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Effect of Ambient Temperature and Density on the Transition of Hot Temperature Combustion to Low Temperature Combustion Using Commercial Diesel and Waste Plastic Diesel in an Optical Access Machine

By

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Outlines of Presentation

1. Introduction

- i. Background
- ii. Literature Review
- iii. Statements of Research

2. Material and Methods

3. Results and Discussion

4. Conclusion



Introduction

Background of Waste Plastic

- ❑ Plastics are essential materials due to their numerous applications in daily life. Consequently, a huge number of plastic products accumulate as waste in the environment.
- ❑ Plastic waste is a big issue in the world including Thailand, because the amount of recycled plastic remains low due to recycling problems.
- ❑ Thailand produces about 3.5 million tonnes of plastic waste, only 18% of which is recyclable



THE SEVEN TYPES OF PLASTIC	01 PETE 1) Polyethylene Terephthalate (PETE) Used in: Clear bottles (look for a 'bubble' on the bottom of a bottle), food trays (clear, green, black etc.). Recycled? One of the most commonly recycled plastics, clear bottles are likely to be recycled, remove lids first. Looks like? A tough plastic which discolours if you bend it.
02 HDPE 2) High Density Polyethylene (HDPE) Used in: White milk bottles all sizes, bleach type bottles, washing machine liquids and some bottle caps. Recycled? Very commonly recycled, remove lids first. Looks like? A thick tough plastic which will spring back if bent, caps can usually be flexed.	03 PVC-U 3) Polyvinyl Chloride (PVC - U) Used in: Clear bottles (look for a line on the bottom of the bottle), food trays, toys, piping, wire insulation. Recycled? Rarely recycled, check your local area. Looks like? More fragile and will crack and/or shatter bent if stressed, bottles make a 'crinkle' cracking sound if squeezed.
04 LDPE 4) Low Density Polyethylene (LDPE) Used in: Plastic bags, plastic wrapping, cling film. Recycled? Reuse of bags and targeted collection in supermarkets most likely, dispose of materials contaminated with food. Looks like? Can be very thin to thick, but usually flexible and easily torn.	05 PP 5) Polypropylene (PP) Used in: Butter and margarine tubs, clear fresh soup containers, some bottle caps, glass jar caps. Recycled? Not generally recycled, check your local area. Looks like? Will shatter into stripes if compressed, caps will usually be too hard to flex.
06 PS 6) Polystyrene or Styrofoam (PS) Used in: Yoghurt pots, insulated disposable cups, some trays, parcel packaging. Recycled? Not generally recycled, check your local area. Looks like? Will tear or pull apart depending on the form.	07 OTHER 7) OTHER Used in: Reading glasses, CDs, DVDs and cases, some electrical connections, wiring, general household plastics. Recycled? Reuse of items more likely, avoid placing in your recycling unless specifically instructed to do so. Looks like? The majority of these plastics are very tough and are likely to shatter if pressure is applied.



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- ❑ One of the recycling problems is **economy** as they need to be collected separately or sorted before the process can begin. Most plastics are not compatible with each other and hence they **cannot be processed together during recycling**.
- ❑ For instance, a polyvinyl chloride (PVC) bottle in polyethylene terephthalate (PET) recycle can ruin the **entire batch** by **becoming yellowish and brittle**.

<https://investforesight.com/russia-to-ban-single-use-plastic-items/>



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- ❑ Unlike recycling, pyrolysis does not require the separation of different plastics.
- ❑ The fast pyrolysis of mixed waste plastic into alternative fuels is an effective method for waste plastic management.



Pyrolysis

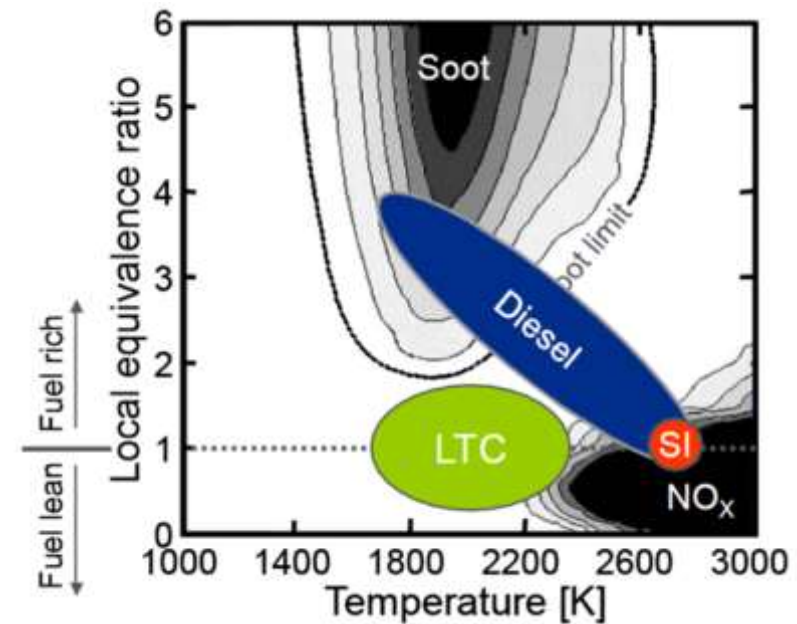




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Background of Diesel Engine

- ❑ Direct injection diesel engines are used extensively as the prime movers for public transportation, agricultural and heavy machinery, and electricity generation because they enable **high efficiency and lower fuel costs**.
- ❑ However, diesel engine emissions are a significant contributor to environmental pollution, especially **NO_x and smoke**.
- ❑ Emissions from diesel engines have become more important due to the increasing strictness of **emission regulations**.



