重型柴油车排放耐久性研究

Investigation on the emission durability of heavy-duty diesel vehicles

柴油机后处理快速老化技术的应用

Accelerated aging technology for catalyst

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01 重型车排放耐久性要求 / Emission durability

- **耐久性要求 /** Requirement of emission durability
- **耐久性评价方法 /** Evaluation method of emission durability

02 后处理装置快速老化技术/ Accelerated aging of aftertreatment devices

- **基本原理 /** Fundamental
- **老化对应关系 /** Aging equivalence
- **快速老化试验方法 /** Accelerated aging method

03 对排放的影响研究 / Emission durability

- **后处理装置转化效率 /** Aftertreatment devices conversion efficiency
- **污染物排放变化 /** Change of pollutant emission

HDV＆HD engine *with/out aftertreatment systems	Useful life *Whichever come first		Minimum test mileage by type approval	Useful life *Whichever come first		Minimum test mileage by type approval	Useful life *Whichever come first		Minimum test mileage by type approval
	China-III（GB20890-2007）			China-IV, China-V, EEV（GB17691-2005）			China-VI（GB17691-2018）		
M_1	80000km	5 years	50000km	100000km	5years	100000km	200000km	5years	160000km
M_2	80000km	5 years	50000km	100000km	5years	100000km	200000km	5years	188000km
M_3 (I、II、A、B(GVM≤7.5t))	100000km	5 years	60000km	200000km	6years	125000km	300000km	6years	188000km
M_3(III、B(GVM>7.5t))	250000km	6 years	80000km	500000km	7years	167000km	700000km	7years	233000km
N_1				100000km	5years	100000km	200000km	5years	160000km
N_2	100000km	5 years	60000km	100000km	6years	125000km	300000km	6years	160000km
N_3(GVM≤16t)	100000km	5 years	60000km	200000km	6years	125000km	300000km	6years	188000km
N_3(GVM>16t)	250000km	6 years	80000km	500000km	7years	167000km	700000km	7years	233000km

有效寿命期内的各阶段柴油车和柴油机不能超过对应排放限值的要求

排放法规升级，排放耐久性要求不断加严

Emission durability requirements are increasingly stringent

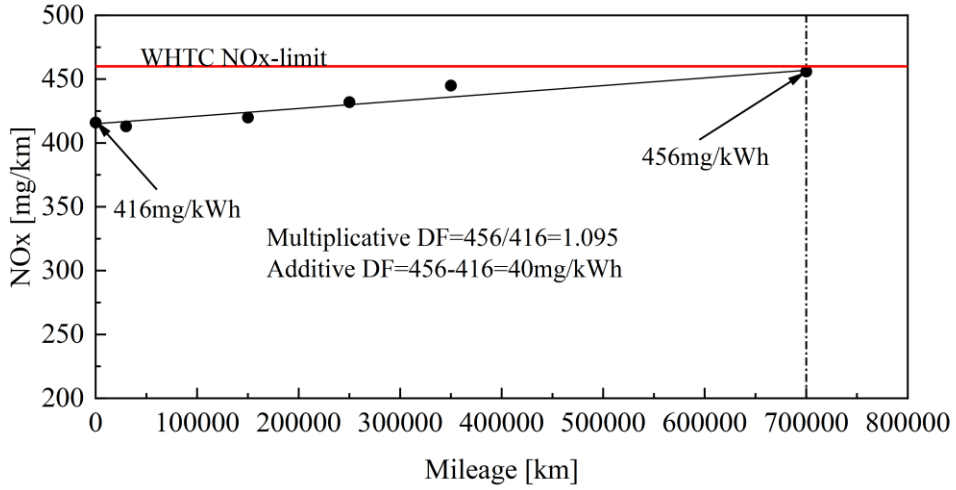
- **整车或发动机耐久性试验二选一，耐久性循环企业自定**

  Only one vehicle durability test or engine durability test need to be done, and the durability cycle is determined by the manufacturers
- **发动机耐久试验里程数按燃油消耗量对应，也可通过发动机转速-车速等关系对应**

  Durability test mileage is converted according to fuel consumption, also can be converted by engine-vehicle speed and so on
- **耐久性试验过程中需进行ESC和ETC试验(国Ⅳ、Ⅴ)或WHTC和WHSC试验(国Ⅵ)，排放测试点不应少于5个点，包括耐久性起点和终点，间隔里程不能大于30000km**

  ESC and ETC(China-Ⅳ&China-Ⅴ), WHTC and WHSC(China VI) emission factors should be tested regularly during the durability test
- **最小二乘法确定劣化系数 /** DFs determined by ordinary least squares
- **劣化系数为有效寿命终点和耐久性试验起点的排放之比(乘法劣化系数)或排放之差(加法劣化系数)**

