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不同排放标准公交车燃用生物柴油颗粒物排放特性

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摘要: 基于重型底盘测功机, 对比研究了满足国Ⅲ、国Ⅳ、国Ⅴ排放标准的柴油公交车分别燃用生物柴油与柴油混合燃料B0/B5/B10在中国典型城市公交车循环下的颗粒物排放特性。结果表明燃用B0/B5/B10时, 国Ⅴ车相对国Ⅲ车总颗粒数量和质量排放分别降低约68.1%、56.2%、57.5%和52.7%、64.8%、88.5%, 相对国Ⅳ车, 总颗粒质量排放分别降低了约43.0%、47.3%和42.1%, 但数量排放分别上升了约4.0%、7.6%和14.7%。国Ⅲ车核态颗粒排放主要来自高速行驶工况, 而国Ⅳ、国Ⅴ车主要来自中低速行驶工况; 国Ⅲ、国Ⅳ、国Ⅴ车聚集态颗粒排放主要都来自中低速行驶工况。其中在车速较低时, 国Ⅴ、国Ⅳ车相对国Ⅲ车核态颗粒数量和质量排放明显降低, 聚积态颗粒也有降低, 但国Ⅴ车相对国Ⅳ车改善不明显, 核态颗粒数量和质量排放反而增加, 且随着生物柴油掺混比例的上升, 增幅越明显。在高速时, 国Ⅲ车核态颗粒数量和质量排放急剧增加, 国Ⅴ、国Ⅳ车略有增加, 且国Ⅳ车聚集态颗粒数量和质量排放明显大于国Ⅴ车和国Ⅲ车。燃用生物柴油掺混比例较大的B10时, 国Ⅲ车较大粒径颗粒排放急剧恶化, 聚集态颗粒数量和质量排放大幅增加, 不适合推广应用较大生物柴油掺混比燃油。

关键词: 柴油公交车; 生物柴油; 颗粒排放; 排放标准; 中国典型城市公交循环

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Emission Characteristics of Particulate Matter from Diesel Buses Meeting Different China Emission Standards Fueled with Biodiesel

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Abstract: Based on heavy chassis dynamometer, an experimental study was conducted in diesel buses compliant with China Ⅲ, Ⅳ, V emissions standards respectively, fueled with three different blends of petroleum diesel/biodiesel (0%, 5% and 10%, V/V biodiesel blends), which investigated the characteristics of particulate matter (PM) emission under CCBC driving cycle. Results of study showed that the total PM number and mass emission from China V bus respectively decreased by 68.1%, 56.2%, 57.5% and 52.7%, 64.8%, 88.5% compared to China Ⅲ bus. When compared to China Ⅳ bus, the PM mass emission decreased by 43.0%, 47.3% and 42.1%, while the number increased by 4.0%, 7.6% and 14.7%. The nucleation mode PM emission of China Ⅲ bus was mainly from high-speed driving condition, while China Ⅳ and V buses were from middle-low speed. The accumulation mode PM emissions of China Ⅲ, Ⅳ and V buses were all mainly from middle-low speed driving conditions. In relatively lower speed conditions, compared to China Ⅲ bus, the nucleation mode PM emissions of China Ⅳ and V buses obviously decreased, so was accumulation mode PM. Compared to China Ⅳ bus, emission of China V bus did not improve obviously and the nucleation mode PM emission even increased. In high-speed driving condition, the nucleation mode PM emission from China Ⅲ bus increased dramatically, while those from China V and Ⅳ buses slightly increased. Meanwhile, the accumulation PM number and mass emission of China Ⅳ bus was obviously higher than those of China V and Ⅲ buses. When fueled with B10, the relatively bigger sizes PM emission of China Ⅲ bus deteriorated rapidly, indicating that China Ⅲ bus was not suitable for fuel with high blending ratio of biodiesel.

Key words: diesel bus; biodiesel; particulate emission; emission standard; China city bus driving cycle (CCBC)

我国自2016年4月1日起开始分区域实施机动车国Ⅴ排放标准, 满足国Ⅴ排放标准的柴油公交车开始得到推广使用, 但其主要运营在北京、上海和深圳等东部大城市, 大量中西部二三线城市仍然以国Ⅳ、国Ⅲ排放标准柴油公交车为主。柴油公交车作为城市主要的公共交通工具, 在提供便利的同时产生大量污染物排放, 尤其是颗粒物排放, 研究表明它可以通过呼吸直达并沉淀在肺部, 对人体健康产生巨大危害^[1~4]。柴油机排气颗粒按尺寸分布可分为聚集态颗粒和核态颗粒: 聚集态颗粒(30 nm <

粒径 < 1 000 nm) 粒径较大, 主要成分为聚集形态的碳烟(soot)及其吸附物质; 核态颗粒(5 nm < 粒径 < 30 nm) 粒径较小, 主要与可溶有机组分SOF和硫酸盐等有关^[5~7]。

生物柴油是可再生的油脂资源(如动植物油脂、

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微生物油脂以及餐饮废油等)经过酯化或酯交换工艺制得的主要成分为长链脂肪酸甲酯的液体燃料,具有润滑性好、含氧量高、十六烷值高等优点^[8~10],是一种理想的柴油替代燃料.低掺混比的生物柴油与柴油混合燃料可在柴油机上直接使用,无需调整和改动发动机,且发动机性能基本保持不变^[11~17].

