Hydrogen Fueled Internal Combustion Engines (H2 ICE)

Eiji Tomita,
Okayama University, (Japan)
tomita@mech.okayama-u.ac.jp

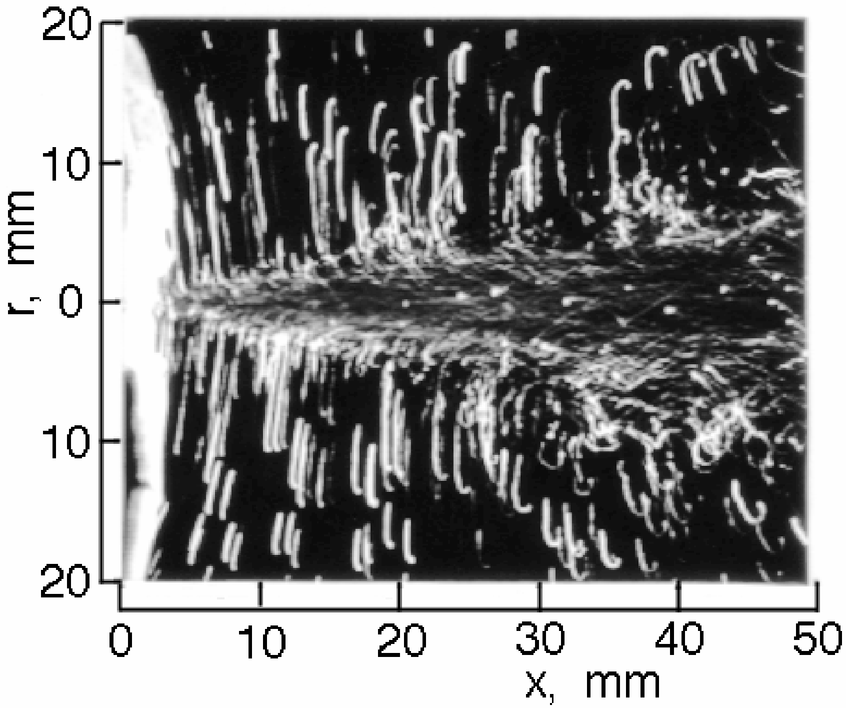
1) Previous study

a) Ambient Air Entrainment into Transient Hydrogen Jet and its Flame Jet

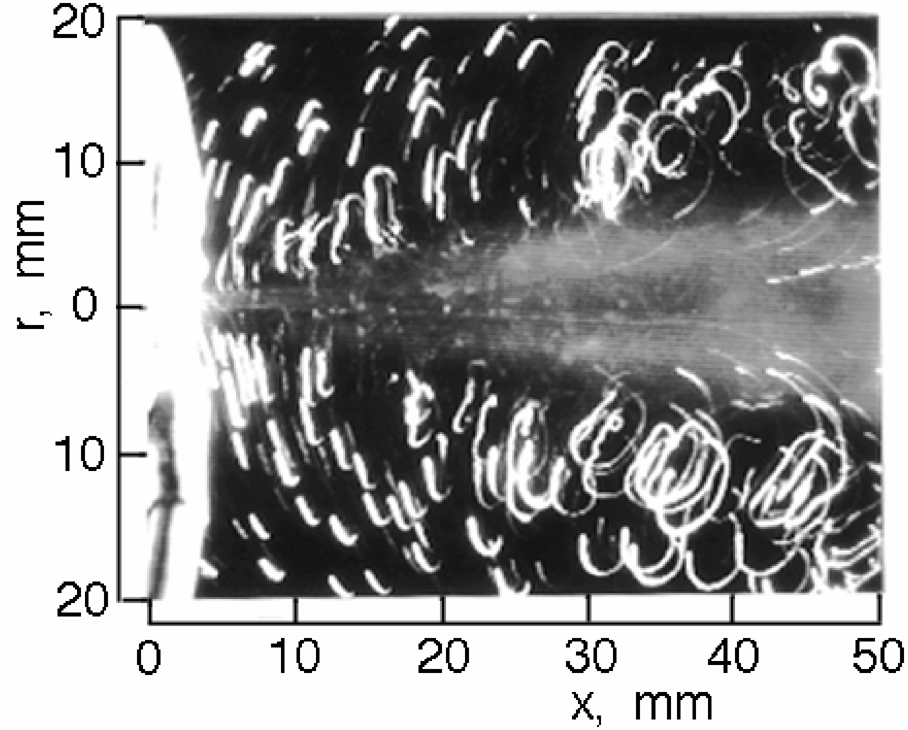
Ambient air entrainment into transient hydrogen jet and its flame jet were investigated with a visualization technique spatially and temporally. (SAE Paper, No.970894)

