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Study on Emission Characteristics of Heavy Duty Diesel Vehicle in Plateau Environment

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Abstract: *In order to understand the emission characteristics of National VI heavy-duty diesel vehicles on long slopes under full load in plateau environment, an N3 heavy-duty diesel vehicle was tested on actual road emissions to study the instantaneous emissions of pollutants from heavy-duty diesel vehicles on long uphill and downhill slopes and compare their emission factors. The results show that the engine exhaust temperature decreases with the decrease of altitude. When heavy diesel vehicles are going uphill, with the increase of road slope, NOx emissions show a downward trend and PN emissions show an upward trend. However, when heavy diesel vehicles go downhill, with the decrease of road slope, NOx emissions show an increasing trend and PN emissions show a decreasing trend. When heavy diesel vehicles go uphill, the pollutant emission is worse than that when they go downhill.*

Keywords: *Plateau, Changpo Road, Actual Road Emissions, the Full Load, Heavy Duty Diesel Vehicle*

1. Introduction

The annual report of China Mobile Environmental Management 2021 shows that the emissions of nitrogen oxides (NOx) and particulate matter (PM) from diesel vehicles exceed 80% and 90% of the total vehicle emissions respectively [1]. China's plateau area covers a vast territory. The area with an altitude of more than 1000 m accounts for 58%, and the area with an altitude of more than 2000 m accounts for 33% [2-3]. The low atmospheric pressure, low oxygen content and high altitude fluctuation in plateau area worsen the combustion in the cylinder of diesel engine and seriously affect the emission performance of diesel vehicles [4]. Therefore, studying the emission characteristics of heavy diesel vehicles on long slopes in plateau areas is of practical significance for improving and protecting the plateau ecological environment and monitoring the emissions of heavy diesel vehicles in plateau areas.

The altitude and road slope will seriously affect the actual road emissions of motor vehicles [5-7]. Chen Jianjie et al. studied the NOx emission characteristics of diesel vehicles at different altitudes. The results showed that with the increase of altitude, NOx emissions increased first and then decreased. Guo Xiaonian [8] and Xu Xiaoliu [9] respectively studied the emission characteristics of light gasoline vehicles and diesel vehicles at high altitude. Zhang Yun [10] studied the impact of road slope on the actual driving emissions of light gasoline vehicles. The results show that when the vehicle is going uphill, the emission factors of carbon monoxide (CO) and particle number (PN) are twice as large as when it is going downhill. Xu Bang [11] and others studied the impact of road slope on the emissions of light vehicles and heavy vehicles. The results showed that the NOx emissions of the two models showed an upward trend with the increase of road slope in the range of - 5%~5%. Kim et al. [6] studied the particulate emission characteristics of light diesel vehicles and found that PM and PN concentrations increased with the increase of road slope. To sum up, scholars at home and abroad pay more attention to the emissions of light gasoline vehicles and diesel vehicles at different altitudes and different road gradients. However, there is less research on the emission characteristics of heavy diesel vehicles on long slope roads in plateau environments.

In this study, an N3 national VI heavy diesel vehicle was tested for actual road emissions under full load, and the actual road emission characteristics of the vehicle during long uphill and downhill were analyzed to compare the pollutant emission factors of heavy diesel vehicles during uphill and downhill.

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2. Materials and methods

2.1. Test vehicle

The test vehicle is a national VI b heavy-duty diesel vehicle, with a displacement of 6.7 L and a rated power of 191 kW. It adopts the aftertreatment technology of diesel oxidation catalyst (DOC)+diesel particulate filter (DPF)+selective catalytic reduction (SCR)+ammonia slip catalyst (ASC). See Table 1 for the main technical parameters of the test vehicle.