底盘测功机测试方法相对发动机台架测试,将道路的实际运行条件及重型车属性充分考虑在内,具有良好的模拟一致性及准确性,成为国外学者研究重型车排放和油耗性能的重要手段.Na等^[18]利用底盘测功机,研究了在城市驾驶循环(urban dynamometer driving schedule, UDDS)及加州重型卡车驾驶循环(California heavy heavy-duty Truck driving schedule, HHDDT)巡航部分下燃用生物柴油和再生柴油对重型柴油卡车常规污染物和温室气体排放的影响.Sandhu等^[19]在底盘测功机上研究了在用重型垃圾卡车在纽约垃圾卡车循环(New York

garbage truck cycle, NYGT)下的动力性、油耗及排放特性.李腾腾等^[20]在重型底盘测功机上,对比分析了混合动力公交车在不同测试循环下的排放特性.但已有的研究^[18~23]基本都是基于同一排放标准的柴油机,而有关燃用生物柴油的不同排放标准柴油公交车的相关研究相对较少.

因此,本文借助重型底盘测功机,对比研究了满足国Ⅲ、国Ⅳ、国Ⅴ排放标准的柴油公交车燃用低掺混比生物柴油与柴油混合燃料在中国典型城市公交车循环下的颗粒物排放特性.

1 材料与方法

1.1 试验样车及燃料

试验样车为分别满足国Ⅲ、国Ⅳ、国Ⅴ排放标准的3辆上海市日常运营的柴油公交车,简称国Ⅲ车、国Ⅳ车和国Ⅴ车,记为G3、G4和G5,都匹配有六缸增压中冷柴油机,基本参数如表1.

表1 试验样车的基本参数

Table 1 Specifications of test buses

项目	排放标准		
	国Ⅲ	国Ⅳ	国Ⅴ
长/宽/高/mm	10 499 × 2 500 × 3 150	11 880 × 2 500 × 3 150	11 995 × 2 530 × 3 150
整备质量/满载质量/kg	10 100/16 000	11 000/17 500	11 900/18 000
发动机额定功率/kW	177	213	199
发动机最大扭矩/N·m	920	1 200	1 000
发动机排量/L	7.146	7.146	7.140
柴油机燃油系统	电控单体泵	电控单体泵	电控高压共轨

试验燃料为市售国Ⅴ0号纯柴油和废弃油脂制生物柴油按一定体积分数(0%、5%、10%)掺混得到的燃料,简称B0、B5、B10,主要理化指标如表2所示.

表2 试验燃料的主要理化特性

Table 2 Basic physical and chemical properties of test fuels

项目	B0	B5	B10
十六烷值	50.8	54.2	53.5
20℃密度/kg·m ⁻³	813.6	821.9	823.5
20℃运动黏度/mm ² ·s ⁻¹	3.59	4.39	5.24
S含量/mg·kg ⁻¹	1.4	4.8	3.9
O含量/%	—	2.42	4.1
氧化安定性/mg·(100 mL) ⁻¹	0.2	0.4	0.5
10%蒸余物残炭/%	0.01	0.01	0.01
脂肪酸甲酯/%	<0.1	4.7	8.8

1.2 试验装置及循环

试验在MAHA-AIP重型底盘测功机上开展,采用美国TSI公司的379020型旋转盘稀释器和EEPS-3090发动机排气颗粒数量及粒径分析仪组成的系

统快速测取颗粒物数量和粒径分布,测量粒径范围为5.6~560 nm,包含粒径在30 nm以下的核态颗粒区域和粒径30 nm以上的聚集态颗粒,在0.1 s内可测取一个完整的颗粒粒径分布图谱,并同步输出32个粒径通道的颗粒数量和粒径分布数据.试验装置如图1所示.

试验循环采用GB/T 19754-2005推荐的中国典型城市公交车循环(CCBC).循环运行时间为1 314 s,平均车速为16.16 km·h⁻¹,行驶里程5.89 km.试验时将试验车辆固定在重型底盘测功机上,按车辆装载质量的65%进行加载.为消除驾驶员操作随机性因素,每辆车循环重复进行3次,试验结果取循环平均值.