b) Hydrogen Combustion and Exhaust Emissions Ignited with Diesel Oil in a Dual Fuel Engine

(SAE Paper, No.2001-01-3503)



Cold jet



Hot jet

Laser sheet, Shutter open =2ms
Length of path line is counted.
It is estimated when, where, how much and how the ambient air is entrained.

Visualization of ambient air entrainment

Hydrogen Combustion and Exhaust Emissions Ignited with Diesel Oil in a Dual Fuel Engine

Okayama University **Eiji Tomita,**
Nobuyuki Kawahara,
Zhenyu Piao,
Shogo Fujita
Yoshisuke Hamamoto

Hydrogen is induced from intake port and gas oil is injected into the cylinder and combustion characteristics and exhaust emissions were investigated.

(SAE Paper, No.2001-01-3503)

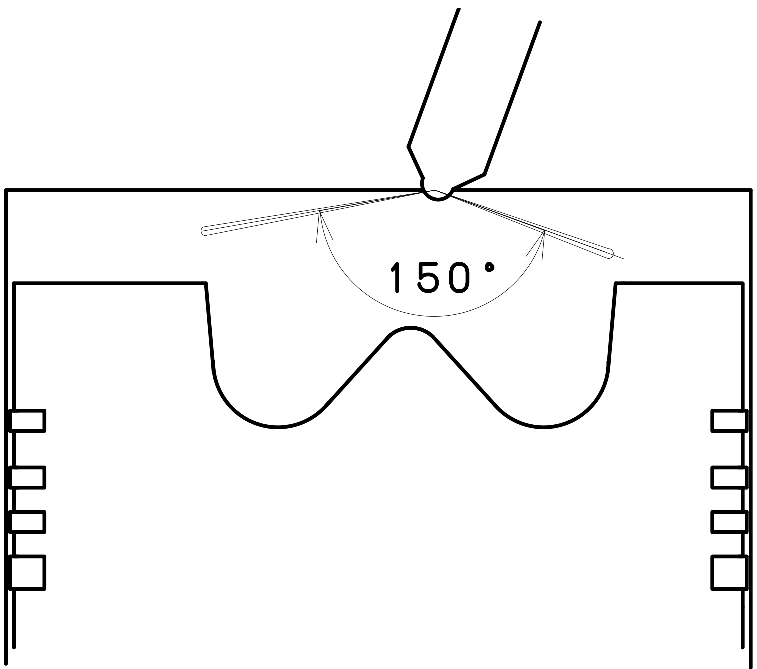
Objectives

- Low smoke ← Premixed combustion (Early injection)
  Hydrogen
- Low NOx ← Premixed combustion (Early injection)
- Low HC ← Hydrogen
- Extremely low CO_2 ← Hydrogen