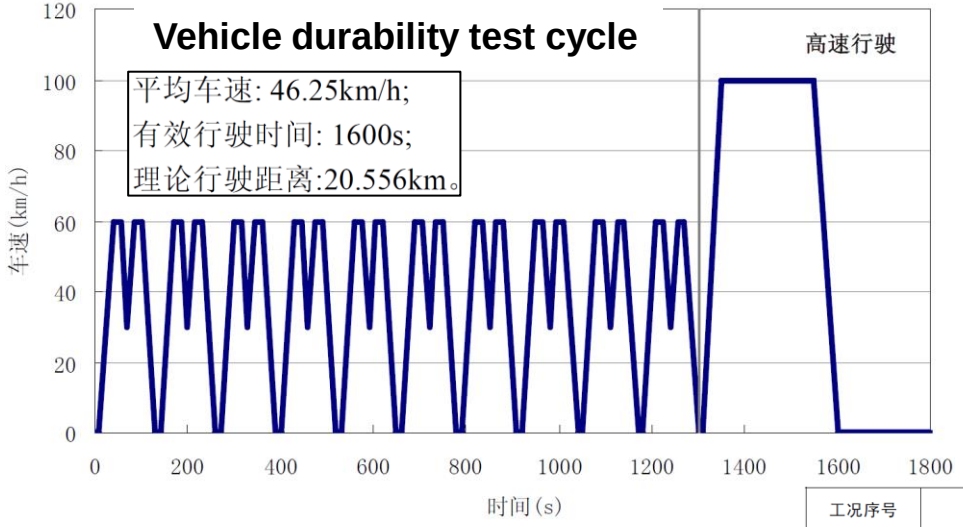
  The emission ratio of useful life end point and durability test start point is Multiplicative DFs , and the difference is the Additive DFs



China-VI Multiplicative DFs for substitution

Test cycle	CO	THC	NOx	NH_3	PM	PN
WHSC	1.3	1.3	1.15	1.0	1.05	1.0
WHTC	1.3	1.3	1.15	1.0	1.05	1.0

GB20890-2007的推荐整车和发动机台架耐久性试验循环



	Vehicle durability cycle	Engine durability cycle
Cycle time [h]	0.27	5
Cycle mileage [km]	20.556	800（Recommended）
Time for 100000km [h]	2200	625
Number of cycles for 100000km [#]	4865	125

重型车排放耐久性试验周期长、耗费大量财力物力

Normal durability test is time-consuming and resource-wasteful

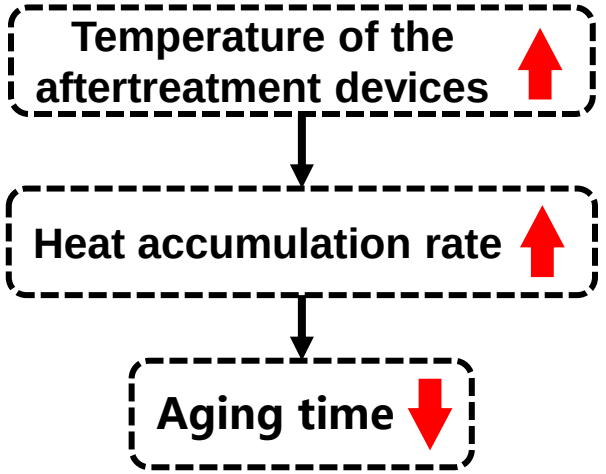
工况序号	转速（r/min）	负荷（%）	运转时间（s）
1	怠速	0	120
2	最大扭矩转速	10	600
3	最大扭矩转速	100(90)[2]	1200
4	怠速	0	120
5	额定转速[3]	25	600
6	额定转速[3]	50	600
7	额定转速[3]	75	600
8	额定转速[3]	100(90)[2]	1200
9	1/2（最大扭矩转速+额定转速）[4]	25	600
10	1/2（最大扭矩转速+额定转速）[4]	50	600
11	1/2（最大扭矩转速+额定转速）[4]	75	600
12	1/2（最大扭矩转速+额定转速）[4]	100(90)[2]	1200
13	最大扭矩转速	25	600
14	最大扭矩转速	50	600
15	最大扭矩转速	75	600
16	最大扭矩转速	100(90)[2]	1200
17	怠速	0	120
18	1/2（最大扭矩转速+额定转速）[4]	25	600
19	1/2（最大扭矩转速+额定转速）[4]	50	600
20	1/2（最大扭矩转速+额定转速）[4]	75	600
21	1/2（最大扭矩转速+额定转速）[4]	100(90)[2]	1200
22	额定转速[3]	25	600
23	额定转速[3]	50	600
24	额定转速[3]	75	600
25	额定转速[3]	100(90)[2]	1200
26	怠 速	0	120
27	停车	0	720

(1) 一个循环所用时间为 5 小时；
(2)
(3)
(4)
(5)

Engine bench durability test cycle

快速老化研究目的 / Purpose of accelerated aging

- 降低成本，节约时间和资源 / Lower cost and save resources
- 快速制作OBD验证老化件 / Fast production of aged aftertreatment devices for OBD verification
- 判断排放恶化程度，确定劣化系数 / Determine the emission deterioration and determine the DFs



快速老化基本原理 / Fundamental of accelerated aging method

- DOC/SCR/cDPF失效的主要原因——催化剂热老化

  Main failure cause of DOC / SCR / cDPF devices is high-temperature thermal aging of catalyst