2 结果与讨论

2.1 循环总颗粒数量和质量排放

图2所示为不同排放标准公交车燃用不同燃料时瞬时总颗粒数量排放速率,图3所示为试验公交

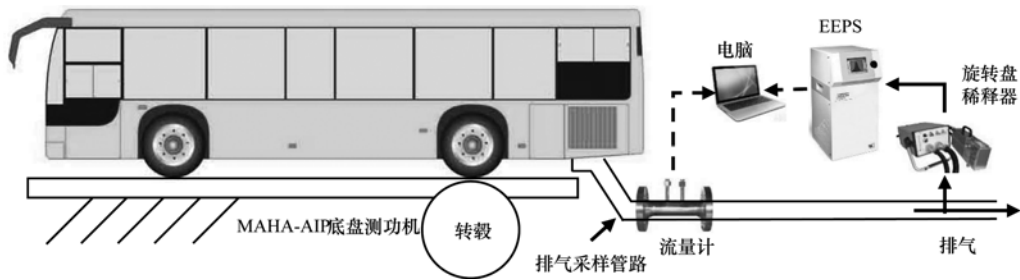


图1 试验装置示意

Fig. 1 Schematic diagram of PEMS

车在CCBC下的循环总颗粒数量和质量排放因子,其中均标明最大的标准误差线.从中可以看出,国Ⅴ、国Ⅳ车相对国Ⅲ车,总颗粒数量和质量排放均大幅下降,燃用B0/B5/B10时,国Ⅴ车总颗粒数量和质量排放因子分别为 3.30×10^{13} 、 3.28×10^{13} 、 3.39×10^{13} 个 $\cdot\text{km}^{-1}$ 和 9.39×10^{-3} 、 8.34×10^{-3} 、 8.28×10^{-3} g $\cdot\text{km}^{-1}$,相对国Ⅲ车分别降低约68.1%、56.2%、57.5%和52.7%、64.8%、88.5%;国Ⅳ车总颗粒数量和质量排放因子分别 3.18×10^{13} 、 3.04×10^{13} 、 2.95×10^{13} 个 $\cdot\text{km}^{-1}$ 和 1.65×10^{-2} 、 1.58×10^{-2} 、 1.43×10^{-2} g $\cdot\text{km}^{-1}$,相对

国Ⅲ车分别降低约69.4%、59.3%、62.9%和17.0%、33.3%、80.1%.而国Ⅴ车相对国Ⅳ车总颗粒质量排放明显下降但数量排放略有上升,燃用B0/B5/B10时,国Ⅴ车相对国Ⅳ车质量排放分别降低约43.0%、47.3%和42.1%;数量排放则分别上升约4.0%、7.6%和14.7%.

随着生物柴油掺混比例的增加,国Ⅲ车质量排放增加,而国Ⅳ、国Ⅴ车质量排放则减少,燃用B5/B10时,国Ⅲ车质量排放相对燃用B0分别增加约19.4%和262.7%;而国Ⅳ、国Ⅴ车则分别减少约4.0%、13.2%和11.2%、11.8%.

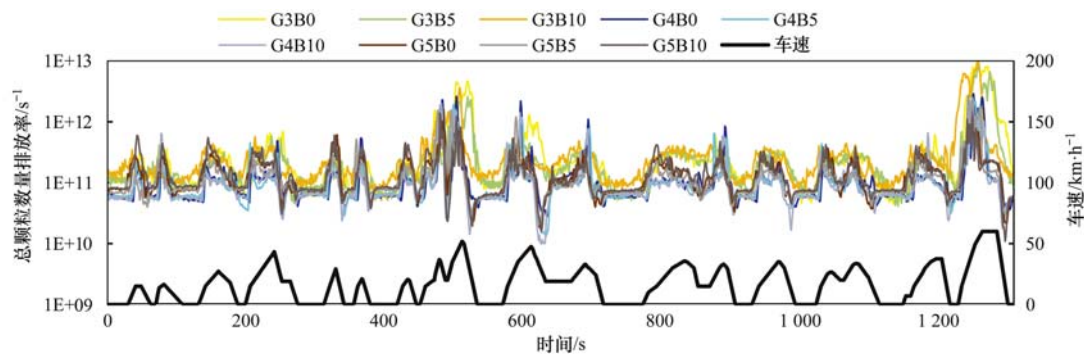


图2 试验公交车CCBC循环的总颗粒排放速率

Fig. 2 Total particulate number emission rate of buses under CCBC cycle

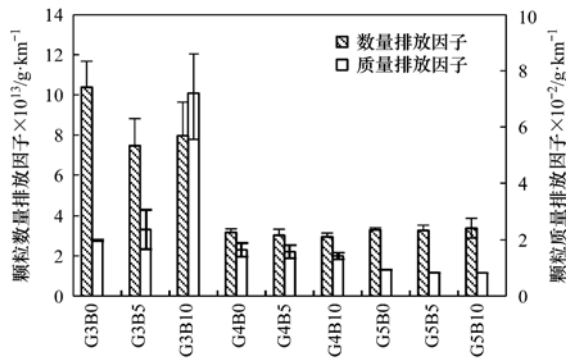


图3 试验公交车CCBC循环总颗粒数量和质量排放因子

Fig. 3 Total particulate number and mass emission factors of buses under CCBC cycle

从图2中还可以看出,瞬时总颗粒数量排放与车速跟随性较好,为了对循环中公交车的行驶工况进行分析,将CCBC循环划分为怠速工况 $[0, 0.5]$ km $\cdot\text{h}^{-1}$ 、低速工况 $(0.5, 20]$ km $\cdot\text{h}^{-1}$ 、中速工况 $(20, 40]$ km $\cdot\text{h}^{-1}$ 和高速工况 $(40, 60]$ km $\cdot\text{h}^{-1}$ 四类行驶工况,所占比例分别为29.0%、34.1%、30.7%、6.2%.

