

Supplementary Material for article 10.3389/fmech.2020.00043

1 CALIBRATION AND UNCERTAINTY OF THE UV SPECTROMETER

All the uncertainty derivation methodologies used in this section are derived by the authors in [2]. The uncertainty on the measurement of the nitrogen exhaust species is obtained from the TETHYS EXM 400 UV spectrometer calibration. The UV sensor renders the three molecules concentrations (in ppm) in the exhaust gas. To do so, the analyser uses the Beer-Lambert law to convert the measured light intensity at the user-prescribed wavelength, where the gases of interest are known to absorb, into concentrations. However, as the analyser bandpass resolution is not infinitesimal, the output of the Beer-Lambert law behave non-linearly with increasing absorbances (i.e. increasing concentrations of gases absorbing in the prescribed bandpass), see Figure S1. Therefore, the analyzer non-linearity has to be assessed through a calibration process. The calibration is performed using three standard gas bottle from which mole flows are drawn by MFCs. Used bottles are 1.263%mol. NH_3 , 1.008%mol. NO and 0.502%mol. NO_2 , but lower concentrations are achievable through dilution with air. Figures S1 to S3 display the analyser raw measurements, and associated uncertainties, as a function of the injected gas concentration. The mixture reference uncertainty is obtained from the MFC uncertainties and bottle purity. The repeatability/variability errors of the analyser are finally taken into account.

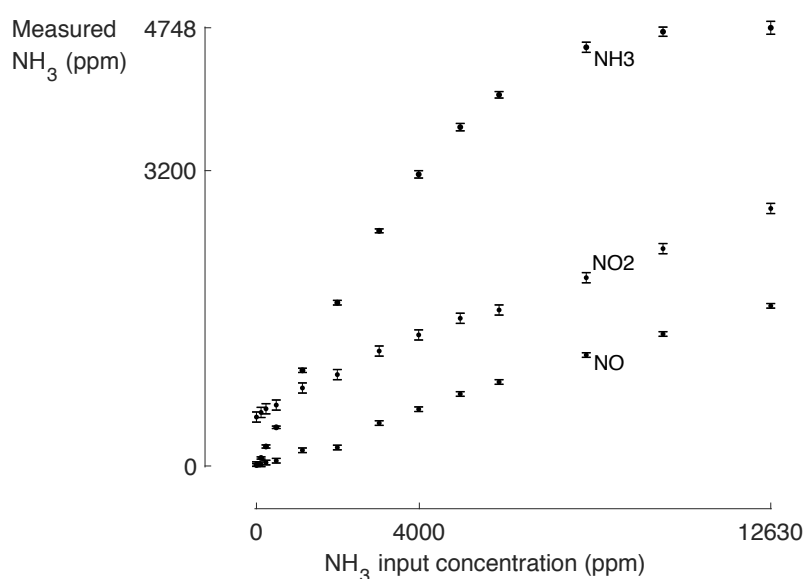


Figure S1: NH_3 raw measurement, and associated uncertainty at a 95% confidence level, as a function of the input NH_3 concentration. The raw measurement can be seen saturating for input concentrations above 4000 ppm. Ghost measurements of NO and NO_2 can be seen and are linearly correlated to the NH_3 input concentration. This interference is due to the NH_3 molecule that is absorbing at the specific lookup wavelengths chosen for NO and NO_2 .

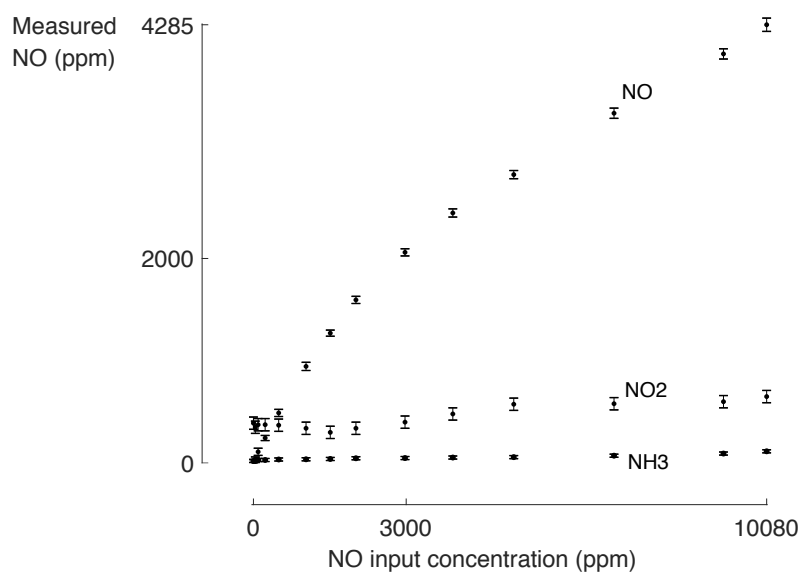


Figure S2: NO raw measurement, and associated uncertainty at a 95% confidence level, as a function of the input NO concentration. The raw measurement can be seen changing slope for input concentrations above 3000 ppm. Still the response stays linear and no pure saturation is observed for the range of interest. Finally NO is barely interfering with NH₃ and NO₂ measurements: an additional 100 ppm is obtained for both going from zero to maximum NO input concentration.

