The University Of Sheffield.

Department Of Mechanical Engineering.

Evaluating The Effects of Effective Density Measurements on Particle Mass Emissions From a Gas Turbine

Introduction

Questions have been raised about the suitability of the gravimetric technique for the measurement of low PM emissions - characteristic of gas turbines. Sampling times of the order of several hours are required to obtain sufficiently high sample sizes with minimum errors to quantify low particle mass emissions. Low particle mass emissions pushes the gravimetric method nearer its sensitivity and reproducibility limits However, the use of real time instruments has also posed different challenges in measuring particle concentrations from combustion sources. For instance to obtain the mass concentration of PM emission from particle size number distribution instruments, the knowledge of the different particle size effective density is important. Studies have shown that the size dependence of effective density and dynamic shape factor is been sacrificed by assuming a uniform particle density. With the development of a new technique for evaluating the size-resolved effective density, preliminary studies have developed the power law that could govern gas turbine mobility diameter and effective density distribution. Thus, this poster presents the difference the real effective density can impact on the PM mass from real time size distribution instruments..

Methodology

- Tests have been performed including gaseous and particulate emissions analysis on a Auxiliary Power Unit (APU) engine which has been installed at the Low Carbon Combustion Centre at The University of Sheffield.
- The fuel tested was standard automotive diesel.
- The APU was ran at three conditions
- Test condition lasted for six minutes after the APU was stabilised.

	EGT(°C)	AFR	Fuel (g/s)
Condition 1	300±10°C	123±2	18
Condition 2	440±10°C	75±2	27
Condition 3	580±10°C	50±2	36