Φ -T map

<https://www.greencarcongress.com/2011/05/ltc1-20110520.html>

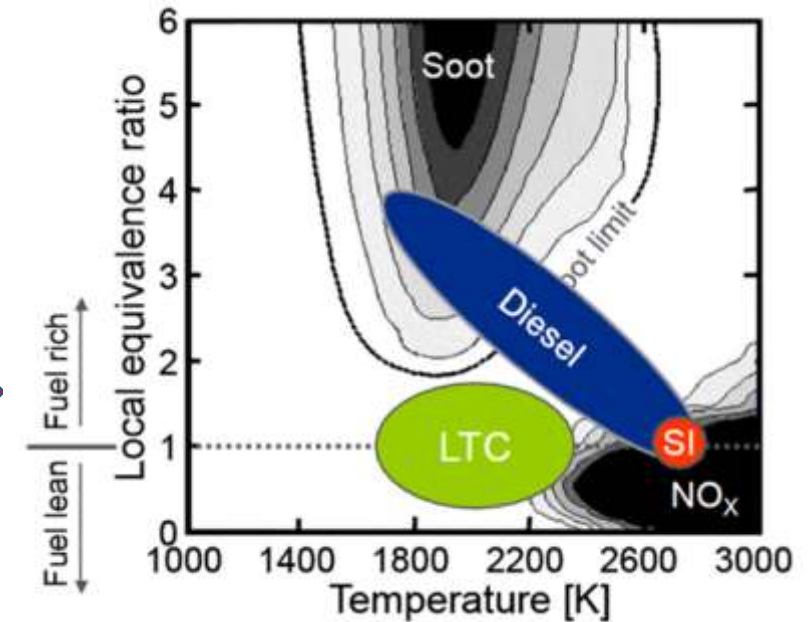
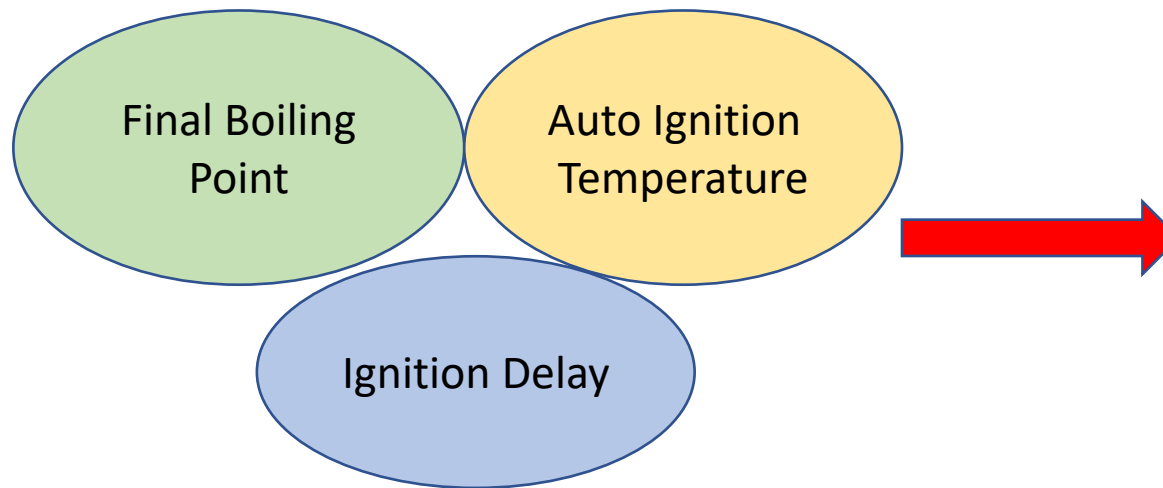


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What is the Low Temperature Combustion?

- LTC in diesel engines is capable of avoiding NO_x and PM formation zones.
- LTC is a general term for homogeneous charge compression ignition (HCCI), premixed charge compression ignition (PCCI), and reactivity control compression ignition (RCCI) combustion mode.