2.2 不同行驶工况下的颗粒物数量排放特性

图4和图5分别为不同排放标准公交车在不同行驶工况下的核态颗粒和聚集态颗粒数量排放,并各自标注不同行驶工况产生的排放对其CCBC循环整体排放的贡献率.

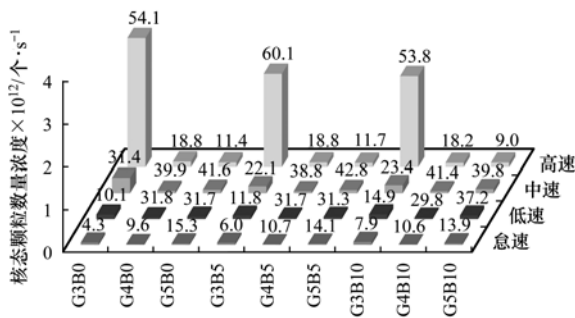


图4 不同排放标准公交车不同行驶工况下核态颗粒数量排放

Fig. 4 Nucleation mode particulate number emission of buses with different emission standards under different driving conditions

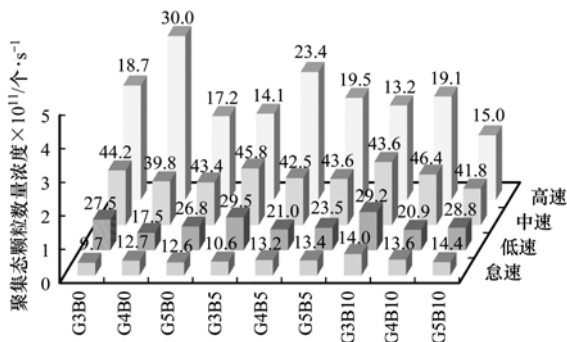


图5 不同排放标准公交车不同行驶工况下聚集态颗粒数量排放

Fig. 5 Accumulation mode particulate number emission of buses with different emission standards under different driving conditions

由图4可见,国V、国IV车相对国III车,核态颗粒数量排放大幅下降,且高速时更加明显,燃用B0/B5/B10,国V、国IV车高速时核态颗粒数量分别为 1.09×10^{11} 、 9.93×10^{10} 、 1.06×10^{11} 个·s⁻¹和 1.28×10^{11} 、 1.09×10^{11} 、 1.00×10^{11} 个·s⁻¹,相对国III车分别减少约96.4%、95.5%、95.0%和95.8%、95.0%、95.3%。而国V与国IV车相比,其核态颗粒数量排放变化不大,在怠速及中低速工况,国V车核态颗粒数量排放甚至大于国IV车,且基本随着生物柴油掺混比例的增加,增幅更加明显,在怠速/低速/中速工况下国V车核态颗粒数量相对国IV车分别增加约123.9%(B0)、94.5%(B5)、179.2%(B10),40.0%(B0)、45.1%(B5)、164.6%(B10)和46.4%(B0)、61.9%(B5)、103.9%(B10),这可能是因为,国V车的发动机相对国IV车,在标定时为了达到排放标准会牺牲部分动力性,如表1所示,导致在相同车速下的相同驱动功率需求时,其转速相对国IV车有变高的趋势,因此发动机循环燃烧时间变短,燃烧恶化,未燃碳氢增加,以可溶有机组分SOF为主要成分的核态颗粒数量增加。而生物柴油挥发性低、黏度高,使燃油雾化变差,燃烧恶化,也会导致缸内未燃或者未完全燃烧的燃油即未燃碳氢增

加,核态颗粒数量上升,所以随着生物柴油掺混比例的增加,核态颗粒数量会显著增加^[24]。此外,由图4可见,国V、国IV车核态颗粒数量排放主要来自约占CCBC循环核态颗粒数量总排放70%的中低速行驶工况,而国III车核态颗粒数量排放主要来自于高速行驶工况,其约占循环总排放多达50%~60%。

由图5可见,在中低速工况下,国V、国IV车相对国III车,聚集态颗粒数量排放下降,燃用B0/B5/B10时,国V、国IV车低速时聚集态颗粒数量分别为 7.08×10^{10} 、 6.69×10^{10} 、 6.74×10^{10} 个·s⁻¹和 5.17×10^{10} 、 6.23×10^{10} 、 6.11×10^{10} 个·s⁻¹,相对国III车分别减少约22.5%、31.7%、40.8%和43.4%、36.5%、46.3%。在高速工况,国IV车聚集态颗粒数量排放明显大于国V、国III车,燃用B0/B5/B10时,国IV车聚集态颗粒数量相对国V、国III车分别增加约95.6%、25.4%、60.1%和43.2%、48.2%和9.4%,这是因为试验所用国III、国IV车柴油机的喷油系统采用的是电控单体泵,单体泵喷油量一致性在高转速时较差,而中等转速较好^[25],随着排放标准的提高,发动机喷油压力增大,喷油一致性在高速下更是难以保证,导致油气混合均匀性变差,局部缺氧现象严重,碳烟大量生成,进而导致聚集态颗粒大量产生。而试验所用国V车柴油机的喷油系统采用的是高压共轨,喷油压力与转速无关,从而可以避免这种情况的发生。此外,由图5可见国III、国IV、国V车聚集态颗粒数量排放主要都来自中低速行驶工况,占CCBC循环总排放约65%。

