Improvement of HCCI Engine Performance by Fuel Composition

Dr. Gen Shibata  Chief Engineer of Fuel Production R&D
Nippon Oil Corporation

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Outline

1. Background of Research and Motivation
   -What is the DP-HTHR combustion?-  

2. Possibility of Significant CO oxidation in 2\textsuperscript{nd} HTHR 

3. Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries 

4. Implications of DP-HTHR: a Study of HCCI Combustion Process 

5. Conclusions
**Background of Research and Motivation**

- What is the DP-HTHR combustion? -

**Gasoline HCCI**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine type</td>
<td>4 cylinder MPI</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>15:1</td>
</tr>
<tr>
<td>Bore</td>
<td>86mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>86mm</td>
</tr>
<tr>
<td>Displacement</td>
<td>1998cc</td>
</tr>
<tr>
<td>Exhaust valve open</td>
<td>53°C CA BBDC</td>
</tr>
<tr>
<td>Exhaust valve close</td>
<td>7°C CA ATDC</td>
</tr>
<tr>
<td>Intake valve open</td>
<td>1°C CA ATDC</td>
</tr>
<tr>
<td>Intake valve close</td>
<td>19°C CA ABDC</td>
</tr>
</tbody>
</table>

**Test Conditions**

- Engine speed: 1000rpm
- Intake pressure: 155kPa (abs)
- Intake air temperature: 58°C

Parameter: Maximum pressure rise rate
- 900, 800, 700, 600, 500, 400, 300kPa/deg (over 400 cycles average)
Background of Research and Motivation

- What is the DP-HTHR combustion? -

Definition of heat release in this presentation

Dashed Area--- Integrated heating value of High Temperature Heat Release

HTHR CA50 --- The crank angle of 50% burn of High Temperature Heat Release
Background of Research and Motivation
- What is the DP-HTHR combustion? -

Test fuel properties

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>PRF90</th>
<th>NDB90</th>
<th>NMP85</th>
<th>NTL75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research octane number</td>
<td>90.0</td>
<td>89.3</td>
<td>85.0</td>
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<tr>
<td>Density g/cm³ @15°C</td>
<td>0.6938</td>
<td>0.7076</td>
<td>0.6723</td>
<td>0.7986</td>
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<td>Hydrocarbons</td>
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<tr>
<td>n-Heptane</td>
<td>10.0</td>
<td>38.1</td>
<td>19.7</td>
<td>40.5</td>
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<tr>
<td>iso-Octane</td>
<td>90.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vol%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Di-isobutylene</td>
<td></td>
<td></td>
<td>61.9</td>
<td></td>
</tr>
<tr>
<td>4Methyl-1-pentene</td>
<td></td>
<td></td>
<td></td>
<td>80.3</td>
</tr>
<tr>
<td>Toluene</td>
<td></td>
<td></td>
<td></td>
<td>59.5</td>
</tr>
<tr>
<td>H/C</td>
<td>2.27</td>
<td>2.12</td>
<td>2.07</td>
<td>1.53</td>
</tr>
<tr>
<td>CH wt %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>84.09</td>
<td>84.99</td>
<td>85.28</td>
<td>88.68</td>
</tr>
<tr>
<td>H</td>
<td>15.91</td>
<td>15.01</td>
<td>14.72</td>
<td>11.32</td>
</tr>
<tr>
<td>Heating value kJ/kg</td>
<td>44367</td>
<td>44249</td>
<td>44249</td>
<td>41937</td>
</tr>
</tbody>
</table>
Background of Research and Motivation

- What is the DP-HTHR combustion? -

**Graph:**
- **PRF90:** n-Heptane 10% + iso-Octane 90%
- 523.5kPa
- 800kPa/deg
- 900kPa/deg
- 700kPa/deg
- 600kPa/deg
- 500kPa/deg
- 400kPa/deg
- 300kPa/deg
- 303.9kPa
- 0.76CA
- 4.68CA

**Graph Images:*
- **IMEP 523.5kPa**
  - HTHR CA50 0.76CA
- **IMEP 303.9kPa**
  - HTHR CA50 4.68CA
Improvement of HCCI Engine Performance by Fuel Composition

PRF90: n-Heptane 10% + iso-Octane 90%
NDB90: n-Heptane 38.1% + Diisobutylene 61.9%
NMP85: n-Heptane 19.7% + 4-Methyl-1-pentene 80.3%
NTL75: n-Heptane 40.5% + Toluene 59.5%
Background of Research and Motivation

- What is the DP-HTHR combustion? -

There is a difference between those two operational IMEP ranges.