- 后处理装置热老化与热累积形成的损伤线性相关且只与温度有关，老化效果遵循Arrhenius方程

  The thermal aging of the aftertreatment devices is linearly related to heat accumulation and only related to temperature, which follows the Arrhenius equation

Arrhenius Equation

Activation energy，J·mol^{-1}

$$Rate(k) = Ae^{-E_a/RT}$$

Kelvin temperature，K

Pre-exponential factor　Gas constant，8.314J·mol^{-1}·K^{-1}

Equivalent time

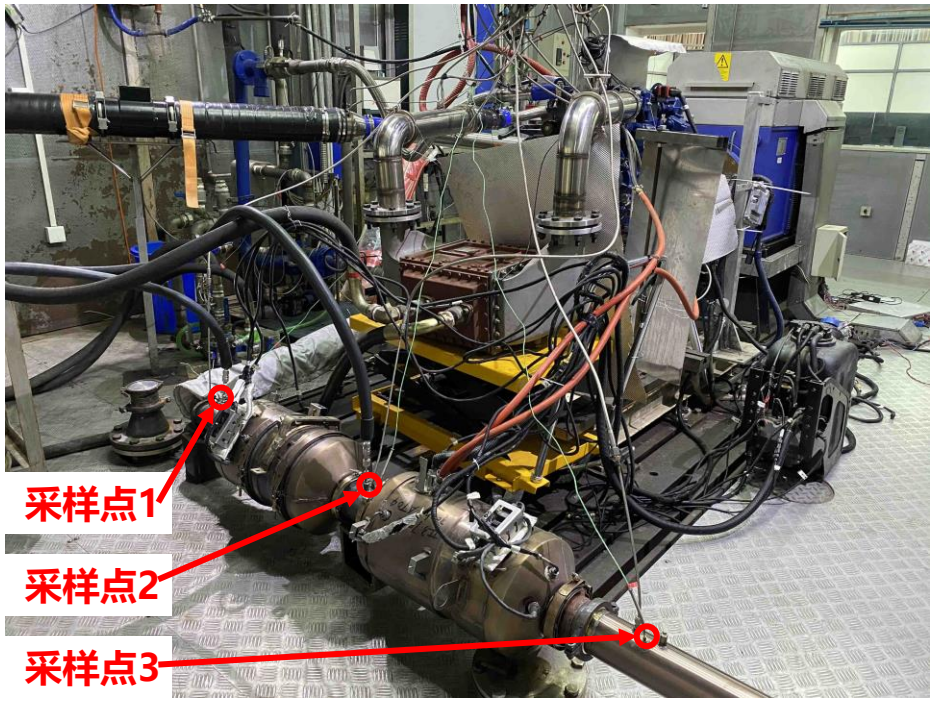
Equivalent time，h　Time sum of i^{th} group，h

$$t_e = \sum_{i=1}^{n} t_r^i \qquad t_r^i = t_{bin}^i e^{E_a\left(\frac{1}{T_r}-\frac{1}{T_{bin}^i}\right)}$$