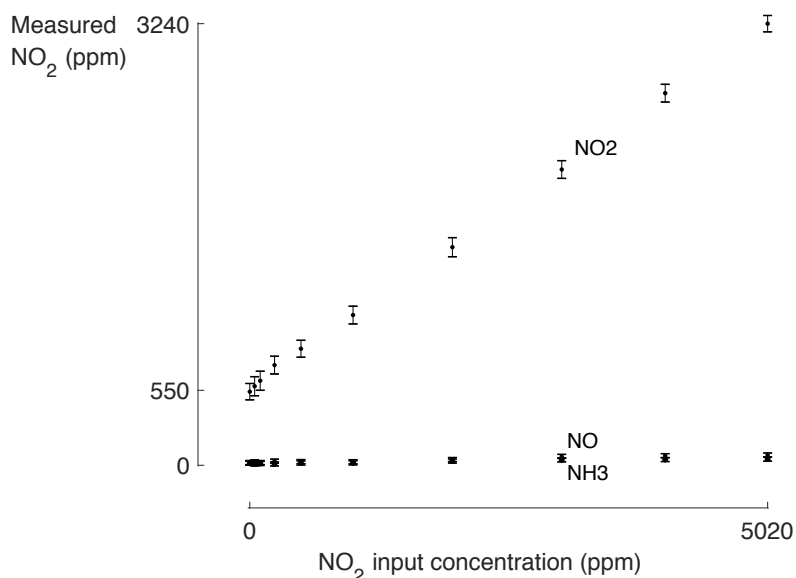


Figure S3: NO₂ raw measurement, and associated uncertainty at a 95% confidence level, as a function of the input NO₂ concentration. The raw measurement is not saturating for the input range of interest and stays linear. Finally NO₂ is not interfering with NH₃ and NO measurements.

The fact that NO₂ measurements start at around 550 ppm is due to a different measurement method: the measurements done at the specified wavelengths are compared to a reference wavelength where NO₂ is known to absorb the least. The specified lookup wavelengths are: 207-213 nm for NH₃, 214-216 nm for NO, and 219-223 nm compared to 278-282 nm for NO₂. These wavelengths have been chosen to minimise the mutual interferences, while minimising measurement saturation in the concentration range of interest.

Before obtaining the final post-treated measurement, the linearisation and interference must be taken into account. For each specie, a conversion factor (depending on the input specie concentration) is computed to linearise the measurements. This conversion factor can have a huge impact on the uncertainties, as can be seen in Figure S4, especially if the measurement is saturated. Indeed, when saturating the repeatability of the measurement becomes of the same order of magnitude as the change in measurement. The interferences are linearised in the same way. To finally account for the interferences, an iteration until convergence is performed where the retained value for a given specie is the post-processed value to which the obtained interferences from both other species is subtracted. During the convergence, the retained value for each specie at each step will give smaller and smaller interferences with the two other species, until convergence.

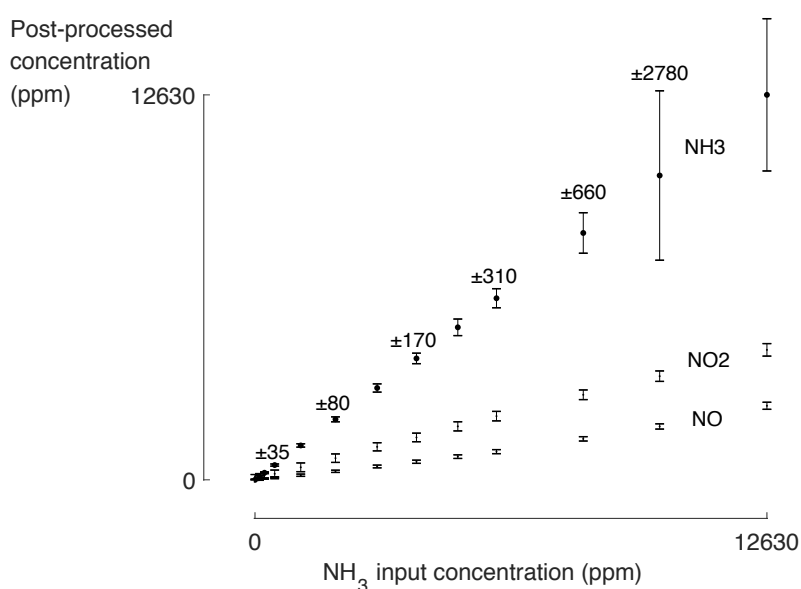


Figure S4: NH₃ post-processed measurement, and associated uncertainty at a 95% confidence level, as a function of the input NH₃ concentration. The uncertainty is greatly impacted by the conversion factor when measurement is saturated.

2 COMPLEMENTS OF INFORMATION ON THE EFFECTIVE COMPRESSION RATIO

The link between the desired effective 21.9:1 and the geometric compression ratio has to be asserted. Indeed, the effective compression was what we wanted but the geometric compression ratio was what had to be built. Using the previous experimental results of Bhaduri et al. with this engine [1], an effective compression ratio of 12.2:1 was found during the data post-processing although the geometric compression

ratio has been measured to be 12.6:1. Using the paper single-zone model, such a reduction in compression ratio corresponds to an effective Intake Valve Closure (IVC) at -152 CAD ATDC. Using this effective IVC, a geometric compression of 23.0:1 is needed to obtain an effective compression ratio of 22.0:1.

REFERENCES

- [1]Bhaduri, S., Berger, B., Pochet, M., Jeanmart, H., and Contino, F. (2017). HCCI engine operated with unscrubbed biomass syngas. *Fuel Processing Technology* 157. doi:10.1016/j.fuproc.2016.10.011
- [2]Pochet, M., Jeanmart, H., and Contino, F. (2019). Uncertainty quantification from raw measurements to post-processed data : a general methodology and its application to an Homogeneous-Charge Compression-Ignition engine. *International Journal of Engine Research*. doi:10.1177/1468087419892697