Hong Kong Remote Sensing Symposium

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Remote Sensing Measurement -Current Technology and Future Development 遙測現今技術及未來發展

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感謝

Green Emission Environmental Consultant Ltd (GEEC) 陳國豐先生提 供遙測數據及算法用作是次數據分析

- Review current measurement technique and limitations
 - 現有技術的限制
- Illustration of real world remote sensing measurement challenges

- 現實中遙測的挑戰

- Developments for higher precision and accuracy
 一向更高精准度的發展
- Way forward

Remote Sensing Measurement – Issues 遙測問題

• Accuracy in real world affected by gas flow behind vehicle

- 車尾後的氣流影響數據

- Need higher NOx precision for dirty screen of Euro 4 or above petrol/LPG vehicles and for diesel
 - 歐4及較新汽油/石油氣、柴油車等抓高排 車需更精確量度氮氧化物

How Accurate is Remote Sensing? 遙測的準確性

- Hong Kong EPD deploys Dual Sensor 雙遙測儀器 setup such that 2 measurements are about 1 second apart
- Matched data shows some scattering已配對的數據見到有分散



How Accurate is Remote Sensing?

遙測的準確性

- However, emission profiles from both scopes agree on large scale data set, i.e., individual emission data is transient
 - 兩組大廢氣數據形態相同 個別數據是<mark>瞬態</mark>
- Analyzed over 4 million data for vehicle dynamic effect (speed and acceleration) on the instantaneous variations of the emission level
 - 分析4百萬數據,研究速度、加速度對瞬時廢氣的影響



See site selection and data QC at the end

Effect of Speed and Acceleration on Remote Sensing Measurement

- Over 4 million data from 2011-2017
- Average out the emission variation between vehicles均 化不同車輛的廢氣 差異
- Group by speed, acceleration and fuel type with at least 1,000 point in each grid每矩陣點最少 1000點
- Speed is a prominent factor on emission level車速對廢氣數 值有明顯影響



Effect of Speed and Acceleration on Remote Sensing Measurement 車輛速度/加速度對遙測的影響



Effect of Speed and Acceleration on Remote Sensing Measurement



NOx Stand Deviation vs Mean over Speed/Accel Matrix 車速/加速度矩陣點內的標準差vs平均值



- Variance of emission within each grid point of speed/accel
- 加減速矩陣點內廢 氣的差異
- Mean values grow with variances
- 平均值隨差異增加
- Diesel has lower variance with the same mean NOx level
- 同一平均值時柴油 車的廢氣差異較低

• Gas is measured by RS even at hard deceleration – the exhaust gas is dragged by the vacuum pocket behind vehicle

車輛廢氣被車輛後面的真空範圍吸引,故在猛烈減速時仍量到廢氣

• Gas IR/UV absorbance will vary due to turbulence - varying pressure and temperature at localize vortexes inside the vacuum pocket

在亂流內不同空間點的壓力及溫度有差異,氣體在紅外、紫外光吸收值會不同

- Measurements at high speed site may cause higher variance diesel vehicle have less variance due to large exhaust plume from the un-throttled engine thereby lowering the turbulence effect 監測點車速較高會有較高的數據差異,柴油車排氣量高,受影響較低
- Important to check sites and RS equipment for variance in data set for better site selection and data QC

重點是要查證檢測點及儀器差異的程度



- Vacuum is created behind a moving vehicle, generally higher with speed
- 行車時車後方會產生負壓,並隋 速度增高
- Exhaust gas is dragged along RS still measure gas even at vehicle deceleration
- 廢氣會被真空吸住,故減速時廢 氣仍會存在

Frequency Distribution of RS Signal 遙測訊號頻率分佈

Bench vs Tailpipe 枱式 vs 排氣喉



Little high frequency signal in bench test vs the measurement directly over the exhaust of a van driven on dynamometer. Higher frequency spectrum may vary gas absorbance. 枱式測試几乎沒有高頻訊號,功 率機測試則明顯,並會影響遙測 數值