Premixed compression ignition (PCI) is a basic concept of LTC.





ii. Literature Review



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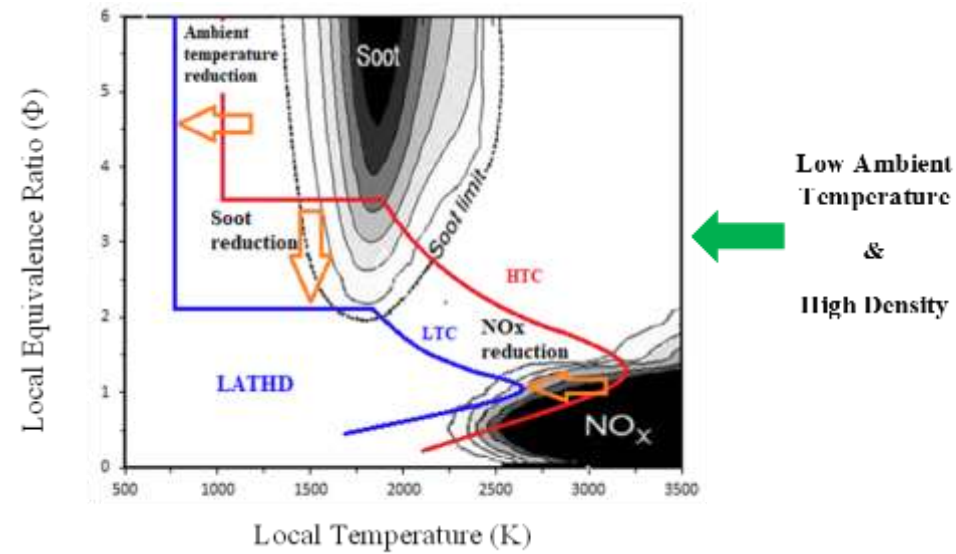
Conventional Combustion

(Trade-off of NO_x and Soot)

- Injection Timing
- Injection pressure
- Heavy EGR
- Low Compression Ratio
- Low Cetane Fuels

Low Temperature Diesel Combustion

(Trade-off of NO_x and Soot & UHC and CO)





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iii. Statements of Research

- ❑ Motivation: The new emissions trade-off for LTC is NO_x and Soot vs UHC and CO.
- ❑ Objective: The purpose of this research is to reduce NO_x and soot without damaging fuel efficiency.
- ❑ Contribution: Propose to investigate the combustion characteristics under different temperature and density at constant pressure without EGR and low cetane fuels.

RQ: How is the combined effect of temperature and density on combustion characteristic to change from convectional combustion to low temperature combustion?



Materials and Methods



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Table 1. Physical properties and CHSO of test fuels

Property	ASTM Method	CD	WPD
Density@15°C (kg/m ³)	D4052	824	806
Viscosity@40°C (Cst)	D445	3.24	2.9
Cetane Index	D976	56.43	67.93
Energy Content (MJ/kg)	D240	45.86	46.29
Flash Point (C)	D93	52	40
Auto ignition Temp (°C)	E-659	218	201
T ₁₀ (°C)			
T ₅₀ (°C)	D85	208	182
T ₉₀ (°C) volume%	D85	288	291
	D85	352	385
Paraffin Content (wt. %)			
Total Aromatics Content (wt.%)	D3238	60.61	80.41
Sulfur Content (wt. %)	D3238	13.48	5.05
Carbon Content (wt. %)	D5453	0.003	0.014
Hydrogen Content (wt. %)	D5373	84.75	83.45
H/C Ratio	D5373	13.62	14.14
Ash Content (wt. %)	D189	1.93	2.03
	D482	0.001	0.001
Fatty acid methyl ester, %vol	EN14078	8.7	0
Copper strip corrosion	D130	1a	1a
Total Acid Number (mgKOH/g)	D664	0.27	0.26



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Table 2. Experimental conditions

Parameters	Values
Injection Pressure	140 MPa
Ambient Pressure	4 MPa
Ambient Temperature	1050K, 900K, 750K
Ambient Density	13.27, 15.49, 18.58 kg/m ³
Injected Amount	30 mg
Energizing Time	2.13 ms for CD 2.148 ms for WPD
Oxygen Concentration	21% (volume)
Temperature of Cylinder Wall, Inlet and Exhaust	453 K
Nozzle Diameter	0.2 mm (single hole)

