Ignition and combustion characteristics of biomass derived fast pyrolysis bio-oil in a combustion research unit

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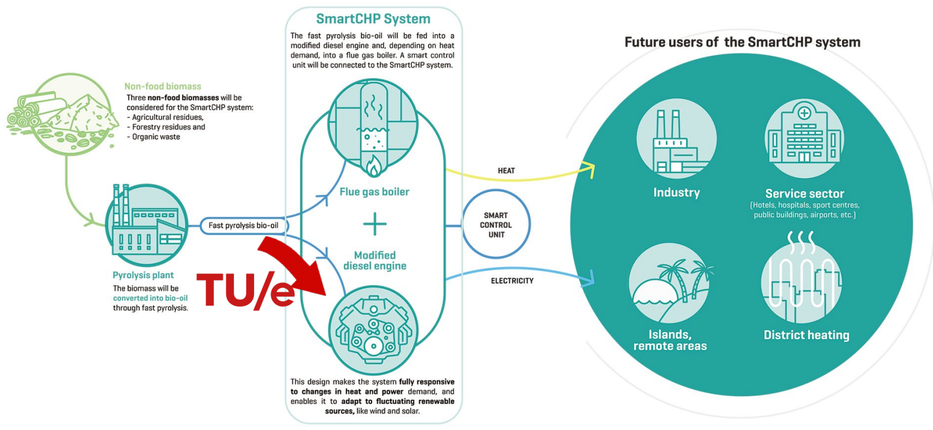
SmartCHP: aim and impact

- The EU research project SmartCHP will develop a novel, flexible small scale **cogeneration unit** to produce heat and electricity from **sustainable biomass**.
- The main technical novelty is the use of **fast pyrolysis bio-oil (FPBO)** from lignocellulosic biomass in a **converted diesel engine**.
- This will help boost the use of renewables in the electricity and heating & cooling sectors, contributing to the **2030 climate and energy targets**.

With a market potential of **€4 billion**, and an estimated **85 to 95% reduction in GHG emissions** compared to fossil fuels, the installation of the SmartCHP technology in Europe can help mitigate **climate change** by introducing more **renewables** while bringing **new jobs**.

SmartCHP process



Challenge: how to apply FPBO in a diesel engine.

Status quo	FPBO < 30%:	FPBO+alcohol+(biodiesel, etc.) [1-2]
SmartCHP target	FPBO ≥ 70%:	FPBO+alcohol; FPBO+Beraid

Diesel vs FPBO

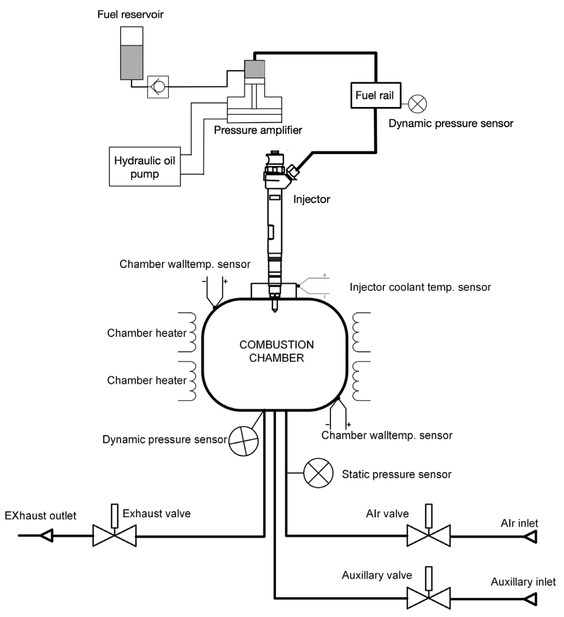
Property	Diesel	FPBO*
LHV (mJ/kg)	42.6	16.4
Density (kg/L)	0.82	1.17
C (wt%)	85.0	42.8
H (wt%)	12.6	7.8
O (wt%)	-	49.2
Water (wt%)	-	24.1
Solid (wt%)	-	0.04
Viscosity (cSt at 40 ℃)	2.7	21.0
Cetane number	54.8	-

* Data from wood-based FPBO [3].

Experimental method

Combustion research unit (CRU)

CRU operation condition	
Chamber volume [L]	0.475
Chamber wall temperature, T [ºC]	300 – 590
Initial chamber pressure, P_{init} [bar]	10 – 70
Injection pressure, P_{inj} [bar]	200 – 1000
Injection duration [ms]	0 – 1.5



Data process & indicator definition

Pressure profile from CRU

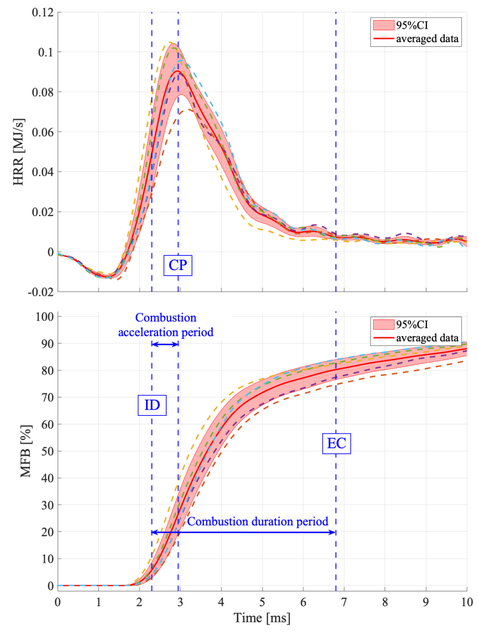
Derivative — Speed of sound correction; Heat transfer correction