Target temperature，K　Mean temperature of i^{th} group，K

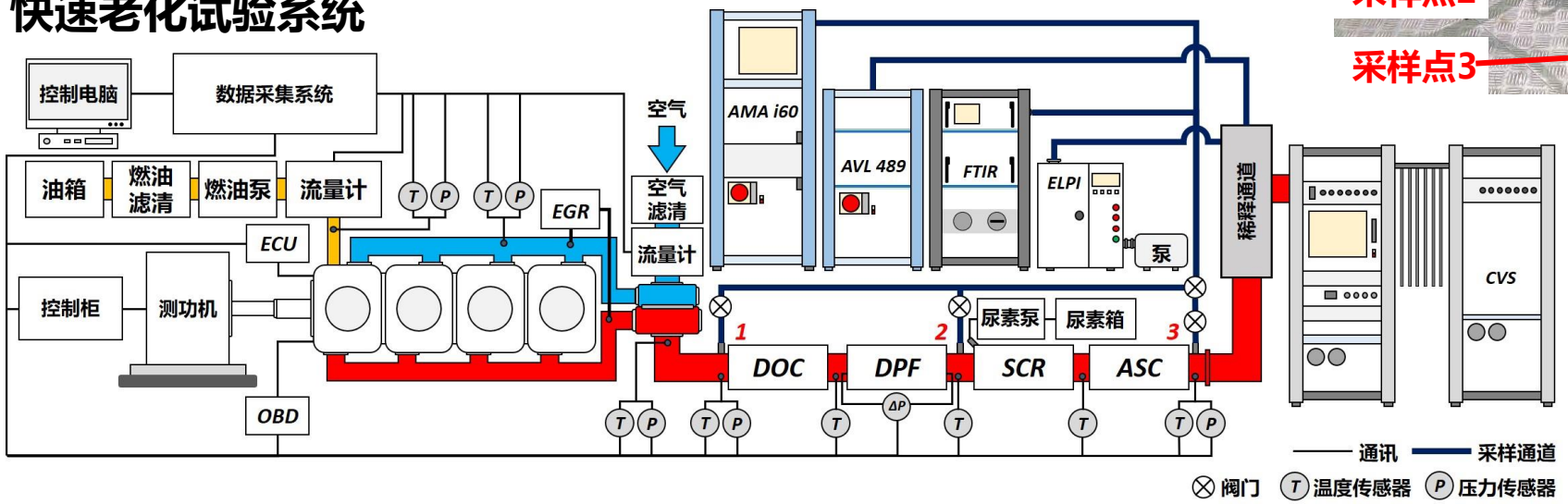
快速老化试验方法 / Accelerated aging method

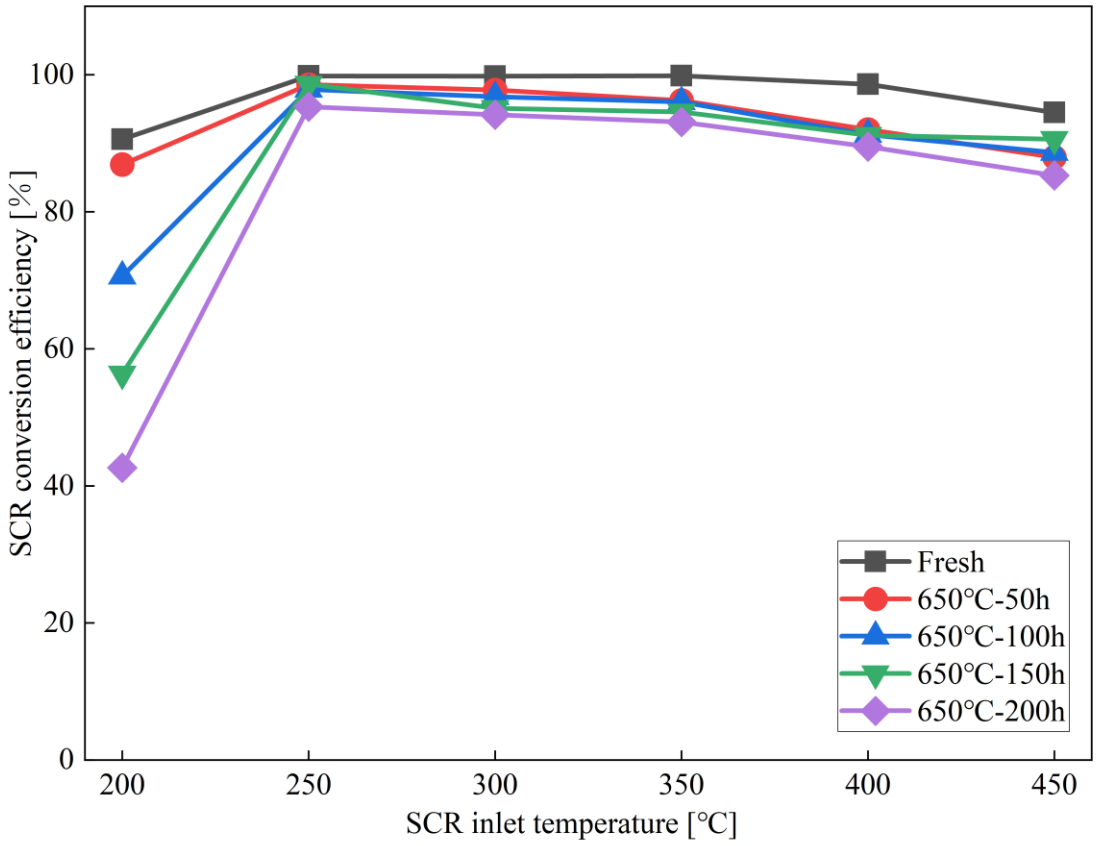
- **发动机实验（后喷）、外置燃烧器、马沸炉实现高温环境**
  High temperature: engine post-injection, external burner and muffle furnace
- **不同后处理装置的活化能不同，同时老化时以最长老化时间为准**
  The longest time prevails when the aging time of different devices is inconsistent
- **老化过程定期测试后处理装置转化效率、排放因子和cDPF平衡点温度**
  The conversion efficiency of aftertreatment devices, emission factors and the balanced point temperature of cDPF devices shall be tested regularly