↓

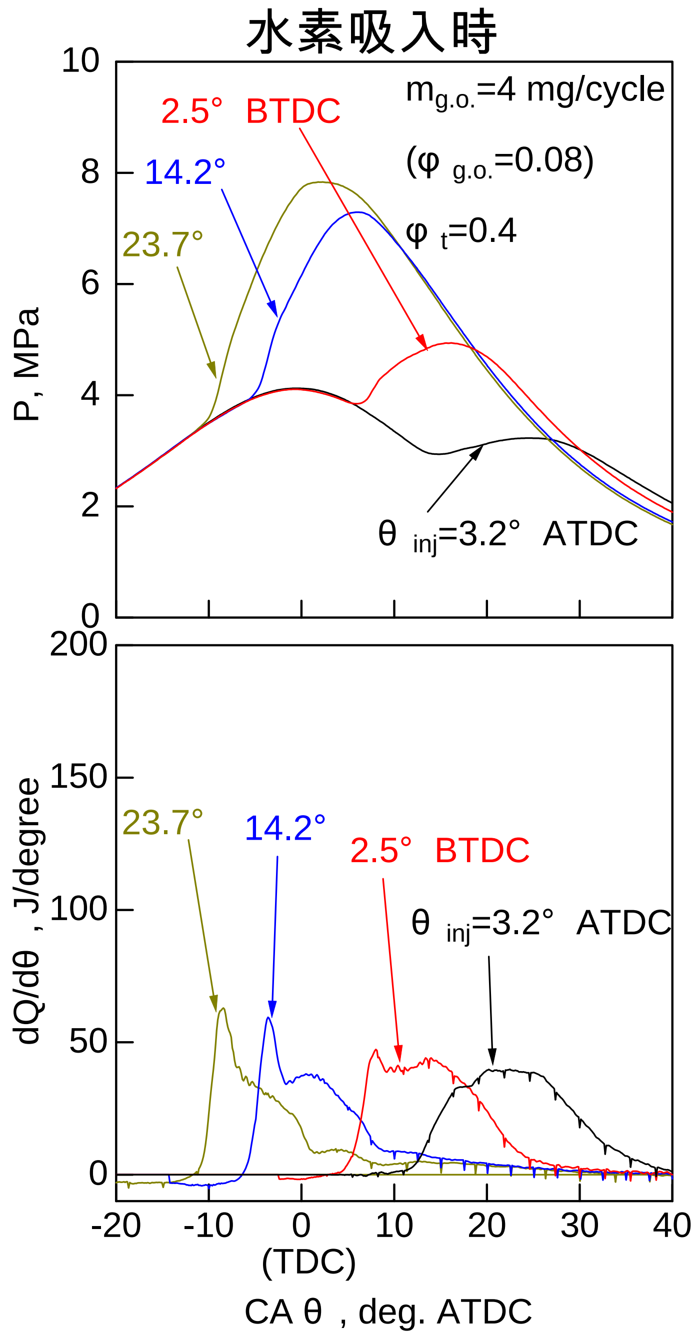
Dual fuel engine ← high self-ignition temperature
(Gas oil and hydrogen) of hydrogen
+
Premixed compression ignition

Test engine and experimental conditions



Bore	92 mm
Stroke	96 mm
Compression ratio	17.7
Combustion chamber	Deep dish
Nozzle	4 holes (ϕ0.26 mm)
Injection angle	150 degrees
Injection timing	Variable
Inlet gas	Air, Hydrogen+air
Equivalence ratio	0.3, 0.4, 0.5
Engine speed	1000 rpm