![Graph showing operational ranges of different fuels]

- PRF90: n-Heptane 10% + iso-Octane 90%
- NDB90: n-Heptane 38.1% + Diisobutylene 61.9%
- NMP85: n-Heptane 19.7% + 4-Methyl-1-pentene 80.3%
- NTL75: n-Heptane 40.5% + Toluene 59.5%
Background of Research and Motivation

- What is the DP-HTHR combustion? -

Point A is the position where the HCCI engine can be run at the same HTHR CA50 and IMEP conditions with 4 different fuels.

Point A

![Graph showing different fuels and their HTHR CA50 and IMEP values.]

- PRF90: n-Heptane 10% + iso-Octane 90%
- NDB90: n-Heptane 38.1% + Diisobutylene 61.9%
- NMP85: n-Heptane 19.7% + 4-Methyl-1-pentene 80.3%
- NTL75: n-Heptane 40.5% + Toluene 59.5%
Background of Research and Motivation

- What is the DP-HTHR combustion? -

The heat release data of 4 different fuels measured at Point A
1) Maximum heat release of NTL 75 is the lowest
2) The heat release phasing of NTL75 is obviously different

- Fuel Composition -

**PRF90**: n-Heptane 10% + iso-Octane 90%
**NDB90**: n-Heptane 38.1% + Diisobutylene 61.9%
**NMP85**: n-Heptane 19.7% + 4-Methyl-1-pentene 80.3%
**NTL75**: n-Heptane 40.5% + Toluene 59.5%
Background of Research and Motivation

- What is the DP-HTHR combustion? -

n-Heptane

C-C-C-C-C-C-C

Radicals and low molecular weight hydrocarbons
(R, OH, ROOH, RO2, H2O2, HCHO, C2H2…)

Blue flame reaction starts (1st HTHR)

High reactivity

Raw n-Heptane

Radicals and low molecular weight hydrocarbons

Low reactivity

Toluene

Aromatics and benzyl radicals

Cool flame (τ2)

750-800K

LTHR

Blue flame

880-950K

HTHR

Hot flame

1100-1150K

Ring opening reaction (Hot flame reaction) (2nd HTHR)

Dual Phase High Temperature Heat Release (DP-HTHR)

Cool flame (τ2)

750-800K

Blue flame

880-950K

Hot flame

1100-1150K
Background of Research and Motivation

- What is the DP-HTHR combustion? -

Characteristics of DP-HTHR combustion

Histories of maximum pressure rise rate over 400 cycles at Point A

DP-HTHR has the potential to enlarge the HCCI operational range to the higher engine load.
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5. Conclusions
H/C of NTL75 is the lowest of the four fuels

It is expected that the CO production must be NTL75 > NMP85, NDB90, PRF90

Question: Was the second bump of DP-HTHR caused by the significant CO oxidation process?

We investigated the possibility of significant CO oxidation in 2nd HTHR.
Possibility of Significant CO oxidation in 2nd HTHR

(1) Temperature histories for four fuels at Point A were investigated

The combustion temperature ranges are same between the fuels at Point A.
Possibility of Significant CO oxidation in 2nd HTHR

(2) CO and CO2 emission trends were investigated

It was very difficult to distinguish the emission trends from those four fuel test data measured at Point A.

so…

We evaluated the CO and CO2 emission trends by the emission data tested previously.
Possibility of Significant CO oxidation in 2nd HTHR

(2) CO and CO2 emission trends were investigated

**CO Emissions:**
- DP-HTHR > *SP-HTHR*
  
  (Effect of H/C ratio)

*SP-HTHR*: single phase HTHR (conventional combustion)
Possibility of Significant CO oxidation in 2nd HTHR

(2) CO and CO2 emission trends were investigated

**CO Emissions:**
DP-HTHR > *SP-HTHR
(Effect of H/C ratio)

**CO2 Emissions:**
No difference between DP-HTHR and SP-HTHR

*SP-HTHR: single phase HTHR (conventional combustion)
Possibility of Significant CO oxidation in 2nd HTHR

CO emissions of DP-HTHR are much emitted than those of SP-HTHR

*SP-HTHR: single phase HTHR (conventional combustion)
Possibility of Significant CO oxidation in 2nd HTHR

CO emissions of DP-HTHR are much emitted than those of SP-HTHR

But, the combustion temperature ranges are same if the combustion conditions (IMEP and HTHR CA50) are same.
Possibility of Significant CO oxidation in 2\textsuperscript{nd} HTHR

CO emissions of DP-HTHR are much emitted than those of SP-HTHR

But, the combustion temperature ranges are same if the combustion conditions (IMEP and HTHR CA50) are same.

