Towards a tar tolerant biomass-gasification-CHP system: Primary experiments with an HCCI engine

S. Bhaduri*, F. Contino**, and H. Jeanmart*

*TFL-iMMC, UCL, Belgium
**Dept. Mech. Eng. & BURN Joint Research Group, VUB, Belgium

1 Context

Raw 'syngas' from biomass gasification is used in Spark Ignition (SI) engines for power generation and consists of gases such as CO, H_2, CO_2, CH_4, N_2, water vapor and impurities such as tars and particulate matter. The syngas exits the gasifier at high temperatures ($\approx$ 500°C) and therefore needs to be cooled down to match the knock limited intake temperature requirements of the SI engine. While cooling the syngas increases its energy density, it also causes the tar impurities to condense into sticky liquids/solids leading to clogging or fouling problems. The Tar Dew Point (TDP) ranges in between ≈300-0°C, and thus, tar filtration becomes necessary in addition to the cooling process. The problems caused by condensation of tars and its filtration/destruction are significant challenges for this domain.

Thus, an alternative system is being developed where the syngas is kept above the TDP, throughout the process chain. This avoids tar condensation and its subsequent problems. A Homogeneous Charge Compression Ignition (HCCI) engine is adapted to operate above the TDP in this novel pathway. Our novel pathway of HCCI operation above the TDP differs from the past studies ([1–3]) which concentrated on using cooled and purified syngas in HCCI engines. In our work so far, we have carried out the following three studies:

Exp-I: Performance of open-loop HCCI combustion with various artificial syngas compositions and operating conditions [4] .

Exp-II: Use of artificial EGR (from 0-25%) for HCCI combustion control [5].

Exp-III: Stability of open-loop HCCI combustion with time varying real syngas supply. supplied in a purified and cooled form, from a 200 $kW_{thermal}$ 2-stage downdraft biomass gasifier.

2 Some Results

This presentation focuses on the results of the Exp-II and Exp-III:

Exp-II In Fig. 1a, the EGR effectively counters the advance of CA50 caused by an increasing equivalence ratio (ϕ_{FIN}). Shaded points mark the experiments with a constant fueling rate. In Fig. 1b, use of EGR significantly reduces the MPRR and thus allows higher IMEP to be realized.

Exp-II In Fig. 1c, the indicated efficiency is high but fluctuates as a result of a fluctuating syngas composition along with other instabilities which are still being investigated. These instabilities may also be responsible for the significant increase in the NO_x emissions near the ending phase of the experiments, as seen in Fig. 1d.

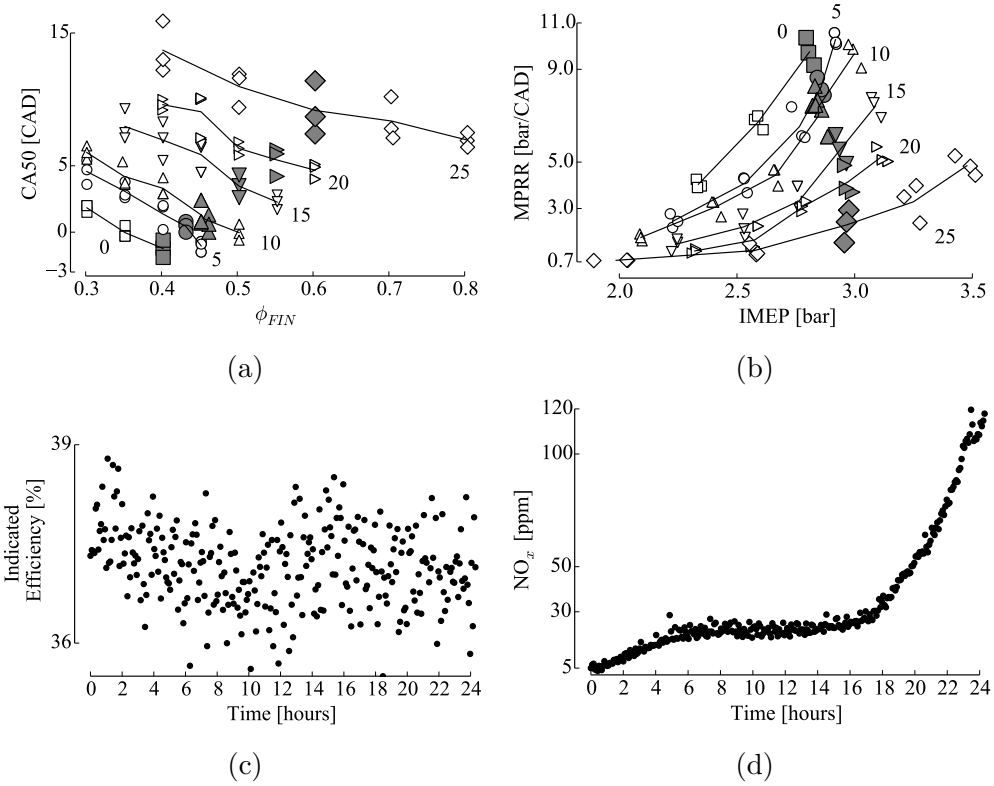

Figure 1

3 Conclusions / Future

- EGR can effectively control the combustion phasing. Maximum gross indicated efficiency=33% and about 25% improvement in the IMEP (from 2.8 without EGR to 3.5 bar with EGR) were achieved.
- Open-loop HCCI operation with real (cooled and purified) syngas seems very promising. High engine instabilities and high NO_x emissions were the main issues.
- Experiments with impure and hot syngas are to be commenced soon.
- EGR based closed-loop control of HCCI engine fueled by raw syngas is planned in near future.

References

[1] Yudai Yamasaki et al. "Combustion Characteristics of Low-Calorific-Value Gaseous Fuels in Small Gas Engine". In: *Journal of Environment and Engineering* 4.1 (2009), pp. 188–197.

[2] Dale Edward Haggith et al. "Experimental Indicated Performance of a HCCI Engine Fuelled by Simulated Biomass Gas". In: *SAE Technical Paper 2010-01-1081*. 2010.

[3] Matthias Achilles et al. "HCCI Gas Engine: Evaluation of Engine Performance, Efficiency and Emissions - Comparing Producer Gas and Natural Gas". In: *SAE Technical Paper 2011-01-1196* (Apr. 2011).

[4] Subir Bhaduri et al. "The effects of biomass syngas composition, moisture, tar loading and operating conditions on the combustion of a tar-tolerant HCCI (Homogeneous Charge Compression Ignition) engine". In: *Energy* 87.0 (2015), pp. 289–302.

[5] Subir Bhaduri et al. "Studies of EGR in Biomass Syngas fueled tar tolerant HCCI engines". In: *Ninth Mediterranean Combustion Symposium*. Rhodes, Greece, 2015.