Table 1: Main Technical Parameters of Test Vehicle

Vehicle type	N3
Emission standard	National VI b
Post processing technology	DOC+DPF+SCR+ASC
Air intake mode	Supercharged intercooling
Output volume/L	6.7
Rated power/kW	191
Rated torque/N·m	1 000
Curb weight/kg	9 100
Maximum total mass/kg	24 500

2.2. Test equipment

The test equipment adopts AVL M.O.V.E is+portable emission measurement system (PEMS), which mainly includes gas module, particle module, exhaust flowmeter, weather station and global positioning system (GPS). The non dispersive infrared (NDIR) method is used to measure the concentration of CO and carbon dioxide (CO2), the non dispersive ultraviolet (NDUV) method is used to measure the concentration of NO and NO2, and the diffusion charge principle is used to measure the concentration of PN. See Table 2 for the main technical parameters of the test equipment. To ensure the reliability of test data, PEMS equipment shall be checked for leakage, zeroed and calibrated before the formal test, and drift check shall be conducted after the test.

Table 2: Main Technical Parameters of Test Equipment

Structural unit	AVL M.O.V.E is+
Gas module	CO: 0~5%;CO_2: 0~20%;NO: 0~5 000 ppm;NO_2: 0~2 500 ppm
Exhaust flow meter	Flow: 2 138 kg/h(4 inch); Temperature:-5~700 ℃
Particulate module	Range: 0~2×10^7 #/cm3; Measuring principle: diffusion charging principle
Weather station	Environmental pressure:0.5~1.5 bar;Ambient temperature:-40~80 ℃;Ambient humidity:0~100%rel.H.
GPS	Speed, altitude, longitude and latitude

2.3. Test conditions

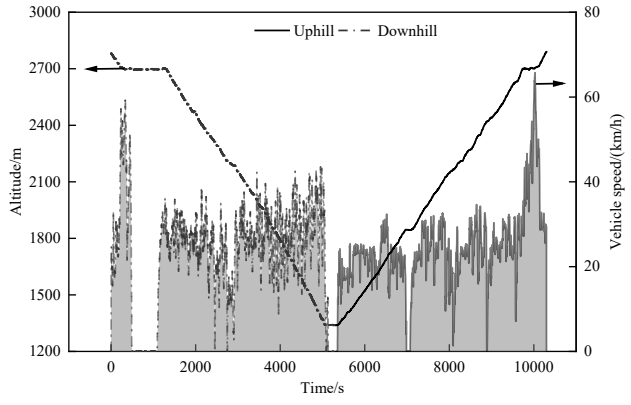

Figure 1: Test Route and Altitude of Heavy Diesel Vehicle on Long Slope Road

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In this study, the round-trip test of the National VI heavy diesel vehicle under 100% load was carried out on the road section from Lijiang City to Jinanqiao, Yunnan Province. The test route is 34 km long, with the highest and lowest elevations of 2787 m and 1331 m respectively. The actual test route and altitude are shown in Figure 1. It can be seen from the figure that there is no significant difference in the speed of the test vehicle when going uphill and downhill, and the average speed is 24.6 km/h and 23.2 km/h.

3. Results and discussion

3.1. Instantaneous emission characteristics of heavy-duty diesel vehicles

See Figure 2 for the exhaust temperature of heavy-duty diesel vehicle when it is fully loaded on long uphill and downhill. When a heavy diesel vehicle is going downhill, the engine exhaust temperature gradually decreases from 350 ℃ to about 125 ℃ with the decrease of altitude, while when it is going uphill, the exhaust temperature rapidly rises from 125 ℃ to more than 280 ℃.

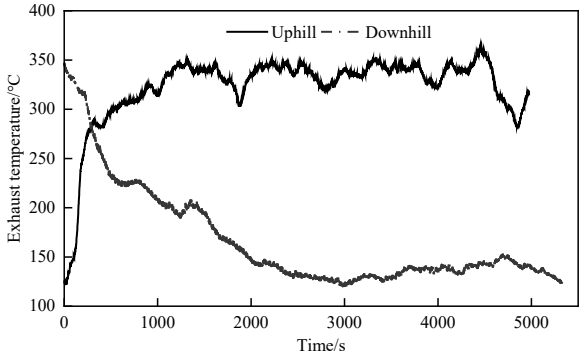

Figure 2: Exhaust Temperature of Heavy duty Diesel Vehicle on Long Uphill and Downhill