As a result, CO\textsubscript{2} emission levels are same between SP- and DP-HTHRs

*SP-HTHR: single phase HTHR (conventional combustion)
Possibility of Significant CO oxidation in 2nd HTHR

Our conclusion is:

The second bump of DP-HTHR (blue area) is NOT caused by the significant CO oxidation processes
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3. Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

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5. Conclusions
Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

• DP-HTHR can be achieved by NTL series fuels.
  (NTL fuel: n-heptane + toluene chemical blended fuel)  SAE 2008-01-0007

• NTL fuels work well for research laboratory fuels, but are not realistic as HCCI market fuels.

From the point of oil industries, our interest is...

“Is it possible to achieve the DP-HTHR combustion with blends of refinery base gasoline fuels?”
Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

Characteristics of NTL fuel to achieve DP-HTHR

Pure n-heptane 45vol%

Pure toluene 55vol%

32vol%

68vol%

- LSR and HSR have high paraffin contents
- L-FMT has high aromatic contents

LSR: light straight run naphtha
HSR: heavy straight run naphtha
L-FMT: light reformatted gasoline

We selected LSR, HSR and L-FMT as base gasolines.

<table>
<thead>
<tr>
<th>BASE gasolines</th>
<th>LSR</th>
<th>HSR</th>
<th>L-FMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octane numbers</td>
<td>RON</td>
<td>72.7</td>
<td>48.1</td>
</tr>
<tr>
<td></td>
<td>MON</td>
<td>77-79</td>
<td>48.5</td>
</tr>
<tr>
<td>Density g/cm³ @15°C</td>
<td>0.6434</td>
<td>0.7305</td>
<td>0.8481</td>
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<tr>
<td>RVP kPa</td>
<td>120.0</td>
<td>13.5</td>
<td>6.5</td>
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<tr>
<td>Distillation</td>
<td>IBP</td>
<td>24.0</td>
<td>80.0</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>33.0</td>
<td>95.0</td>
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<td>30%</td>
<td>38.5</td>
<td>101.0</td>
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<td></td>
<td>50%</td>
<td>43.5</td>
<td>109.0</td>
</tr>
<tr>
<td></td>
<td>70%</td>
<td>50.5</td>
<td>118.0</td>
</tr>
<tr>
<td></td>
<td>90%</td>
<td>61.5</td>
<td>130.0</td>
</tr>
<tr>
<td></td>
<td>EP</td>
<td>70.0</td>
<td>152.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel composition</th>
<th>n-Paraffins</th>
<th>iso-Paraffins</th>
<th>Olefins</th>
<th>Naphthenes</th>
<th>Aromatics</th>
<th>C4-C6 n-Paraffins</th>
<th>C7-C9 n-Paraffins</th>
<th>Toluene</th>
</tr>
</thead>
<tbody>
<tr>
<td>vol%</td>
<td>55.19</td>
<td>38.99</td>
<td>0.01</td>
<td>4.84</td>
<td>0.97</td>
<td>55.14</td>
<td>0.05</td>
<td>0.01</td>
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<td></td>
<td>33.72</td>
<td>35.80</td>
<td>0.47</td>
<td>19.06</td>
<td>10.87</td>
<td>8.02</td>
<td>25.69</td>
<td>3.93</td>
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<td></td>
<td>5.57</td>
<td>4.92</td>
<td>2.91</td>
<td>2.63</td>
<td>83.89</td>
<td>0.03</td>
<td>5.54</td>
<td>76.98</td>
</tr>
</tbody>
</table>
Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

Required fuel characteristics to achieve DP-HTHR combustion for our HCCI engine are…

1. $0.36 < \text{n-paraffins/aromatics (mass ratio)} < 0.64$
   $(70 < \text{RON} < 85)$
Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

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1. \(0.36 < \text{n-paraffins/aromatics (mass ratio)} < 0.64\)
   \((70 < \text{RON} < 85)\)

The following market gasoline characteristics, except octane numbers, are required from the point of environmental restrictions of SIDI combustion.