Heat release rate (**HRR**)

Integral — Injection volume; Fuel LHV

Mass fraction burned (**MFB**)

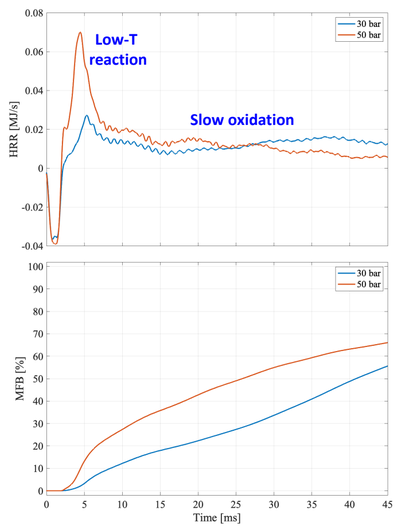
Indicator	Definition
Ignition delay, ID [ms]	5% MFB
Combustion phasing, CP [ms]	Maximum HRR
End of combustion, EC [ms]	80%MFB
Combustion acceleration period [ms]	Between ID and CP (CP–ID)
Combustion duration period [ms]	Between ID and EC (EC–ID)



Results and conclusions

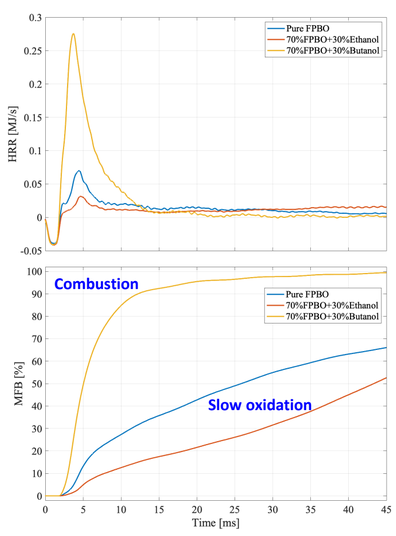
Pure FPBO

T=590 ºC, P_{inj}=1000 bar



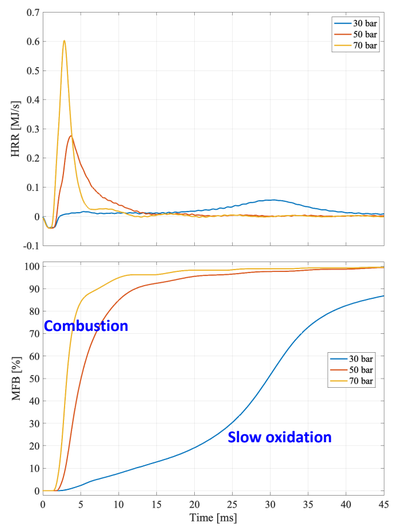
Effects of alcohol addition

T=590 ºC, P_{init}=50 bar, P_{inj}=1000 bar



Effects of P_{init}

T=590 ºC, P_{inj}=1000 bar



Effects of P_{inj}

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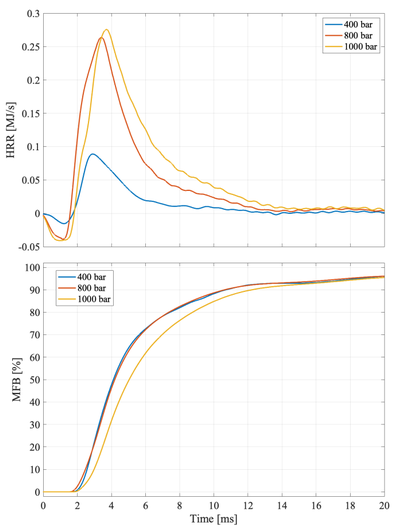
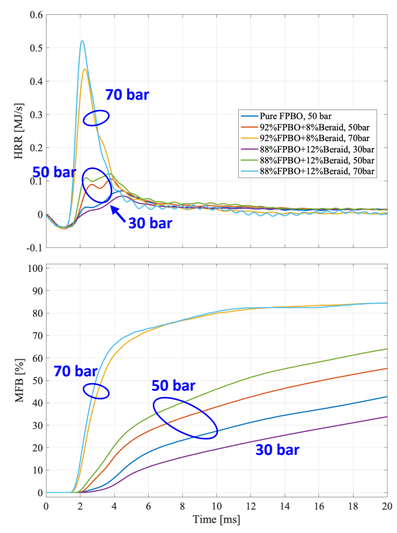


Effects of Beraid addition

T=590 ºC, P_{inj}=1000 bar



FPBO ignitability: between ethanol (CN ~7) and n-butanol (CN 17)

- Compared with ethanol, adding 30% n-butanol could significantly improve the ignition and combustion processes of FPBO.

Chamber pressure & injection pressure

- For 70%FPBO+30%Butanol, higher chamber pressure boosts ignition and combustion processes.
- Once the autoignition succeeds, the intense combustion (maximum HRR) arrivals within around 1 ms.
- Burn duration decreases with higher chamber pressure, while increases with higher injection pressure.

Ignition improver: Beraid is unqualified for FPBO

- When adding 12% Beraid to FPBO, the improvement in ignition behavior is very limited.

References

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[3] B. Beld, *et al*. (2018). The use of a fast pyrolysis oil–Ethanol blend in diesel engines for CHP applications. *Biomass and bioenergy*, 110, 114-122.

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