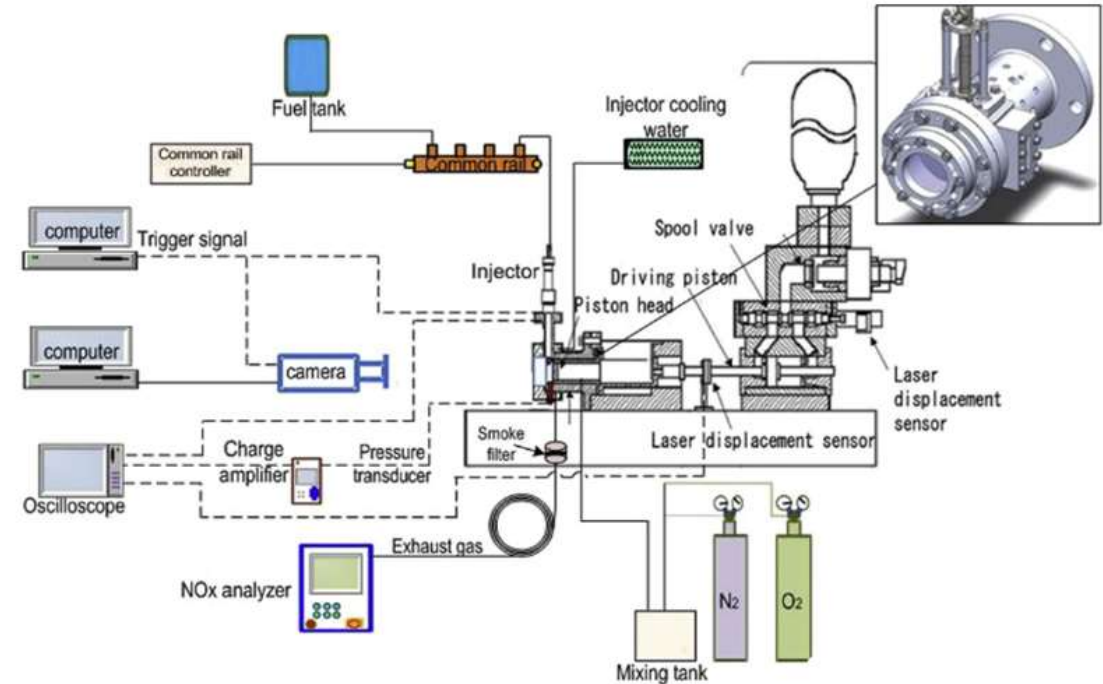


Fig. 2 Schematic diagram of experimental apparatus

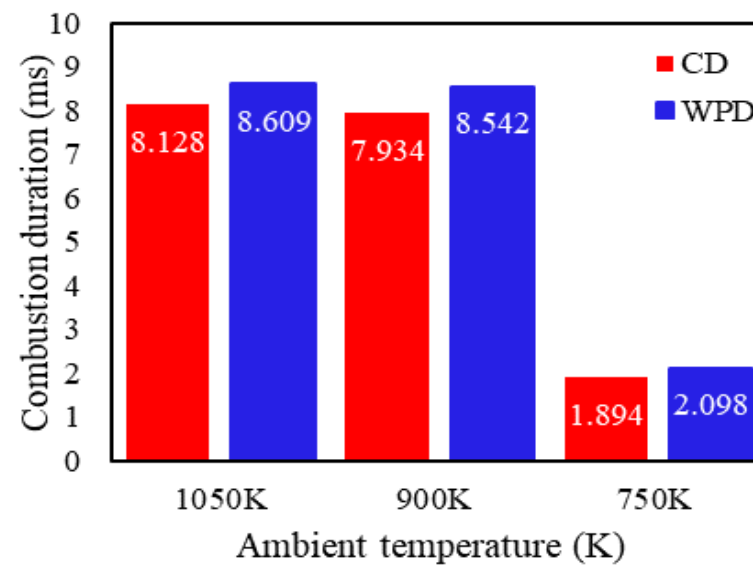
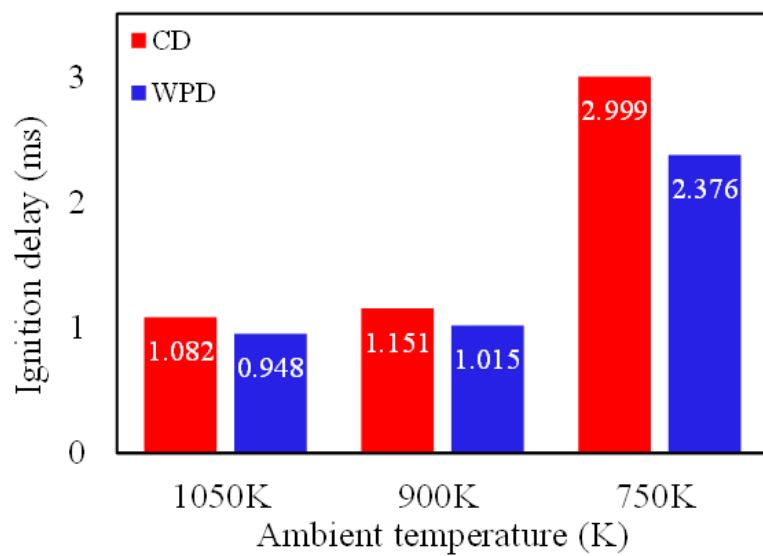