2.3 不同行驶工况下的颗粒物质量排放特性

图6和图7为不同排放标准公交车在不同行驶工况下的核态颗粒和聚集态颗粒质量排放。

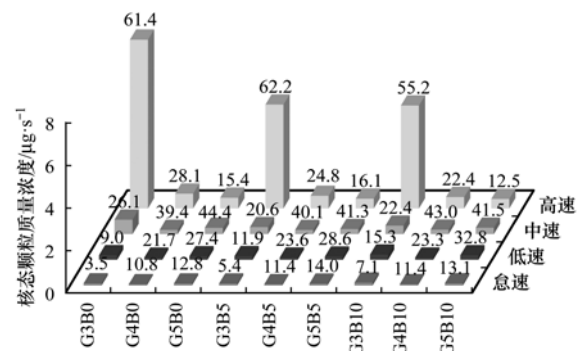


图6 不同排放标准公交车不同行驶工况下核态颗粒质量排放

Fig. 6 Nucleation mode particulate mass emission of buses with different emission standards under different driving conditions

由图6可见,国V、国IV车相对国III车,核态颗

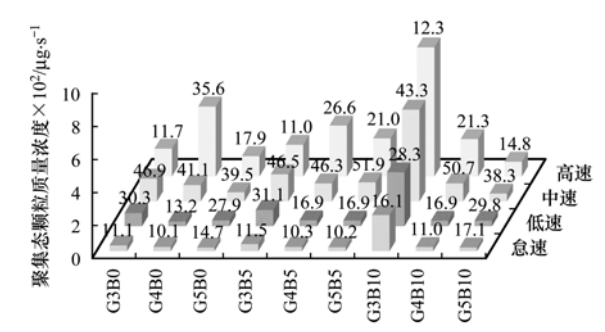


图7 不同排放标准公交车不同行驶工况下聚集态颗粒质量排放
Fig. 7 Accumulation mode particulate mass emission of buses with different emission standards under different driving conditions

粒质量排放大幅下降,且高速时更加明显,燃用 B0/B5/B10 时,国 V、国 IV 车高速时核态颗粒质量分别为 5.01×10^{-1} 、 4.57×10^{-1} 、 $4.44 \times 10^{-1} \mu\text{g}\cdot\text{s}^{-1}$ 和 6.92×10^{-1} 、 5.90×10^{-1} 、 $5.34 \times 10^{-1} \mu\text{g}\cdot\text{s}^{-1}$,相对国 III 车分别减少约 93.7%、90.6%、90.8% 和 91.3%、87.9%、89.0%。此外,由图 6 可见,国 III 车高速时排放的核态颗粒质量较多,占 CCBC 循环核态颗粒质量总排放约 55%~60%,而国 IV、国 V 车核态颗粒质量排放主要来自中低速行驶工况,占循环总排放约 60%~70%。

由图 7 可见,在怠速和中低速工况下,国 V、国 IV 车相对国 III 车,聚集态颗粒质量排放大幅下降,且

基本随着生物柴油掺混比例的增加,降幅增大,燃用 B0/B5/B10 时,国 V、国 IV 车怠速时的聚集态颗粒质量浓度分别为 2.16×10^1 、 2.39×10^1 、 $2.22 \times 10^1 \mu\text{g}\cdot\text{s}^{-1}$ 和 2.57×10^1 、 2.55×10^1 、 $2.51 \times 10^1 \mu\text{g}\cdot\text{s}^{-1}$,相对国 III 车分别减少约 37.2%、44.1%、89.9% 和 25.3%、40.4%、88.5%。国 III 车燃用 B5 时,怠速/低速/中速/高速工况下聚集态颗粒质量分别为 4.27×10^1 、 9.86×10^1 、 1.64×10^2 和 $1.92 \times 10^2 \mu\text{g}\cdot\text{s}^{-1}$,而燃用 B10 时急剧增加到 2.19×10^2 、 3.27×10^2 、 5.56×10^2 和 $7.83 \times 10^2 \mu\text{g}\cdot\text{s}^{-1}$,大幅增加约 412.9%、232.0%、239.5% 和 307.6%。这表明国 III 排放水平的公交车对生物柴油添加比例的适应性差,生物柴油添加比例的增加会急剧恶化其较大粒径颗粒排放,因而不适合推广应用较大生物柴油掺混比燃油。此外,由图 7 可见,国 III、国 IV、国 V 车聚集态颗粒质量排放主要都来自中低速工况,占循环总排放约 55%~77%;而在高速工况下,国 IV 车聚集态颗粒质量排放占循环总排放比例相对国 III、国 V 车较高。