2. \(0.72\text{g/cm}^3 < \rho < 0.78\text{g/cm}^3\) @\(15^\circ\text{C}\) (density)
3. IBP < 40°C
4. 80°C < T50 < 110°C
5. T90 < 180°C
6. Reid vapor pressure < 65kPa
# Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

## Test fuel properties

<table>
<thead>
<tr>
<th>Fuel products</th>
<th>GAS2</th>
<th>GAS3</th>
<th>GAS4</th>
<th>Target range for DP-HTHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octane numbers</td>
<td>RON</td>
<td>80.2</td>
<td>81.2</td>
<td>81.9</td>
</tr>
<tr>
<td></td>
<td>MON</td>
<td>76.7</td>
<td>76.2</td>
<td>76.0</td>
</tr>
<tr>
<td>Density (\text{g/cm}^3@15^\circ\text{C})</td>
<td>0.7295</td>
<td>0.7437</td>
<td>0.7579</td>
<td>0.72 (\leq) p (\leq) 0.78</td>
</tr>
<tr>
<td>RVP (\text{kPa})</td>
<td>68.5</td>
<td>58.0</td>
<td>46.5</td>
<td>RVP (\leq) 65kPa</td>
</tr>
<tr>
<td>Distillation</td>
<td>IBP</td>
<td>32.5</td>
<td>34.5</td>
<td>38.5</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>49.5</td>
<td>55.5</td>
<td>65.0</td>
</tr>
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<td></td>
<td>30%</td>
<td>65.5</td>
<td>75.0</td>
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<td>50%</td>
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<td>70%</td>
<td>104.5</td>
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<td></td>
<td>90%</td>
<td>113.5</td>
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<td>EP</td>
<td>129.5</td>
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<td>Blending ratio %</td>
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<td>HSR</td>
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<td>L-FMT</td>
<td>35.0</td>
<td>40.0</td>
<td>45.0</td>
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<tr>
<td>Fuel composition</td>
<td>n-Paraffins</td>
<td>30.83</td>
<td>27.21</td>
<td>24.27</td>
</tr>
<tr>
<td>mass%</td>
<td>iso-Paraffins</td>
<td>24.49</td>
<td>22.54</td>
<td>20.97</td>
</tr>
<tr>
<td></td>
<td>Olefins</td>
<td>0.31</td>
<td>0.35</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Naphthenes</td>
<td>6.03</td>
<td>6.35</td>
<td>6.97</td>
</tr>
<tr>
<td></td>
<td>Aromatics</td>
<td>38.34</td>
<td>43.55</td>
<td>47.41</td>
</tr>
<tr>
<td>n-Paraffins/Aromatics mass%ratio</td>
<td>0.80</td>
<td>0.62</td>
<td>0.51</td>
<td>0.36 (\leq) nP/A (\leq) 0.64</td>
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<tr>
<td>Stoic. A/F</td>
<td>14.54</td>
<td>14.44</td>
<td>14.36</td>
<td>-</td>
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<tr>
<td>H/C</td>
<td>1.85</td>
<td>1.78</td>
<td>1.73</td>
<td>-</td>
</tr>
<tr>
<td>CH wt %</td>
<td>C</td>
<td>88.64</td>
<td>87.07</td>
<td>87.41</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>13.36</td>
<td>12.93</td>
<td>12.59</td>
</tr>
<tr>
<td>Heating value</td>
<td>kJ/kg</td>
<td>45480</td>
<td>45210</td>
<td>44940</td>
</tr>
</tbody>
</table>

**Our estimation**

**GAS2**: SP-HTHR

**GAS3**: Intermediate combustion between SP- and DP-HTHR

**GAS4**: DP-HTHR
Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

Test results

<Test condition>
Engine speed: 1000rpm
Boost pressure: 155kPa abs
Initial intake air temp: 58°C
Max dP/dθ: 700kPa/deg

Our estimation
GAS2: SP-HTHR
GAS3: Intermediate combustion between SP- and DP-HTHR
GAS4: DP-HTHR

BINGO!

(1) As the increase of aromatic content in the fuel, combustion phase changes from single phase to dual phase.