Results and Discussion



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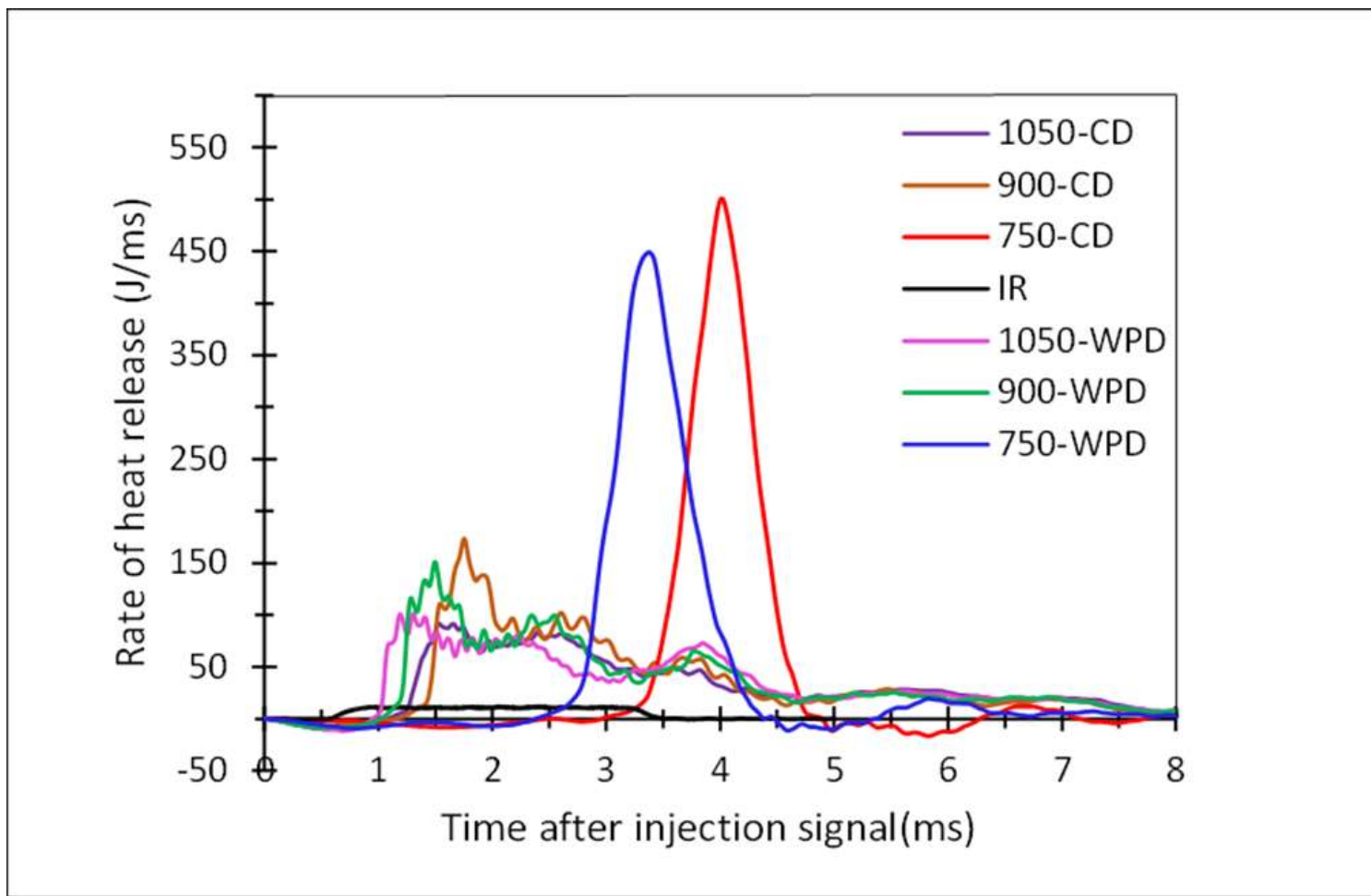
Ignition Delay and Combustion duration





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Heat Release Rate (HRR)