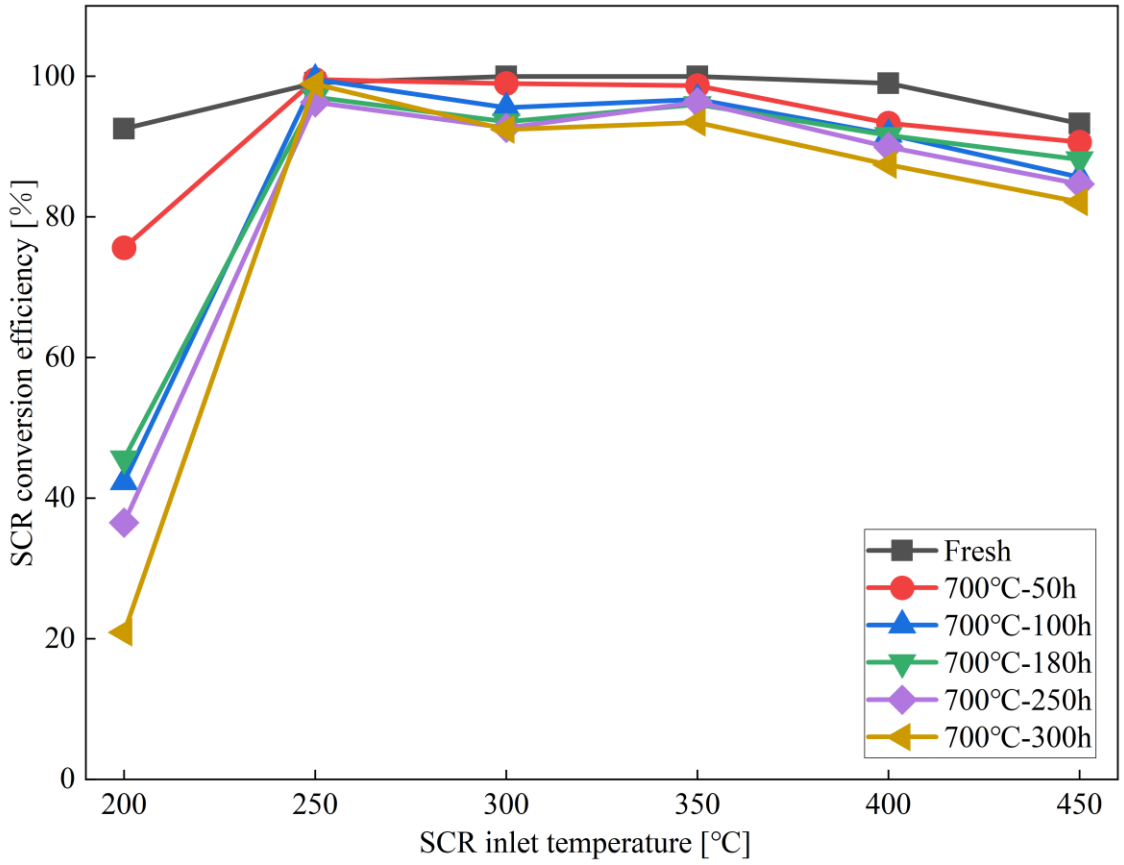


发动机台架布置-排放测试

快速老化试验系统

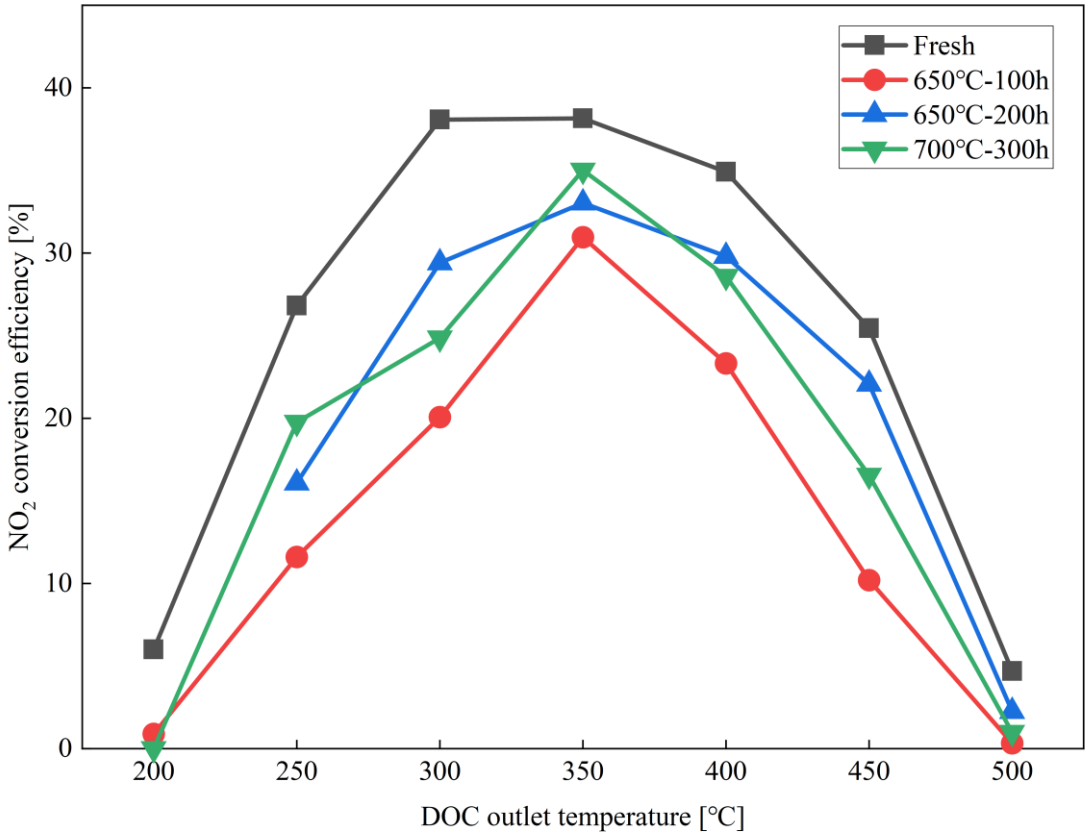


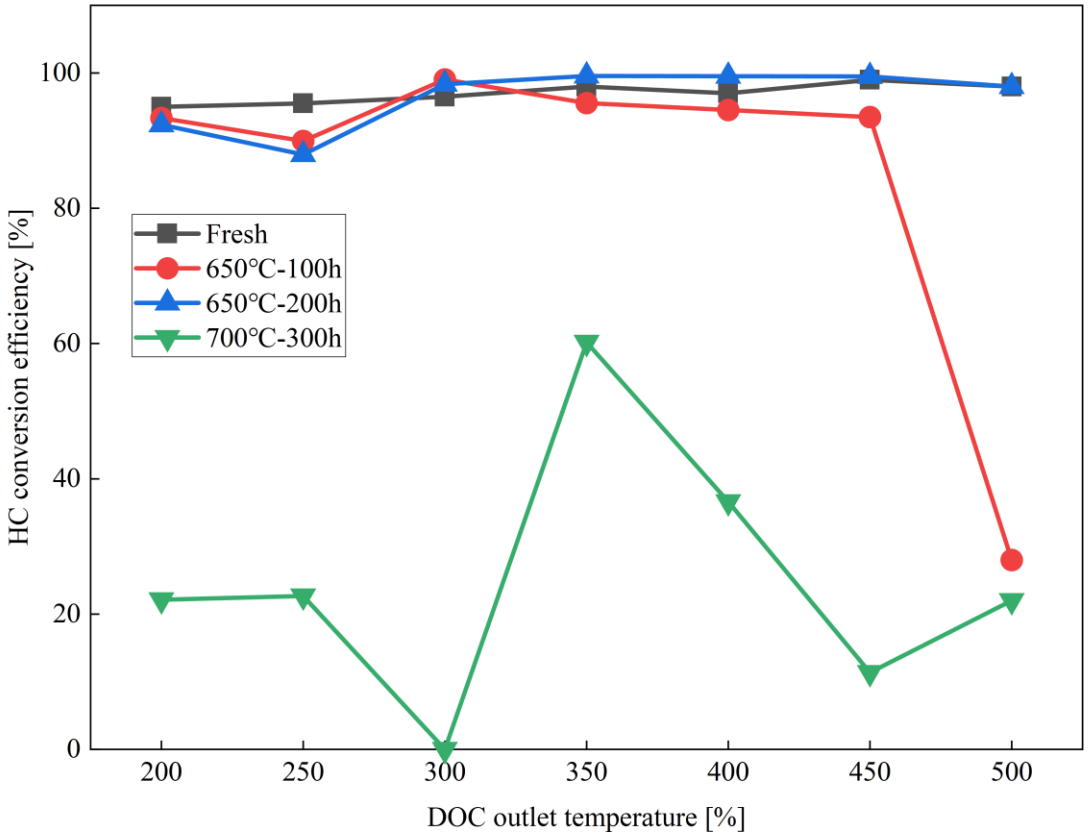




SCR转化效率 / SCR conversion efficiency

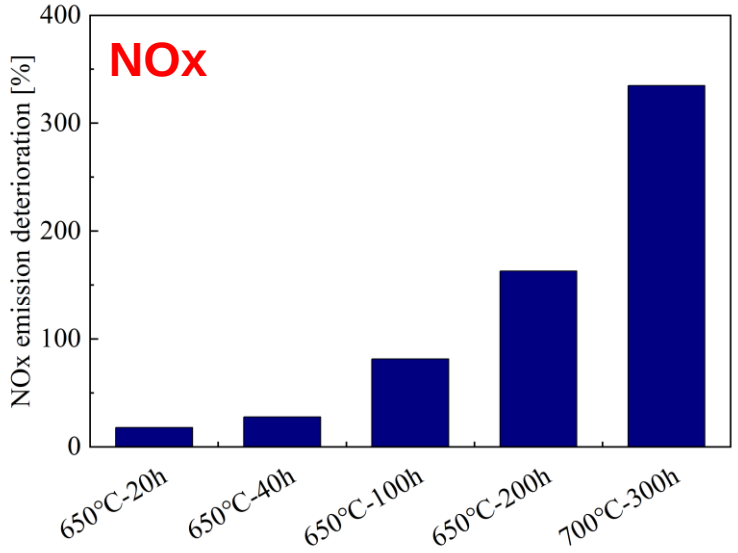
- **SCR转化效率在低温下劣化更加显著 /** The deterioration of SCR conversion efficiency is more obvious under low temperature
- **SCR转化效率的下降与老化温度高度正相关 /** The deterioration of SCR conversion efficiency is positively correlated with aging