2.4 不同行驶工况下的颗粒物粒径分布特性

图 8~10 为燃用 B0/B5/B10 时,不同排放标准公交车在不同行驶工况下的的颗粒物数量排放粒径分布特性。

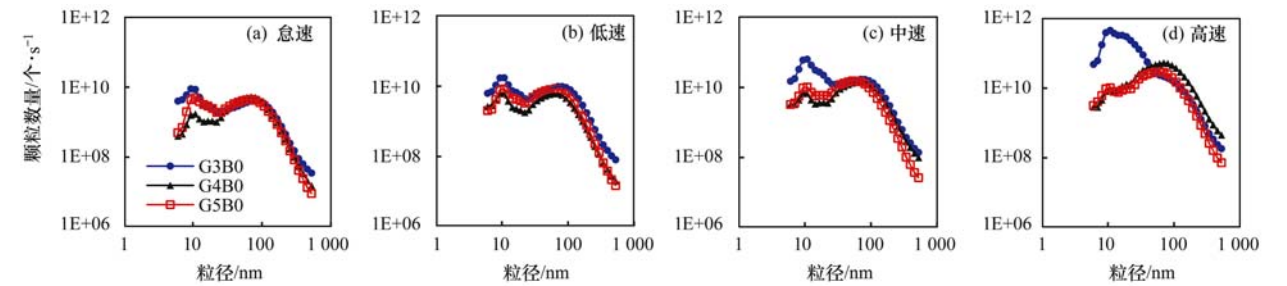


图8 燃用 B0 时不同排放标准公交车不同行驶工况下颗粒物数量排放粒径分布特性
Fig. 8 Particulate distribution characteristics of buses with different emission standards burning fuel B0 under different driving conditions

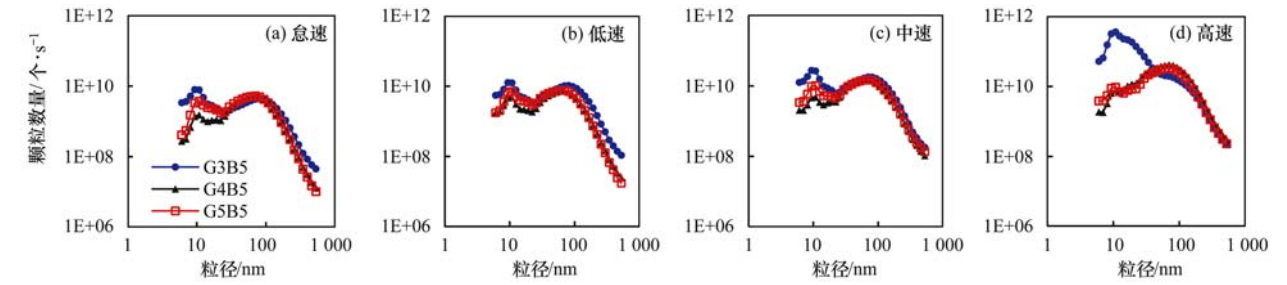


图9 燃用 B5 时不同排放标准公交车不同行驶工况下颗粒物数量排放粒径分布特性
Fig. 9 Particulate distribution characteristics of buses with different emission standards burning fuel B5 under different driving conditions

由图 8~10 可见,各公交车排气颗粒数量粒径分布大体上都呈明显的核态颗粒和聚积态颗粒的双峰对数分布,且在中低速及怠速时更为明显。国 V、国 IV 车核态颗粒数量排放率峰值相对国 III 车明显降

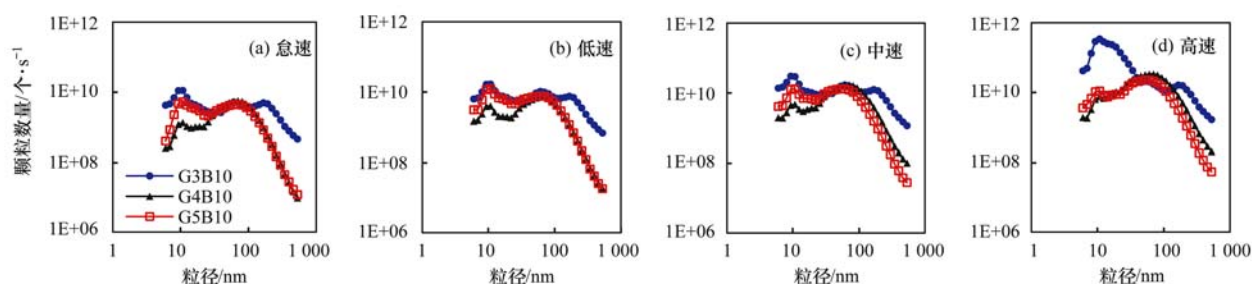


图 10 燃用 B10 时不同排放标准公交车不同行驶工况下颗粒物数量排放粒径分布特性

Fig. 10 Particulate distribution characteristics of buses with different emission standards burning fuel B10 under different driving conditions

低,而聚集态数量峰值降幅不明显.高速时,国V、国IV车的聚集态峰值较明显,峰值对应排放率高于国III车,而国III车的核态颗粒数量排放率高,核态峰值非常明显.