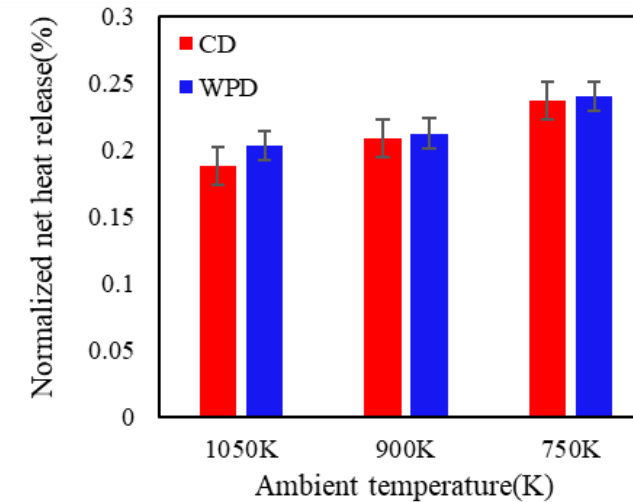
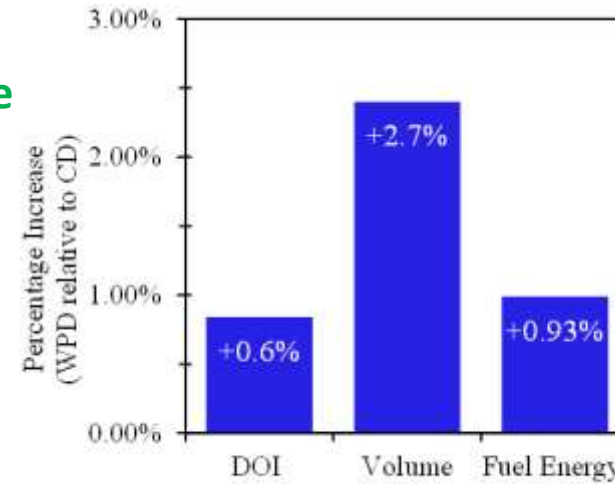
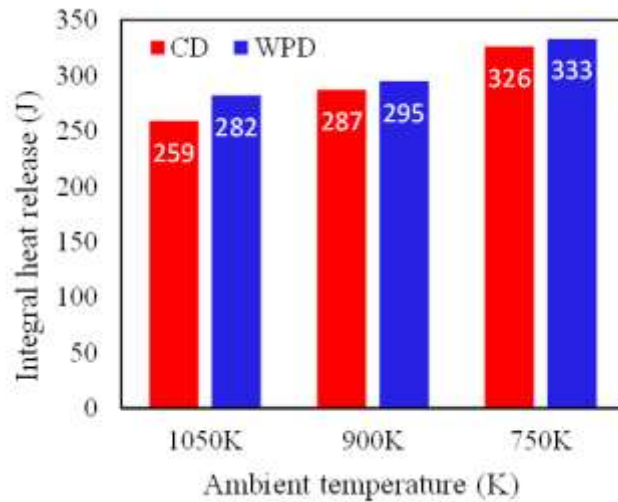


Integral Release Rate (IRR)

- Heat transfer loss is greatly reduced with low flame temperature and a short combustion duration.



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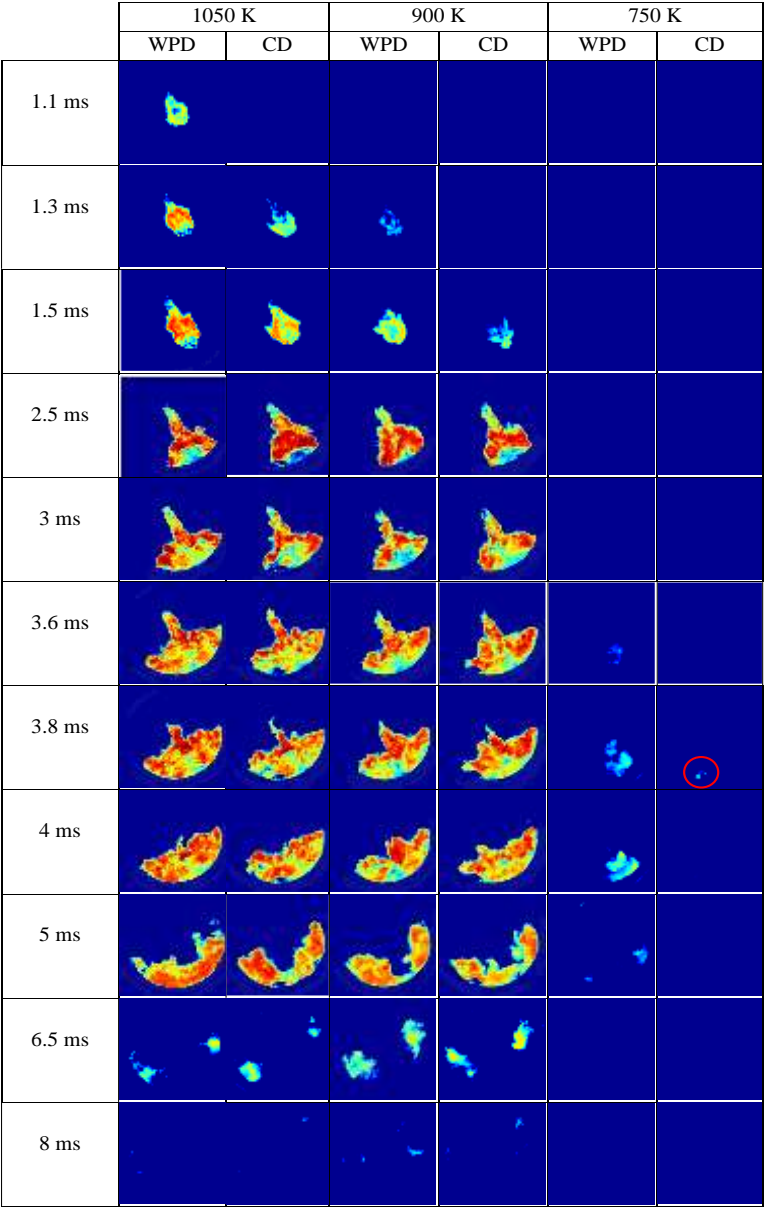