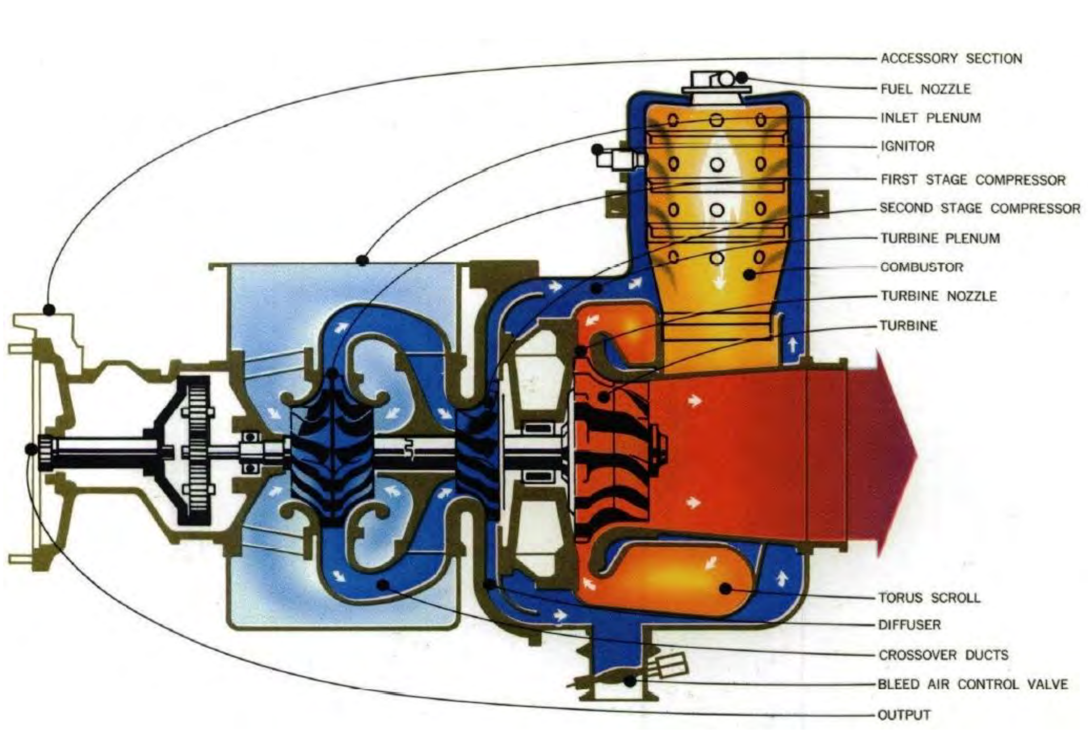

Figure 1. Schematic of the APU

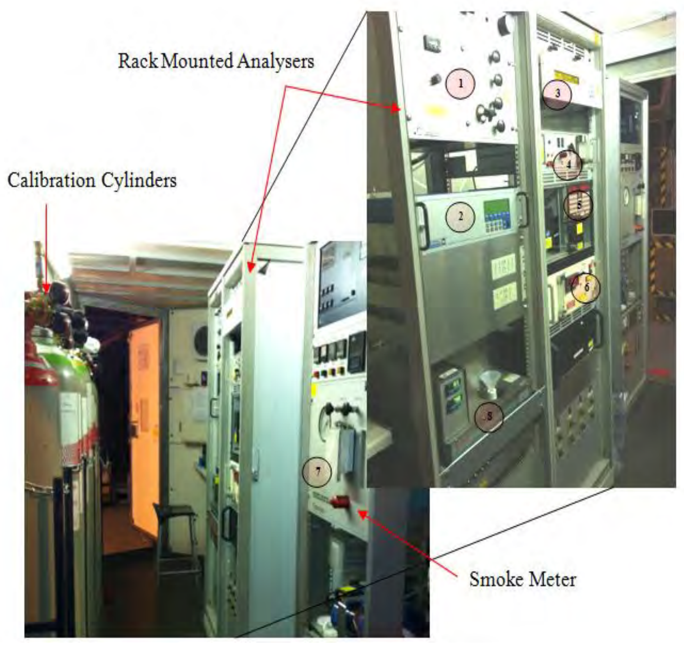

Figure 2. Measurement Instruments

No.	Analyser	Gas
1	Routing Unit	--
2	FID	UHC
3	CLD	NO, NO_2, NO_x
4	NOx GEN	--
5	NDIR, CHILLER	CO, CO_2
6	MAG	O_2
7	Smoke Meter	SMOKE
8	FTIR	UHC Speciation & other gases
9	DMS 500	PM
10	Vibration Analyser	--

Data Processing

- Concentration, measured in μg/m³ for particulate mass, #/m³ for particulate number, and ppm for gas phase species, was used as the basis of comparison for the various measurement methods.
- The DMS 500 established flow rate using a critical orifice and reports number and mass concentrations. Using the Cambustion Excel utility number concentration and mass concentration data were evaluated.

Using the following relationship

mass = $\rho \times dp^n$

ρ = density factor × Diameter^Weighting Index.

From the primary model established for gas turbine particles figure 3, the :