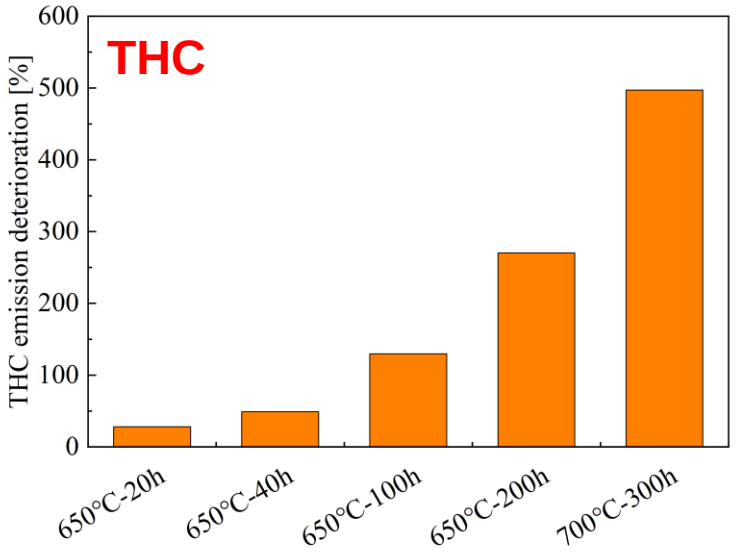


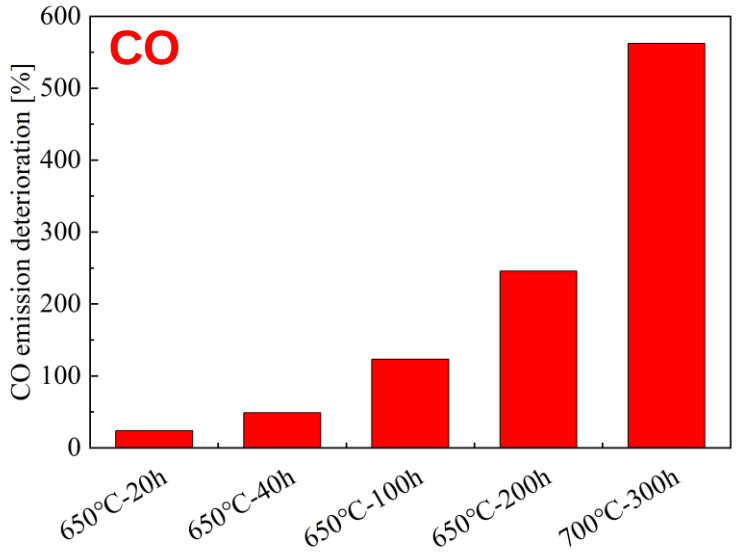


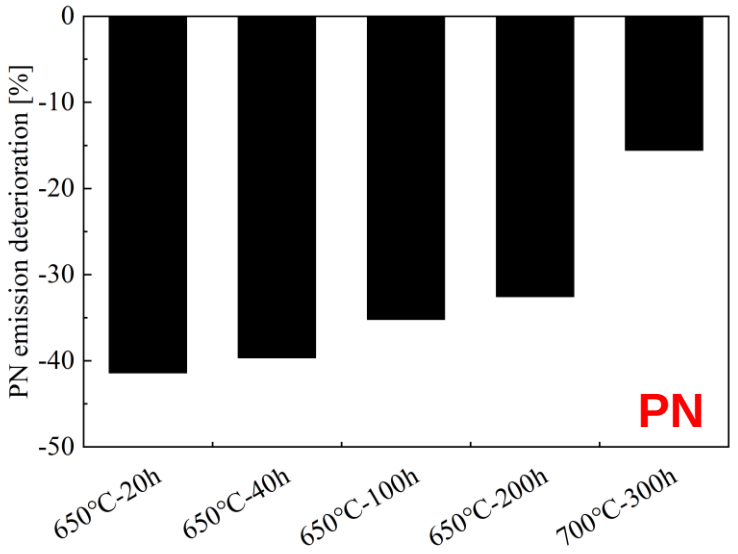
DOC转化效率 / DOC conversion efficiency

- **NO----NO_2转化效率小幅下降 /** The conversion efficiency of DOC to NO_2 deteriorates slightly
- **THC转化效率明显下降/** The conversion efficiency of DOC to THC deteriorates and fluctuated significantly