国V车相对国IV车的聚集态颗粒数量排放率峰值变化不大,仅在高速时明显减少;而相对国IV车的核态颗粒数量排放率峰值则明显增大,且大体呈现车速越低增幅越大,燃用B10,在高速/中速/低速/怠速时,国V车的核态颗粒峰值为 1.11×10^{10} 、 1.33×10^{10} 、 1.25×10^{10} 和 5.36×10^9 个·s⁻¹,相对国IV车分别增加约 45.7%、181.2%、210.8% 和 293.1%.

此外,国III车燃用低生物柴油掺混比燃油B5时,颗粒数量浓度粒径分布变化不大,但当生物柴油掺混比例增至10%,即燃用B10时,国III车较大粒径颗粒排放急剧恶化,颗粒数量排放率在各车速下都明显增加,并出现新的峰值,从而呈现不规则的三峰对数分布.可见,国III排放水平的公交车对生物柴油添加比例的适应性差,不适合推广应用较大生物柴油掺混比燃油.

3 结论

(1) 国V、国IV车相对国III车,总颗粒数量和质量排放均大幅下降,而国V车相对国IV车总颗粒质量排放明显下降但数量略有上升.随生物柴油掺混比例增加,国III车颗粒质量排放增加,而国IV和国V车则减少.

(2) 国V车相对国III车,核态颗粒数量大幅下降,但相对国IV车,变化不大,在怠速及中低速工况,甚至高于国IV车,且随生物柴油掺混比例的增加更加明显.在中低速工况,国V、国IV车聚集态颗粒数量相对国III车下降,而在高速工况,国IV车明显高于国V、国III车.

(3) 国V、国IV车相对国III车,核态和聚集态颗粒质量均下降,且聚集态颗粒质量下降幅度随生

物柴油掺混比例的增加更加明显.相比燃用B5,国III车燃用B10时聚集态颗粒质量急剧增加.

(4) 国III车核态颗粒排放主要来自高速工况,而国IV、国V车则主要来自中低速工况;国III、国IV、国V车聚集态颗粒排放主要都来自中低速工况.

(5) 低车速时,公交车排气颗粒数量的粒径分布大都呈双峰对数分布.高速时,国III车的核态峰值凸显,而国V和国IV车聚集态峰值略明显,甚至略高于国III车.燃用B10时,国III车的大粒径聚集态颗粒明显增加,形成新的峰值,粒径分布总体近似呈三峰对数分布.

参考文献:

- [1] Oravijärvi K, Pietikäinen M, Ruuskanen J, *et al.* Diesel particle composition after exhaust after-treatment of an off-road diesel engine and modeling of deposition into the human lung [J]. *Journal of Aerosol Science*, 2014, **69**: 32-47.
- [2] Xu J, Jin T S, Miao Y N, *et al.* Individual and population intake fractions of diesel particulate matter (DPM) in bus stop microenvironments [J]. *Environmental Pollution*, 2015, **207**: 161-167.
- [3] Wierzbicka A, Nilsson P T, Rissler J, *et al.* Detailed diesel exhaust characteristics including particle surface area and lung deposited dose for better understanding of health effects in human chamber exposure studies [J]. *Atmospheric Environment*, 2014, **86**: 212-219.
- [4] 楼狄明, 徐宁, 范文佳, 等. 国V柴油机燃用丁醇-柴油混合燃料颗粒粒径分布特性试验研究 [J]. *环境科学*, 2014, **35** (2): 526-532.
Lou D M, Xu N, Fan W J, *et al.* Particulate distribution characteristics of Chinese phrase V diesel engine based on butanol-diesel blends [J]. *Environmental Science*, 2014, **35** (2): 526-532.
- [5] Kittelson D B. Engines and nanoparticles: a review [J]. *Journal of Aerosol Science*, 1998, **29**(5-6): 575-588.
- [6] Tan P Q, Hu Z Y, Deng K Y, *et al.* Particulate matter emission modelling based on soot and SOF from direct injection diesel engines [J]. *Energy Conversion and Management*, 2007, **48** (2): 510-518.
- [7] 谭丕强, 胡志远, 楼狄明. 车用发动机燃用生物柴油的颗粒数量排放 [J]. *汽车安全与节能学报*, 2010, **1**(1): 83-88.