Exhaust emissions: NO_x, HC, CO, CO_2, Smoke



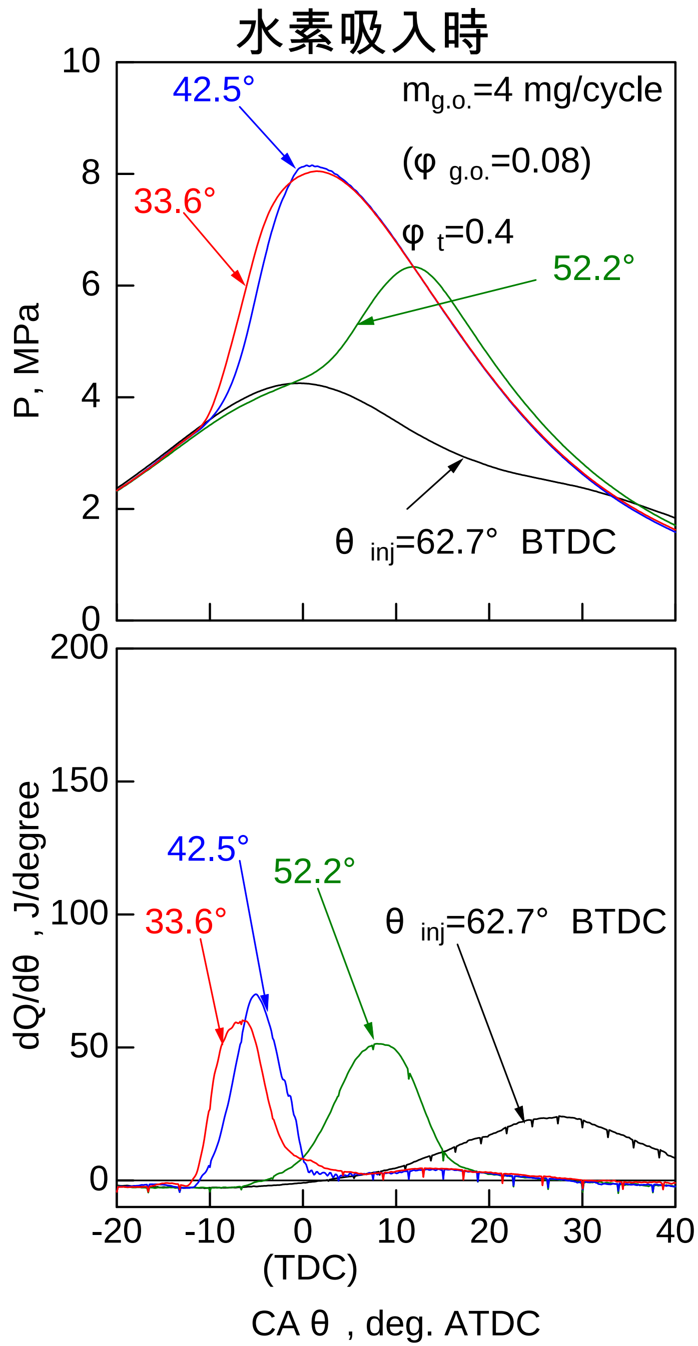
Pressure and heat release rate (Dual fuel operations)

(1) P_{max} is larger.

(2) $(dQ/d\theta)_{max}$ is smaller.

(3) $dQ/d\theta$ is similar to the ordinary diesel operation at θ_{inj} = 2.5 ~ 23.7 °BTDC, while the second peak corresponds to the combustion of hydrogen that starts from the ignition points due to light oil.

(4) In θ_{inj}=3.2 °ATDC, $dQ/d\theta$ shows only one mild peak. The longer ignition delay promotes the diffusion of light oil and then lean premixed combustion occurs.



Pressure and heat release rate (Dual fuel operations)