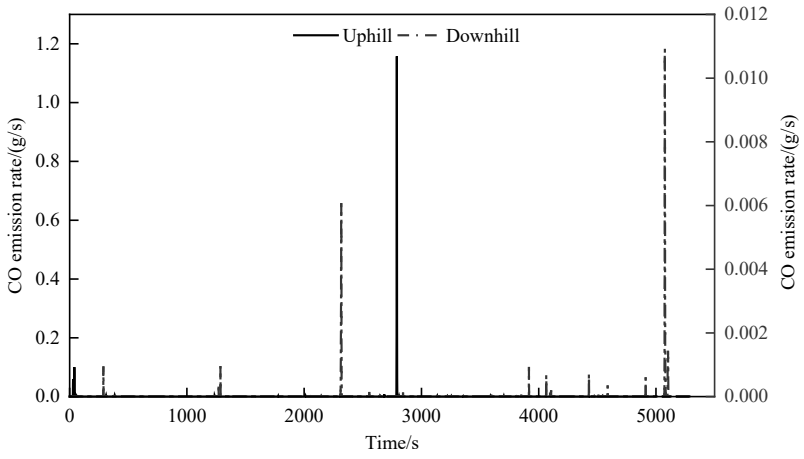

Figure 3: CO Instantaneous Emission Characteristics of Heavy Vehicles on Long Uphill and Downhill

The instantaneous pollutant emission characteristics of heavy diesel vehicles on long uphill and downhill under full load are shown in Figure 3-5. It can be seen from the figure that the CO, NOx and PN emissions of heavy diesel vehicles are higher when they go uphill than when they go downhill. This is due to the increase of road slope and engine load to overcome resistance when heavy-duty diesel vehicles are going uphill. The combustion of the mixture is too rich and worsens, resulting in increased pollutant emissions. For CO, the emissions are low when the vehicle is going uphill and downhill. When a heavy diesel vehicle is going uphill, NOx emissions are mainly concentrated at the beginning of the uphill phase. At this time, the exhaust temperature is low (see Figure 2), and the SCR system does not work. As the vehicle continues to climb the slope, the exhaust temperature gradually increases, and the SCR system starts to work. SCR system will reduce NOx to N2 and H2O, resulting in reduction of NOx emission. In addition, when the vehicle accelerates uphill, the air fuel ratio decreases, resulting in a rapid increase of NO [12]. When the vehicle is going downhill, NOx emissions will increase as the exhaust temperature decreases. For PN, when the vehicle is going uphill, the emission is low in the first 2000

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seconds, and then increases. This is because when the vehicle climbs, it needs more power, and the combustion is not sufficient, resulting in an increase in PN emissions. In addition, with the increase of altitude, the oxygen content in the atmosphere decreases, reducing the excess air coefficient, thus increasing PN emissions. When the vehicle goes downhill, the PN high emission area appears in the first 500 seconds.

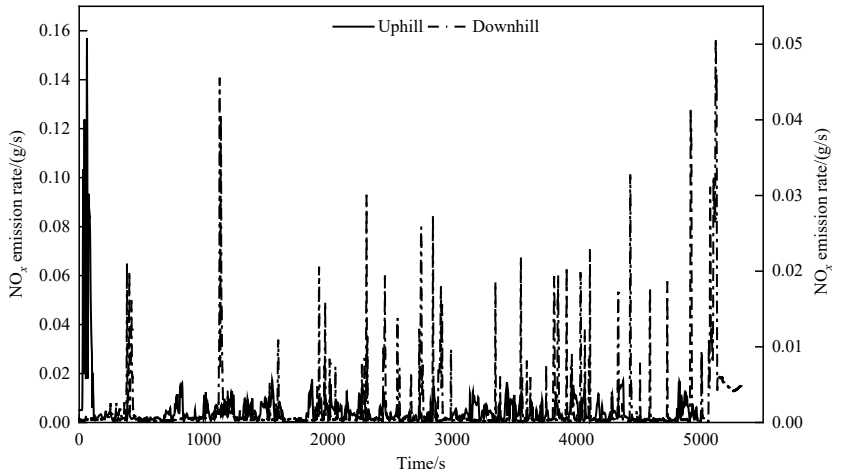

Figure 4: NOx Instantaneous Emission Characteristics of Heavy Vehicles on Long Uphill and Downhill

