Center of Excellence for Aerospace Particulate Emissions Reduction Research

Influence of Ambient Temperature on Gas Turbine Emissions

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Background

The growth of air traffic has generated environmental concern since engine emissions can impact air quality around airports as well as general atmospheric chemistry and climate. An accurate assessment requires that the physical properties, e.g. number concentration, size, mass density, of the PM within the exhaust as it exits the engine, along with its evolution in the aging plumes, be understood and well characterized.

The SAE E31 committee is currently working to develop an ARP (Aerospace Recommended Practice) for gas turbine exhaust nvPM (non-volatile Particulate Matter) number and mass measurements. MS&T has assembled a reference system for this task, including both sampling train and instrumentation.

Honeywell Test Campaign

- July/August 2014
- Intercomparison of the AIR6241 compliant North American mobile reference system operated by MS&T and the Honeywell nvPM System.
- Honeywell turbofan propulsion engine in the 29 – 33 kN thrust range.
- Honeywell San Tan Remote Facility – Phoenix Arizona

Instrumentation

- Number: AVL Particle Counter (APC)
- Mass: AVL Micro Soot Sensor (MSS)
- DMS500 Fast particle size spectrometer

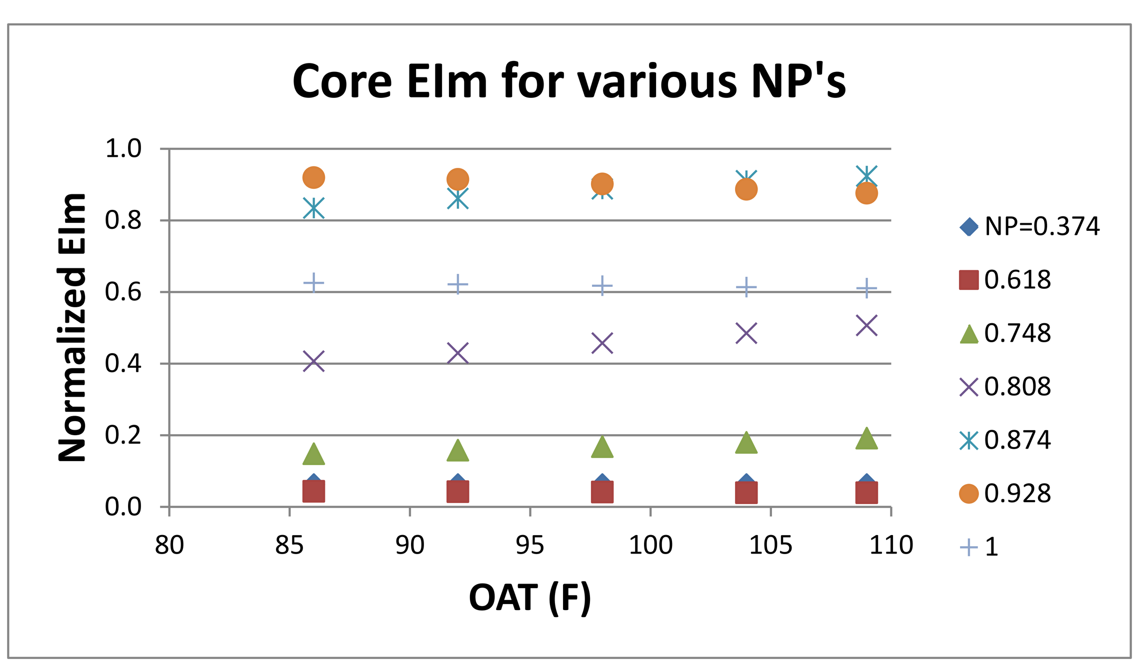
Objectives

- Inter-compare HON system and North American nvPM Reference system
- Compare nvPM emissions sampled from mixed flow and core flow configurations
- **Compare nvPM emissions from tests conducted during different times of the day to investigate the impact of variation in ambient temperature**

Parameters

EIm – Mass based emission index
EImC – EIm corrected for line loss.
GMD – Geometric Mean Diameter
GSD – Geometric Standard Deviation
MMD – Mass Mean Diameter
EIn – Number based emission index.
EInC – EIn corrected for line loss.

Analysis EIm, EIn, GMD, GSD



- OAT denotes outside air temperature.
- NP is a normalized surrogate for engine power.
- Uncertainty weighted linear fit, for each NP.
- Slope, intercept, δslope, δintercept
- Change in aerosol parameter over ΔT = 23 F
  – slope*ΔT
- Uncertainty in that change
  – δslope*ΔT
- Ratio = δslope/slope
  – ≤ 1 ➔ Change in EIm is statistically significant

	Slope Matrix						
Parameter ↓/ NP →	**0.374**	**0.618**	**0.748**	**0.808**	**0.874**	**0.928**	**1.000**
EIm	0.013	-0.113	1.121	2.768	2.286	-1.219	-0.378
EImC	0.013	-0.113	1.121	2.768	2.286	-1.219	-0.378
GMD	-0.021	-0.003	0.022	0.074	0.042	-0.084	-0.094
GSD	0.001	0.000	0.000	0.000	0.000	0.000	0.000
MMD	0.281	0.281	0.281	0.281	0.281	0.281	0.281
EIn	-0.003	-0.001	0.001	0.006	0.000	0.007	0.003
EInC	-0.003	-0.001	0.002	0.007	0.000	0.009	0.005

	δslope/slope Matrix						
Parameter ↓/ NP →	**0.374**	**0.618**	**0.748**	**0.808**	**0.874**	**0.928**	**1.000**
EIm	11.32	0.38	0.40	0.30	0.20	0.19	0.41
EImC	11.32	0.38	0.40	0.30	0.20	0.19	0.41
GMD	0.74	1.82	0.70	0.37	0.24	0.09	0.10
GSD	0.94	0.92	3.61	0.24	2.78	2.11	0.43
MMD	0.28	0.28	0.28	0.28	0.28	0.28	0.28
EIn	1.34	0.16	1.15	0.33	1.21	0.05	0.04
EInC	1.65	0.22	1.02	0.34	1.61	0.05	0.05

	% change Matrix, ΔOAT = 23 F			100*23*slope/average			
Parameter ↓/ NP →	**0.374**	**0.618**	**0.748**	**0.808**	**0.874**	**0.928**	**1.000**
EIm	1	-10	25	23	10	-5	-2
EImC	1	-10	25	23	10	-5	-2
GMD	-2	0	1	4	2	-4	-4
GSD	2	0	0	0	0	0	1
MMD	11	10	8	7	6	5	5
EIn	-7	-4	3	9	0	11	11
EInC	-6	-3	4	8	0	11	10

Results for core flow

- δslope / slope usually ≤ 1
- There is statistically significant temp effect, up to 25% for a 23F change in OAT.
- The effect is stronger at high power.
- Where δslope / slope > 1
  – Parameter vs OAT is pretty flat
  – The %change is small.

Acknowledgment

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