Spatial Distribution of Flame Temperature



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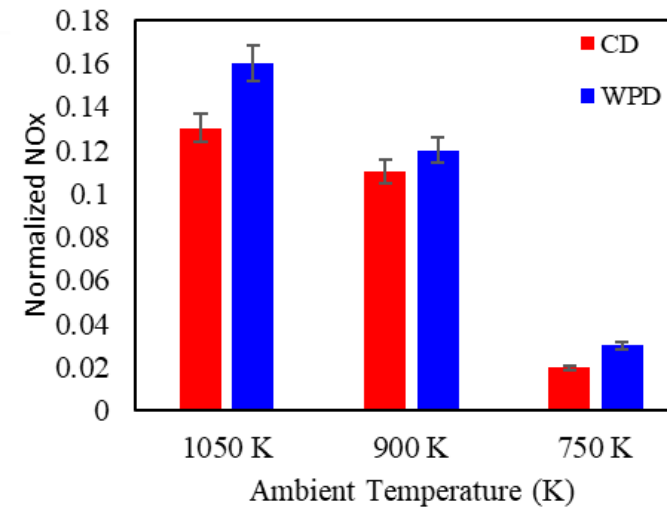
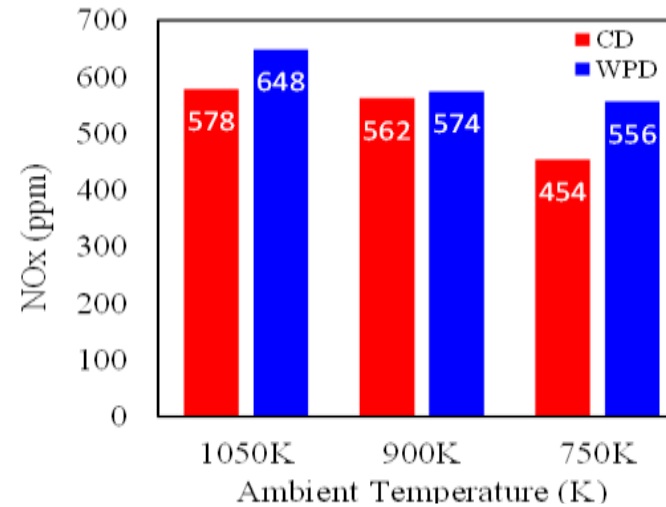
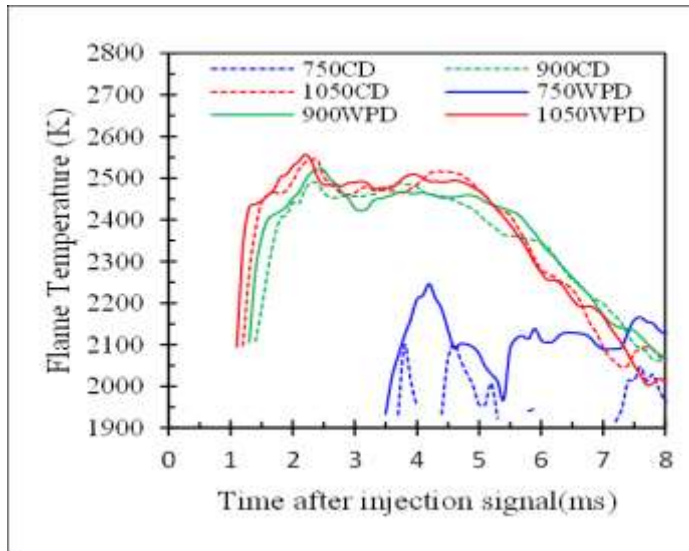
$PV = mRT$
 $Q = mc(T_2 - T_1)$





NO_x Concentrations

- The NO_x of WPD was higher than that of CD because of higher flame temperature, even though it had a **short ID and lower peak HRR**.
- Therefore, IHR is a **dominant factor** to interpret NO_x and flame temperature.