Density factor = 4.28

Weighting Index = -0.3054

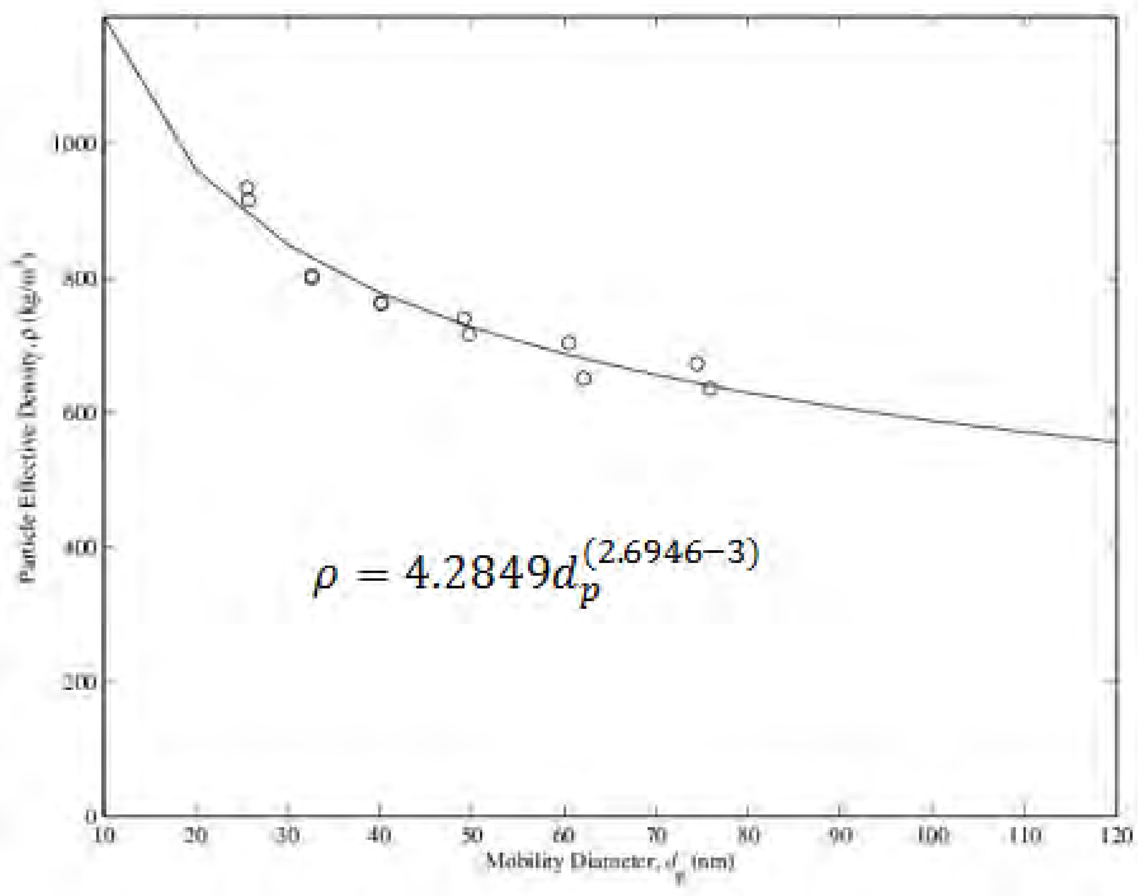

Figure 3. **Size dependent effective particle density measured on a gas turbine engine** (Reference: Sample III, Final Report)