- Tan P Q, Hu Z Y, Lou D M. Particle number emission from a vehicle diesel engine with biodiesel fuel [J]. *Journal of Automotive Safety and Energy*, 2010, **1**(1): 83-88.
- [8] 王常文, 崔方方, 宋宇. 生物柴油的研究现状及发展前景[J]. *中国油脂*, 2014, **39**(5): 44-48.
- Wang C W, Cui F F, Song Y. Research situation and development prospect of biodiesel[J]. *China Oils and Fats*, 2014, **39**(5): 44-48.
- [9] Liew W H, Hassim M H, Ng D K S. Review of evolution, technology and sustainability assessments of biofuel production [J]. *Journal of Cleaner Production*, 2014, **71**: 11-29.
- [10] 楼狄明, 谭丕强. 柴油机使用生物柴油的研究现状和展望[J]. *汽车安全与节能学报*, 2016, **7**(2): 123-134.
- Lou D M, Tan P Q. Present and future of the studies for diesel engines using biodiesel fuel[J]. *Journal of Automotive Safety and Energy*, 2016, **7**(2): 123-134.
- [11] Jaat M, Khalid A, Manshoor B, *et al.* An experimental study on the performance and emissions of diesel engine fuelled with biodiesel derived from palm oil [J]. *Applied Mechanics and Materials*, 2014, **699**: 654-659.
- [12] Özener O, Yükek L, Ergenç A T, *et al.* Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics[J]. *Fuel*, 2014, **115**: 875-883.
- [13] 刘玉梅, 张敬师, 崔丽, 等. 台架试验的生物柴油发动机使用特性[J]. *哈尔滨工程大学学报*, 2014, **35**(2): 189-194.
- Liu Y M, Zhang J S, Cui L, *et al.* The engine performance of biodiesel based on bench test[J]. *Journal of Harbin Engineering University*, 2014, **35**(2): 189-194.
- [14] Tüccar G, Tosun E, Özgür T, *et al.* Diesel engine emissions and performance from blends of citrus sinensis biodiesel and diesel fuel[J]. *Fuel*, 2014, **132**: 7-11.
- [15] Can Ö. Combustion characteristics, performance and exhaust emissions of a diesel engine fueled with a waste cooking oil biodiesel mixture [J]. *Energy Conversion and Management*, 2014, **87**: 676-686.
- [16] Abedin M J, Masjuki H H, Kalam M A, *et al.* Performance, emissions, and heat losses of palm and jatropha biodiesel blends in a diesel engine[J]. *Industrial Crops and Products*, 2014, **59**: 96-104.
- [17] 何金戈, 童开, 肖明伟, 等. 地沟油生物柴油-柴油混合燃料燃烧特性和排放特性的试验研究[J]. *科学技术与工程*, 2014, **14**(14): 261-265.
- He J G, Tong K, Xiao M W, *et al.* An experimental study of combustion characteristics and exhaust emission characteristics on diesel engine fueled with different blending ratio of biodiesel[J]. *Science Technology and Engineering*, 2014, **14**(14): 261-265.
- [18] Na K, Biswas S, Robertson W, *et al.* Impact of biodiesel and renewable diesel on emissions of regulated pollutants and greenhouse gases on a 2000 heavy duty diesel truck [J]. *Atmospheric Environment*, 2015, **107**: 307-314.
- [19] Sandhu G S, Frey H C, Bartelt-Hunt S, *et al.* In-use activity, fuel use, and emissions of heavy-duty diesel roll-off refuse trucks [J]. *Journal of the Air & Waste Management Association*, 2015, **65**(3): 306-323.
- [20] 李腾腾, 秦孔建, 钟绍华. 不同测试循环混合动力客车排放特性对比[J]. *武汉理工大学学报(信息与管理工程版)*, 2011, **33**(1): 62-65.
- Li T T, Qin K J, Zhong S H. Comparison of emission characteristic of hybrid electric bus under different driving cycles [J]. *Journal of Wuhan University of Technology (Information & Management Engineering)*, 2011, **33**(1): 62-65.
- [21] Johnson K C, Durbin T D, Jung H, *et al.* Evaluation of the European PMP methodologies during on-road and chassis dynamometer testing for DPf equipped heavy-duty diesel vehicles [J]. *Aerosol Science and Technology*, 2009, **43**(10): 962-969.
- [22] 楼狄明, 贺南, 谭丕强, 等. DOC/CCRT 老化对柴油公交车气态物排放特性的影响[J]. *环境科学*, 2016, **37**(6): 2059-2064.
- Lou D M, He N, TAN P Q, *et al.* Effect of DOC/CCRT aging on gaseous emission characteristics of an in-used diesel engine bus[J]. *Environmental Science*, 2016, **37**(6): 2059-2064.
- [23] 胡志远, 谢亚飞, 谭丕强, 等. 在用国IV公交车燃用B5生物柴油的排放特性[J]. *同济大学学报(自然科学版)*, 2016, **44**(4): 625-631.
- Hu Z Y, Xie Y F, Tan P Q, *et al.* Emission characteristics of an in-use China four diesel bus fueled with B5[J]. *Journal of Tongji University (Natural Science)*, 2016, **44**(4): 625-631.
- [24] 楼狄明, 陈峰, 胡志远, 等. 公交车燃用生物柴油的颗粒物排放特性[J]. *环境科学*, 2013, **34**(10): 3749-3754.
- Lou D M, Chen F, Hu Z Y, *et al.* Particle emission characteristics of diesel bus fueled with bio-diesel [J]. *Environmental Science*, 2013, **34**(10): 3749-3754.
- [25] 王沛, 张长岭, 张峥, 等. 电控单体泵喷油量不一致性修正的试验研究[J]. *汽车工程*, 2015, **37**(11): 1260-1264, 1283.
- Wang P, Zhang C L, Zhang Z, *et al.* An experimental study on the inconsistency correction of cycle fuel injection quantity for electronic unit pump [J]. *Automotive Engineering*, 2015, **37**(11): 1260-1264, 1283.

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