(2) GAS4 showed the DP-HTHR combustion.
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5. Conclusions
Implications of DP-HTHR: a Study of HCCI Combustion Process

n-Heptane

C-C-C-C-C-C

High reactivity

Radicals and low molecular weight hydrocarbons
(R, OH, ROOH, RO2, H2O2, HCHO, C2H2…)

Raw n-Heptane

Toluene

Low reactivity

Radicals and low molecular weight hydrocarbons

Aromatics and benzyl radicals

The examples of unreactive hydrocarbons have been reported

750-800K

LTHR

880-950K

HTHR

1100-1150K

Cool flame \( \tau_2 \)

Blue flame reaction starts (1st HTHR)

Hot flame

Survive (unreactive)

Ring opening reaction (Hot flame reaction) (2nd HTHR)

Cool flame

Blue flame

Hot flame

750K

900K

1100K

Rate of Net release JCA

Crank angle deg ATDC

Fuel NTL96
Engine speed 1000rpm
IMEP 500kPa
HTHR CA80 1.5deg A
Implications of DP-HTHR: a Study of HCCI Combustion Process

- High Speed In-cylinder Gas Sampling Data (RCM) -

Do hydrocarbon exist when HTHR starts?

Fuel: n-butane

N-butane (fuel) exists in each case when HTHR starts.
Implications of DP-HTHR: a Study of HCCI Combustion Process

The difference of those four fuels is the chemical kind of additional hydrocarbons.

<table>
<thead>
<tr>
<th>Octane numbers</th>
<th>BASE</th>
<th>K05</th>
<th>K07</th>
<th>K09</th>
<th>K10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RON</td>
<td>87.3</td>
<td>76.3</td>
<td>73.8</td>
<td>88.3</td>
<td>92.0</td>
</tr>
<tr>
<td>MON</td>
<td>74.0</td>
<td>68.3</td>
<td>65.5</td>
<td>77.3</td>
<td>76.3</td>
</tr>
<tr>
<td>Density</td>
<td>0.7281</td>
<td>0.7167</td>
<td>0.7207</td>
<td>0.722</td>
<td>0.7529</td>
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<tr>
<td>Reid vapour pressure</td>
<td>38</td>
<td>38.0</td>
<td>34.0</td>
<td>34.5</td>
<td>33.0</td>
</tr>
</tbody>
</table>

**Fuel composition**

<table>
<thead>
<tr>
<th></th>
<th>BASE</th>
<th>K05</th>
<th>K07</th>
<th>K09</th>
<th>K10</th>
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<tbody>
<tr>
<td>n-Pentane</td>
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<td>7.49</td>
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<td>n-Heptane</td>
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<td>Diisobutylene</td>
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<td>Isooctane</td>
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<td>7.40</td>
<td>7.35</td>
<td><strong>24.69</strong></td>
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<td>m-Xylene</td>
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**Stoic. A/F**

<table>
<thead>
<tr>
<th></th>
<th>BASE+ n-Hexane</th>
<th>BASE+ n-Heptane</th>
<th>BASE+ Isooctane</th>
<th>BASE+ Toluene</th>
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<tbody>
<tr>
<td>14.70</td>
<td>14.79</td>
<td>14.78</td>
<td>14.77</td>
<td>14.45</td>
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<td>85.95</td>
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<td>87.04</td>
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**Heating value**

<table>
<thead>
<tr>
<th></th>
<th>BASE</th>
<th>K05</th>
<th>K07</th>
<th>K09</th>
<th>K10</th>
</tr>
</thead>
<tbody>
<tr>
<td>kJ/kg</td>
<td>43502</td>
<td>43719.9</td>
<td>43677.5</td>
<td>43645.9</td>
<td>42889.4</td>
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</tbody>
</table>

Remarks:

- BASE + n-Hexane 17.5%
- BASE + n-Heptane 17.5%
- BASE + Isooctane 17.5%
- BASE + Toluene 17.5%
Implications of DP-HTHR: a Study of HCCI Combustion Process

If a fuel is consisted from n-heptane, n-hexane, iso-octane, and toluene, the HTHR of n-heptane will occur first and the following HTHR combustion order will be n-hexane, iso-octane and toluene, as shown in a dot blue line.
Implications of DP-HTHR: a Study of HCCI Combustion Process

Paraffins (RH)  Olefins

High reactivity (except methane)

Radicals and low molecular weight hydrocarbons
(R, OH, ROOH, RO2, H2O2, HCHO, C2H2…)

Process 1
(LTHR and LTHR inhibitor process)

Naphthenes  Aromatics

Low reactivity

Radicals and low molecular weight hydrocarbons

Process 1

Radicals assist the blue flame reaction

Cool flame (τ2)  Blue flame  Hot flame

750-800K  880-950K  1100-1150K

LTHR  HTHR
Implications of DP-HTHR: a Study of HCCI Combustion Process

Un-reactive hydrocarbons survive the cool flame period, and they start to breakdown in HTHR period respectively, depending on the unique breakdown temperature of each chemical.

