VI diesel;
- 3) For fuel economy, the four vehicles using biodiesel increases the fuel consumption per 100km by 11.51% compared with Beijing VI diesel. Although the difference is great, considering the impact of physical and chemical parameters such as heat value and it is still necessary to further study to determine the best ratio.

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