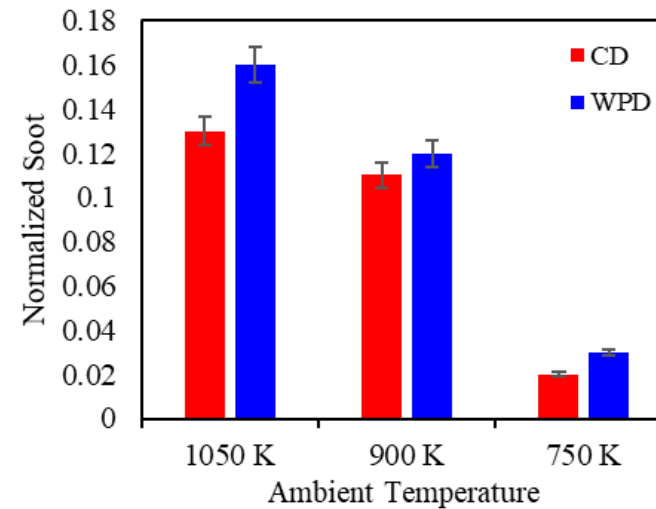
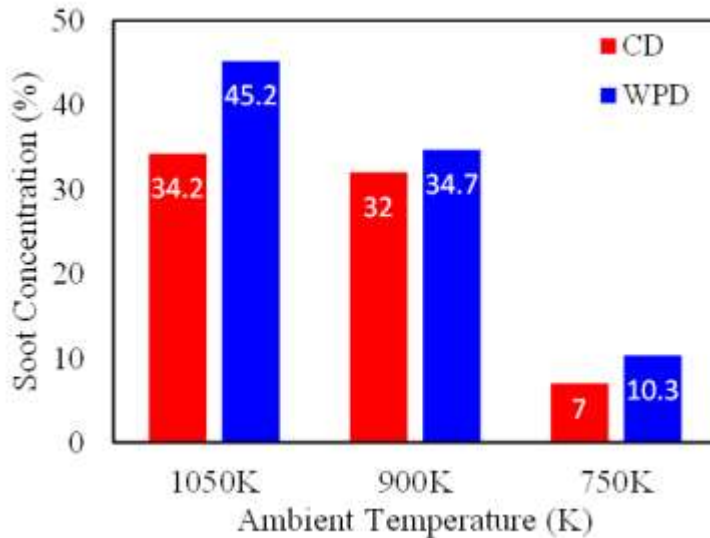
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Soot Concentrations

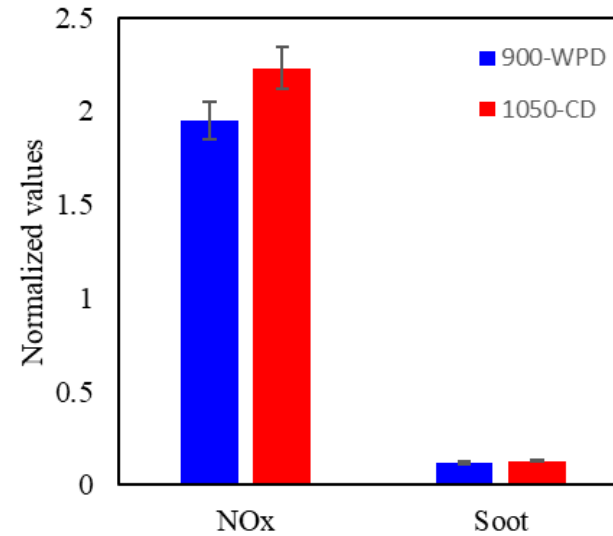
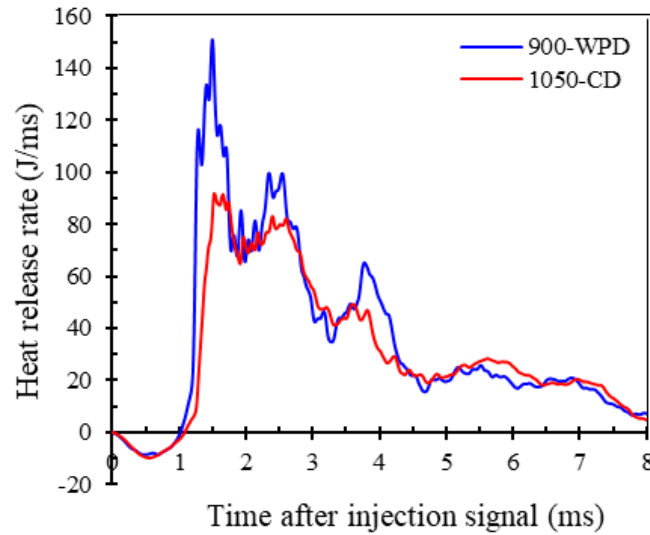
- The **degree of homogeneity and lean mixture** formation of CD can be increased more than WPD because of a **longer ID**.
- Therefore, soot concentrations of WPD are higher than that of CD.





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NOx and soot concentrations at the same ignition delay



- The soot formation **tendency of low aromatic fuel** is decreased at the same ID or cetane number.
- NOx formation is suppressed by the combined effect of low ambient temperature and high density.
- This information involves very important parameters for examining the **optimum combustion phasing** of different cetane fuels for real engine design.



Conclusions/ Summary



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- **Proposed a method** of low temperature combustion **without EGR and low cetane fuel**.
- Effect of low ambient temperature and high density has been studied on low temperature combustion.
- **NOx and soot** can reduce simultaneously while improving **combustion efficiency**.
- Integral heat release is a dominant factor **to interpret NOx** emission.
- NOx and soot concentrations of waste plastic diesel are **higher at same ambient condition**.
- NOx and soot concentrations of waste plastic diesel are **lower at same ignition delay**.