Raw paraffins and olefins

- Process 2 (Temperature of hydrocarbon breakdown process)

- Paraffins (RH)
- Olefins
- Naphthenes
- Aromatics

Naphthenes aromatics and those radicals

- Process 2

Cool flame ($\tau_2$) 880-950K LTHR

Blue flame 750-800K

Hot flame 1100-1150K HTHR

1. Ring opening reaction occurs and olefins were produced
2. Olefins' reaction

Regular tetrahedral structure breaks down

Survive (unreactive)
Implications of DP-HTHR: a Study of HCCI Combustion Process

Paraffins (RH)
- High reactivity
- (except methane)

Olefins
- Radicals and low molecular weight hydrocarbons
  - (R, OH, ROOH, RO2, H2O2, HCHO, C2H2…)
  - (Process 1)

Naphthenes
- Low reactivity

Aromatics

Radicals assist the blue flame reaction

Raw paraffins and olefins
- Survive (unreactive)
- Olefins start to react from blue flame period assisted by radicals

Radicals and low molecular weight hydrocarbons
- (Process 1)

Radicals assist the blue flame reaction

Naphthenes aromatics and those radicals
- Survive (unreactive)
- Regular tetrahedral structure breaks down

Radicals assist the blue flame reaction

Olefins' reaction

1. Ring opening reaction occurs and olefins were produced
2. Olefins’ reaction

Cool flame (τ2)
- 750-800K
- LTHR
Blue flame
- 880-950K
- HTHR
Hot flame
- 1100-1150K

Survive (unreactive)
Implications of DP-HTHR: a Study of HCCI Combustion Process

We are thinking…

Process 1 is important for
(1) radical production
(2) enhancement of T&P

Process 2 also affects the combustion processes of HTHR

Personality of HTHR by Hydrocarbons
Outline

1. Background of Research and Motivation
   -What is the DP-HTHR combustion?-

2. Possibility of Significant CO oxidation in 2nd HTHR

3. Realization of DP-HTHR Combustion of Base Gasoline Blends from Oil Refineries

4. Implications of DP-HTHR: a Study of HCCI Combustion Process

5. Conclusions
Conclusions

1. The 2\textsuperscript{nd} HTHR of DP-HTHR was not caused by a rapid CO oxidation process, but the decomposition and oxidation process of the benzene ring in toluene (benzene radicals and aromatics).

2. DP-HTHR combustion technique was applied for the base gasoline blended fuels. Three gasoline fuels were blended from light naphtha, heavy naphtha, and catalytic reformatted gasoline. Of those gasoline blends, GAS4 showed DP-HTHR combustion.
Conclusions

3. For the GAS2, GAS3 and GAS4 cases, the tendency of single phase high temperature heat release (SP-HTHR) or DP-HTHR can be arranged by n-paraffins/aromatics ratio (n-P/A) in the fuel. Higher n-P/A ratio fuels combust in SP-HTHR, and lower n-P/A ratio fuels combust in DP-HTHR.

4. The key point of DP-HTHR combustion is the blending of two hydrocarbons with distinct auto-ignitability characteristics. One hydrocarbon has a high auto ignitability and the other hydrocarbon has a low auto ignitability.
Conclusions

5. There are two processes that assist HCCI combustion.
   1) LTHR&LTHR inhibitor process
   2) Temperature of hydrocarbon breakdown process in HTHR

6. The reason why the HTHR difference can be found under no LTHR condition at the same load is caused by the difference of the breakdown and oxidation temperature (HTHR start temperatures) of each hydrocarbon in fuel.
Reference Papers

SAE 2008-01-0007
Dual Phase High Temperature Heat Release Combustion

SAE 2009-01-0298
Realization of Dual Phase High Temperature Heat Release Combustion of Base Gasoline Blends from Oil Refineries and a Study of HCCI Combustion Processes
Contact

Gen Shibata

gen.shibata@eneos.co.jp