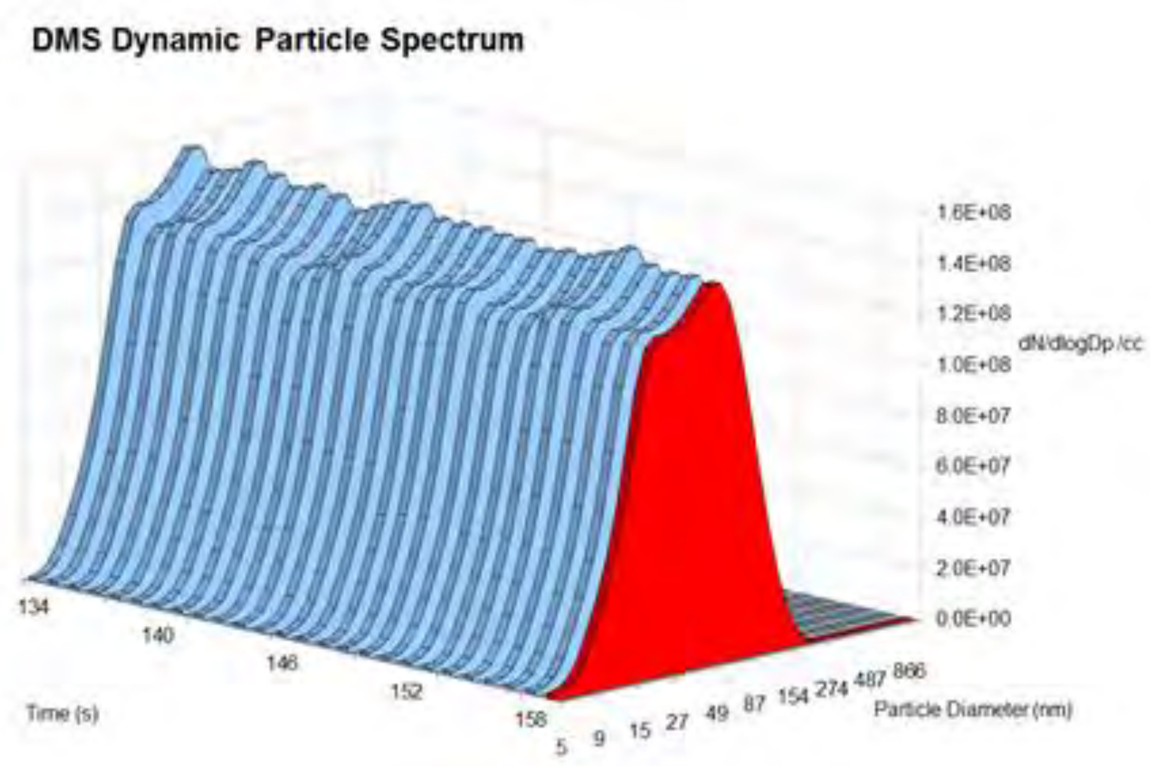

Figure 4. DMS 500 size distribution measurement

Results

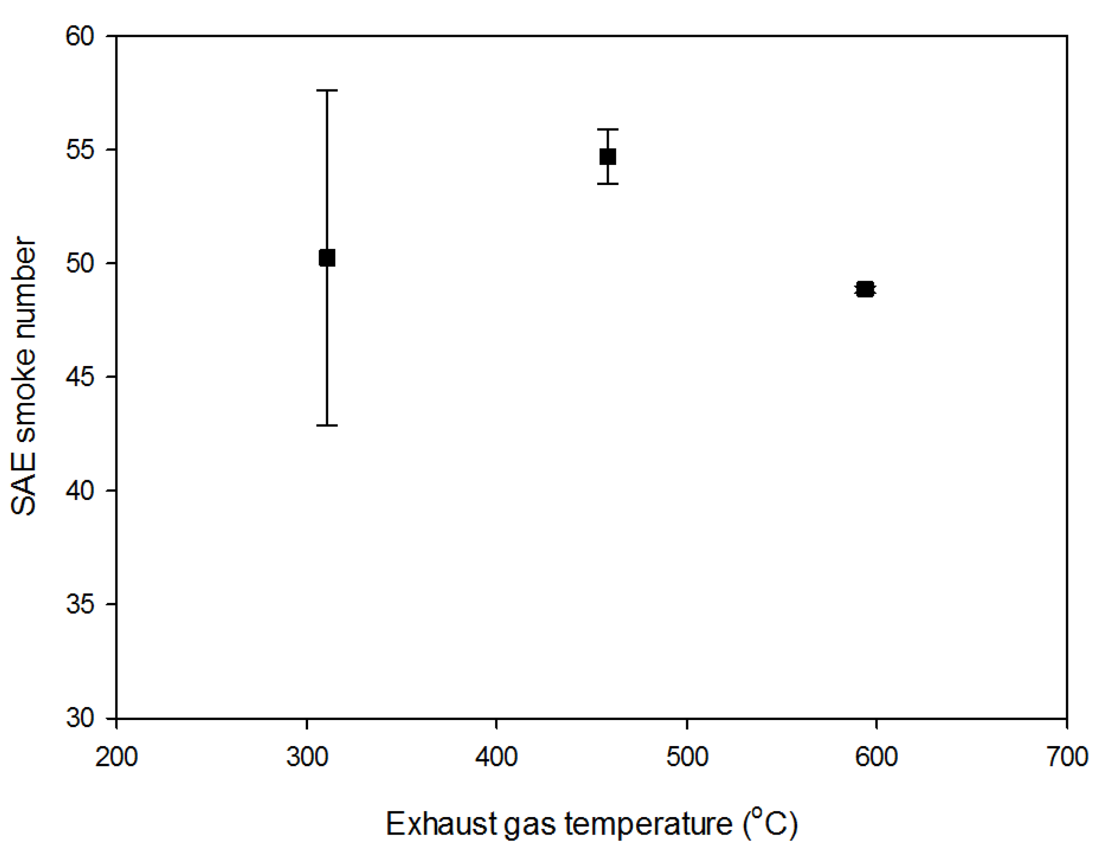

Figure 5. SAE Smoke number results

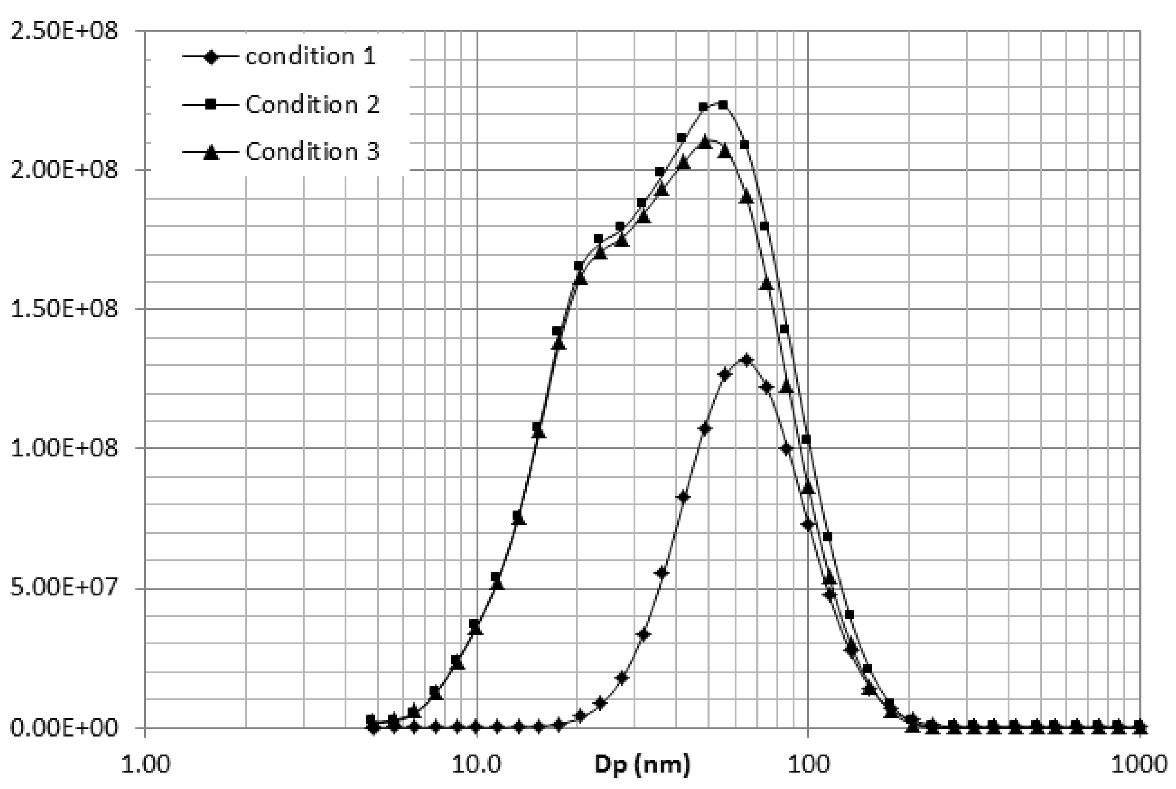

Figure 6: Differential Particle Size Distribution for the APU three conditions

Table 2. Shows the total mass concentration of the in micrograms per cubic centimetre when the a uniform density of 1g/cm³ is applied. The second column indicates the weighted concentration per cubic centimetre.

	Total weighted (W/cc)	Total Mass (μg/cc)
Condition 1	1.74E+08	1.20E-02
Condition 2	2.36E+08	1.65E-02
Condition 3	2.25E+08	1.47E-02

Table 2. Mass concentration and weighted concentration per cubic centimetre

Conclusions

- Smoke & particulate emissions produced have similar trends for diesel.
- The variation in density with particle sizes could impact on the mass concentration estimate of gas turbine particulate estimate.
- The next phase of this work would focus in converting the weighting per cubic centimeter to microgram per cubic centimeter as the use of Cambustion excel utility software is not capable of evaluating the effective density model into unit of mass concentration per unit volume.

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