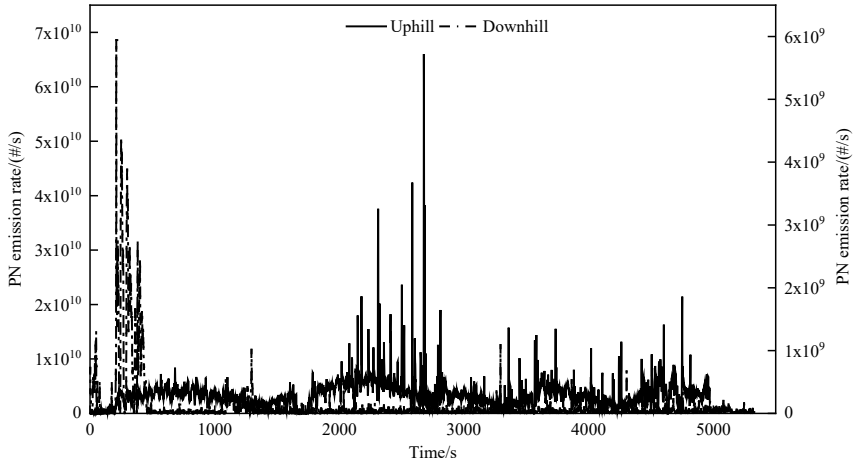

Figure 5: PN Instantaneous Emission Characteristics of Heavy Vehicles on Long Uphill and Downhill

3.2. Heavy duty diesel vehicle pollutant emission factors

Table 3 shows the pollutant emission factors of heavy diesel vehicles when going uphill and downhill. It can be seen from the table that the mileage based emission factors of CO, NOx and PN of heavy-duty diesel vehicles are 39.0, 2.3 and 31.0 times higher when they are going uphill than when they are going downhill, respectively. This shows that when the vehicle is going uphill, the engine load increases and the mixture is uneven, leading to increased pollutant emissions. For heavy diesel vehicles, when going uphill, the specific emissions of CO and PN are higher than those of going downhill, however, the specific emissions of NOx are lower than those of going downhill. This is because when the vehicle is going downhill, the required power is small, resulting in a reduction in overall emissions.

Table 3: Pollutant Emission Factors of Heavy Vehicles When Going Uphill and Downhill

Different calculation methods	CO		NO_x		PN	
	uphill slope	downhill slope	uphill slope	downhill slope	uphill slope	downhill slope
Mileage based emission factor/(g/km) or (#/km)	0.117	0.003	0.679	0.292	5.106×10^{11}	1.648×10^{10}
Specific emission/(g/kW·h)or (#/kW·h)	0.032	0.016	0.187	1.882	1.405×10^{11}	1.062×10^{11}

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4. Conclusion

1) When heavy diesel vehicles are going uphill, with the increase of altitude, NOx emissions show a downward trend and PN emissions show an upward trend. However, when heavy diesel vehicles go downhill, with the decrease of road slope, NOx emissions show an increasing trend and PN emissions show a decreasing trend.

2) When a heavy diesel vehicle goes uphill, the mileage based emission factors of CO, NOx and PN are 39.0, 2.3 and 31.0 times higher than those when it goes downhill. The specific emissions of CO and PN are higher than those in the downhill phase, however, the specific emissions of NOx are lower than those in the downhill phase.

3) The road slope and altitude have a great impact on the pollutant emissions of heavy-duty diesel vehicles, especially in plateau areas.

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