New approaches in RS calibration and data collection 遙測較準與數據收集的新方式







New Remote Sensing Device

- Low profile to avoid measuring hot exhaust gas direct
 - 在較低位置量度,避免排氣喉直噴
- Open path dynamic calibration instead of gas cell type static calibration
 - 開放式動態較準
- Cater for real world turbulence
 - 照顧現實中的亂流問題
- Enhance NOx measurement precision
 - 改善氮氧化物測試精度

New RS Equipment Calibration 較準 and Real World Data 實際數據







Real World RS Measurement Affected by Turbulence Flow

- GEEC (RS manufacturer) provided data for analysis
 由GEEC 提供數據用作分析
- Illustration of vehicle dynamics (speed and acceleration) effect on real world RS measurement
 - 車輛速度加速度影響現實遙測數值
- Measurement optical path already lower than vehicle exhaust to avoid measuring hot gas – gas absorbance is proportion to temperature to power 4

- 光線軌跡低於排氣喉, 避免高溫影響

• Signal processing applied to filter out data with high transient due to turbulence

- 數碼過濾亂流資料

- Multi points collected (say 80) during each RS measurement每一次遙測假設有80點數據
- Transient data filtered leaving only valid points in each RS measurement 有亂流的數據點會被過濾
- Number of valid points is much lower at high speed and deceleration where highest turbulence signal were found高速及减速度時大部份亂流數據點被濾去



- Non-linear signal change in CO2 and other gases resulting in incorrect gas ratios (1)
- 二氧化碳與其他氣體訊號變化不線性



• Non-linear signal change in CO2 and other gases resulting in incorrect gas ratios (2)



- Non-linear signal change in CO2 and other gases resulting in overall incorrect gas ratios (3)
- 整體而言,氮氧與二氧化碳比例較高



- Distribution of road NOx data become normal after removing low valid point data
- 除去低有效值的數據 · 改善不正常高的數值分佈

Percentile of NOx/CO2



- Open path calibration of RS using calibration gas and pure CO2
- 使用標準氣及純二氧化碳·開放式較準
- Road data overlaid 藍色點為路邊量得廢氣數據
- NOx detection limit (3 Sigma) better than 100ppm氮氧的測知限值優於100ppm(3 Sigma方法)



- Gas concentrations vs RS signal tracking well when turbulence is dampen
- 減低廢氣亂流,遙測與分析儀數值走勢接近
- In free exhaust flow format, analyzer concentration does not follow RS signal gas flow in optical path is not uniform自由噴出時,兩者差別明顯



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Way Forward

- Need to enhance the RS roadside data collection method better calibration and equipment audit using dynamic method
 - 更佳的遙測儀器動態標訂及考核方法·改善路邊遙測工作
- Site selection important to avoid high speed high deceleration data
 - 選擇遙測點十分重要,避免高速及急減速駕駛狀況
- Improved RS equipment can meet future enforcement target for NOx – for diesel, possibly in 100-200ppm NOx range over 10% CO2
 - 改善了的遙測儀器可達致未來NOx執法的精確度,對柴油車而言約在100-200ppm之間(10%二氧化碳水平時)
- Dual sensor a safeguard for diesel dirty screen considering the variation due to turbulence at low concentration level
 - 由於亂流及高精度要求等因素,雙遙測設備可減少執法時誤判



Thank you

Site Selection and Data QC

• Dual scope set up aids selecting suitable sites and QC of data collected



Site Selection and Data QC

- Bad data will be screened out during QC
 - Compare profiles between the scopes and site historic data
 - Problem with upstream scope, data rejected





Site Selection and Data QC

- Site with mild consistent slope and medium speed are suitable (most of our data are with speed below 50 kph)
- Higher the speed, bigger is the turbulence behind vehicle
- Beware of nearby vibration sources and consistent wind blows
- Bad sites will have different profiles between scopes and vary day to day
- AVOID bad sites