Ignition and combustion characteristics of n-butanol and FPBO/n-butanol blends with addition of ignition improver

Yu Wang, Jinlin Han, Noud Maes, Bart Somers
Department of Mechanical Engineering, Eindhoven University of Technology, The Netherlands

Background
- Fast Pyrolysis Bio-Oil (FPBO), a biomass-derived fuel, is studied to fuel stationary diesel engine for combined heat and power (CHP) generation
- The special properties of FPBO make the direct application in diesel engines very constrained: high water content (15-30 wt%), solid content, high viscosity, poor ignition quality, etc.
- Blending FPBO with n-butanol can improve the stability and atomization characteristics: reducing viscosity and surface tension, and preventing polymerization
- Additional ignition improver (e.g., 2-ethylhexyl nitrate, EHN), is in need of FPBO/alcohol blends to meet the requirement of compression ignition in the diesel engine
- Ignition and combustion characteristics of FPBO/n-butanol blends with addition of EHN is investigated in this study

Method: Experimental Setup - CRU
- The Combustion Research Unit (CRU) is employed to provide a well-defined and quiescent boundary condition for the investigation of ignition and combustion characteristics
  - Effects of EHN content on n-butanol are first investigated:
    - EHN mass fraction: 2%, 4%, 6%, 8%, 10%
    - Different chamber wall temperature: 520, 550, 580 °C
  - Effects of FPBO content on FPBO/n-butanol with EHN addition of 5% are then studied
    - FPBO mass fraction: 0%, 3%, 10%, 15%, 20%, 25%, 30%
    - Different chamber wall temperature: 490, 505, 520, 535, 550, 565, 580 °C
  - Other fixed operation conditions: initial chamber pressure of 30 bar, injection pressure of 1500 bar, and injection duration of 5.5 ms

Method: Data Processing & Definitions

Results

| Term            | Explanation                                      |
|-----------------|--------------------------------------------------|
| Pressure        | Chamber pressure                                 |
| PRR             | Pressure rise rate                               |
| MFB             | Mass fraction burned                            |
| 95%CI           | 95% confidence interval                         |
| Averaged data   | Averaged result from 5 single tests              |
| Ignition delay  | 5%MFB                                            |
| Combustion phasing | 50%MFB                                      |
| Combustion duration | 90%MFB – 10%MFB                              |

Figure 1: Left: the photo of CRU. Right: the schematic of the constant volume combustion chamber (CVCC) in the CRU.

Figure 2: A typical example of chamber pressure, pressure rise rate (PRR), and mass fraction burned (MFB) profiles (FPBO-30 at 580 °C)

Conclusion
- N-butanol + EHN: the increase of EHN proportion from 2% to 8% could effectively advance the low-temperature heat release phase, and hence shorten the ignition delay. The temperature is the dominant factor for combustion phasing and combustion duration.
- FPBO + N-butanol + 5%EHN: FPBO proportion has negligible effect on ignition delay in the chamber wall temperature range of 490 – 580 °C since its chemical reactivity is lower than n-butanol. The increase of FPBO proportion leads to a delayed combustion phasing and a prolonged combustion duration, while these effects become less obvious at the elevated temperature.
- Chamber wall temperature has a significant influence on the ignition and combustion processes of FPBO/n-butanol blends. A negative temperature coefficient (NTC) phenomenon was observed around a chamber wall temperature of 550 °C.