冷态WHTC排放

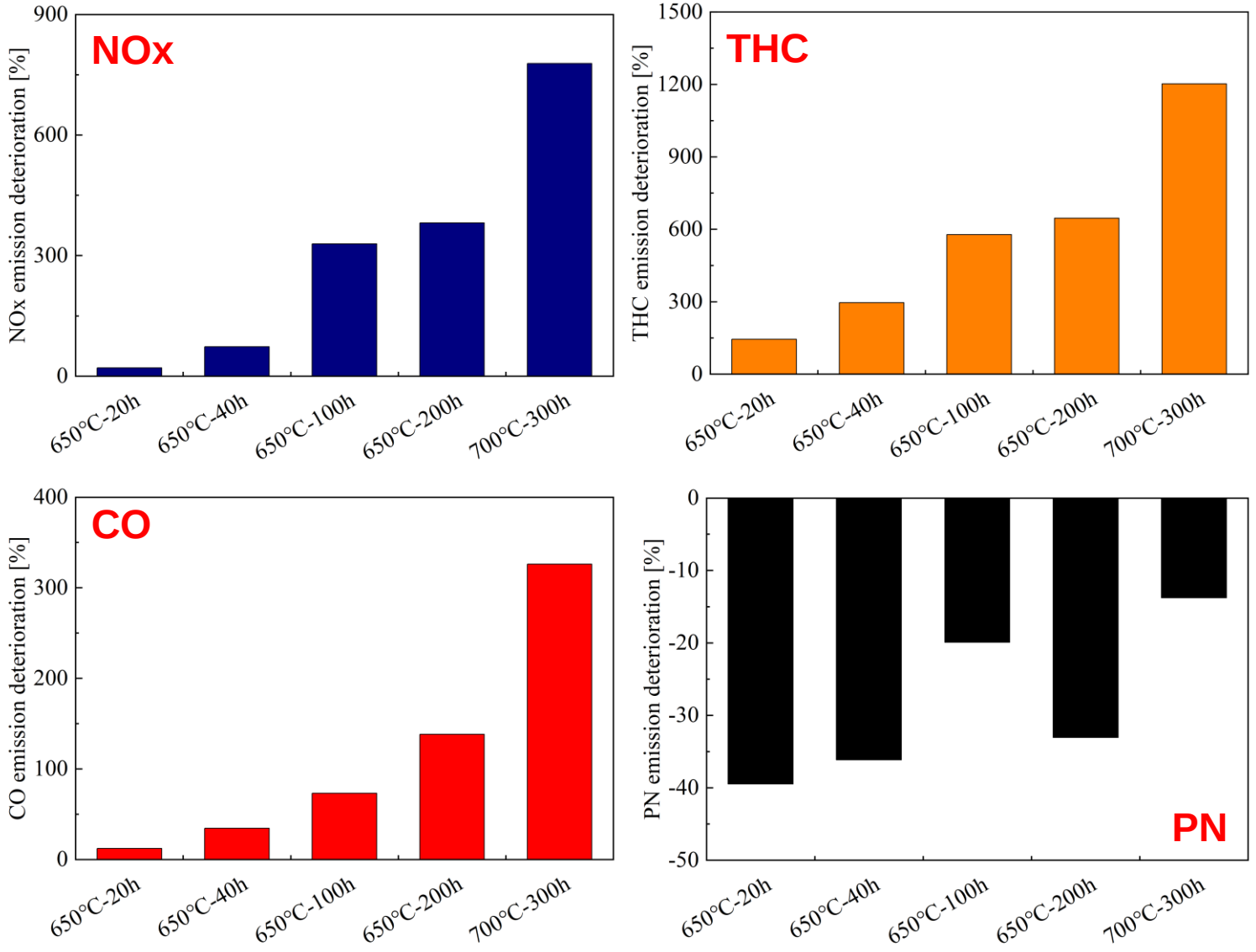
Emission factors of cold-WHTC cycle

- **气态污染物排放劣化与老化时间和温度基本线性相关**

The deterioration of gaseous EFs is linearly related to aging time and temperature

- **新鲜态cDPF装置的PN排放最高，排放变化可能与老化过程中灰分累积量有关**

The PN emission factor of fresh cDPF device is the worst, which may be related to the change of porosity of cDPF caused by ash accumulation during the aging experiment



热态WHTC排放

Emission factors of hot-WHTC cycle

- **热态WHTC排放的与变化冷态一致**

The deterioration trend of hot-WHTC emission factor is consistent with that of cold-WHTC

- **新鲜态后处理装置的热态WHTC排放较低导致气态污染物热态排放的变化幅度明显高于冷态**

The emission factors of hot-WHTC of fresh aftertreatment devices are lower, which leads to more obvious deterioration of hot-WHTC emission factor

- **随着排放标准不断升级，对重型车和发动机排放耐久性的要求不断提高**
  Emission durability requirements of HDVs and HD engines are increasingly stringent
- **常规整车和台架耐久性循环过于耗时费力、耗力，实验评价消耗量巨大**
  Normal aging cycle is time-consuming and resource-wasteful, not suitable for evaluation of emission durability
- **SCR、DOC后处理装置的转化效率基本线性劣化，SCR装置在低温段时劣化明显高于高温段**
  The SCR and DOC conversion efficiency deteriorate linearly. The deterioration of SCR conversion efficiency under low temperature is more obvious than that under high temperature
- **WHTC试验气态污染物排放随老化时间和温度的增加线性恶化**
  The gaseous emission factors of the WHTC cycle deteriorated linearly with the increase of aging temperature and time
- **装有新鲜态的cDPF装置的PN排放最高，可能与灰分累积导致cDPF孔隙率改变有关**
  The PN emission factor of fresh cDPF device is the worst, which may be related to the change of porosity of cDPF caused by ash accumulation during the aging experiment
- **cDPF平衡点温度随老化时间和老化温度的增加而增加**
  The equilibrium temperature of CDPF increases linearly with aging time and temperature
- **基于Arrhenius方程的快速老化方法可满足标准对重型车和发动机排放耐久性评价，以及OBD功能验证**
  Accelerated aging method based on Arrhenius equation can meet the requirements of emission standards for verification and evaluation of emission durability of HDVs and HD engines, and also suitable for OBD emission verification

谢谢聆听，恳请批评指正！

Thanks for listening!

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