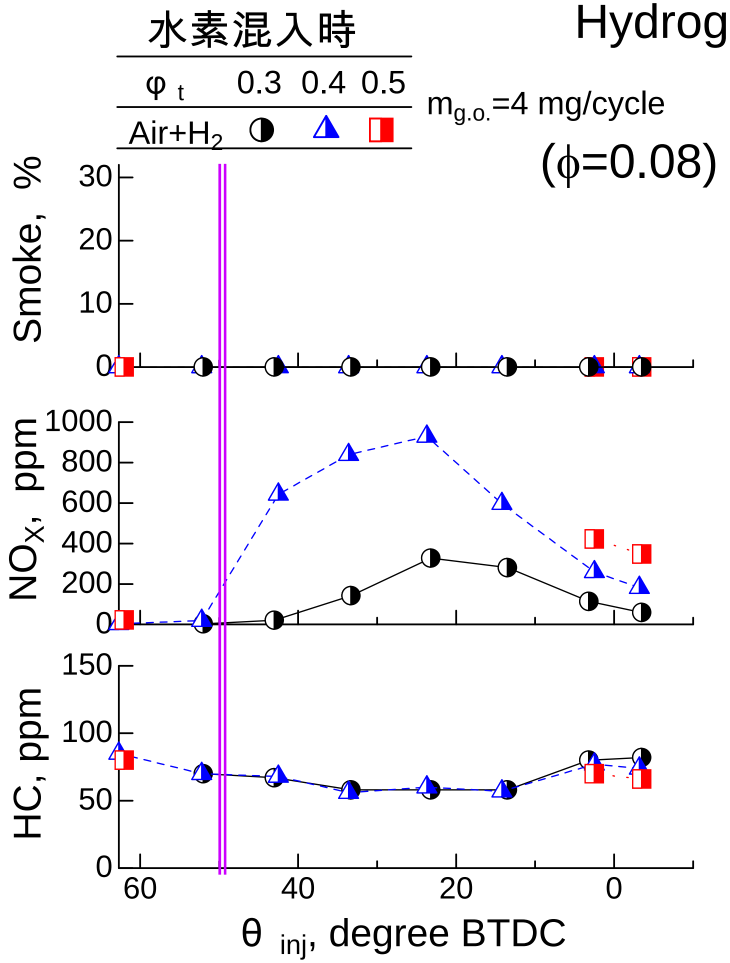
(5)
θ_{inj}< 33.6°BTDC, there is much time when the gas oil is mixed with H_2-air mixture.

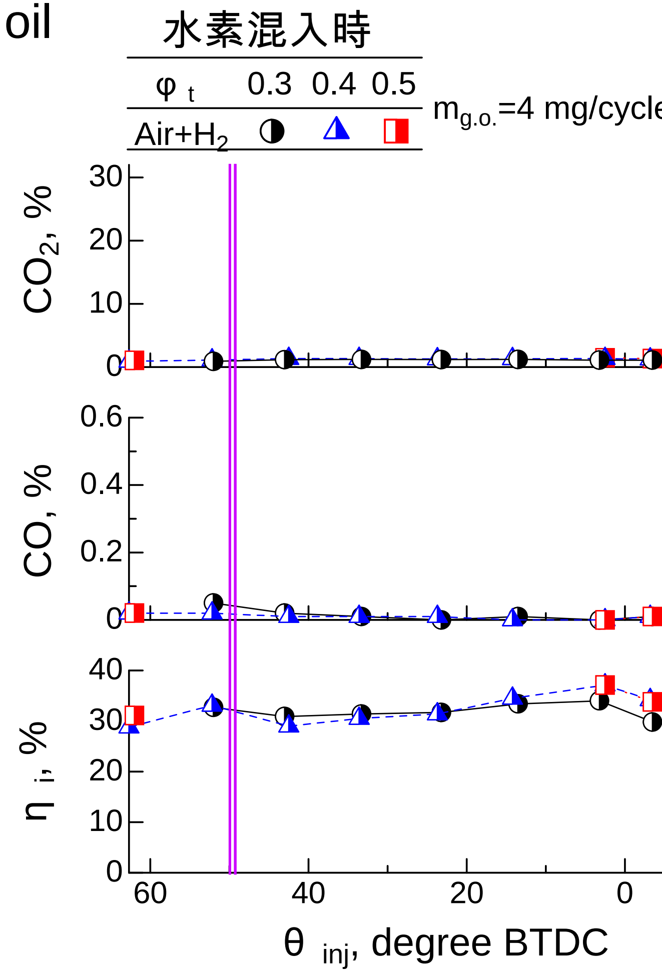
A very lean mixture is prepared in the cylinder and the gas oil becomes the ignition sources in the wide range of the cylinder.

⇩

Therefore, the combustion becomes very slow
and dQ/dθ shows only one mild peak.

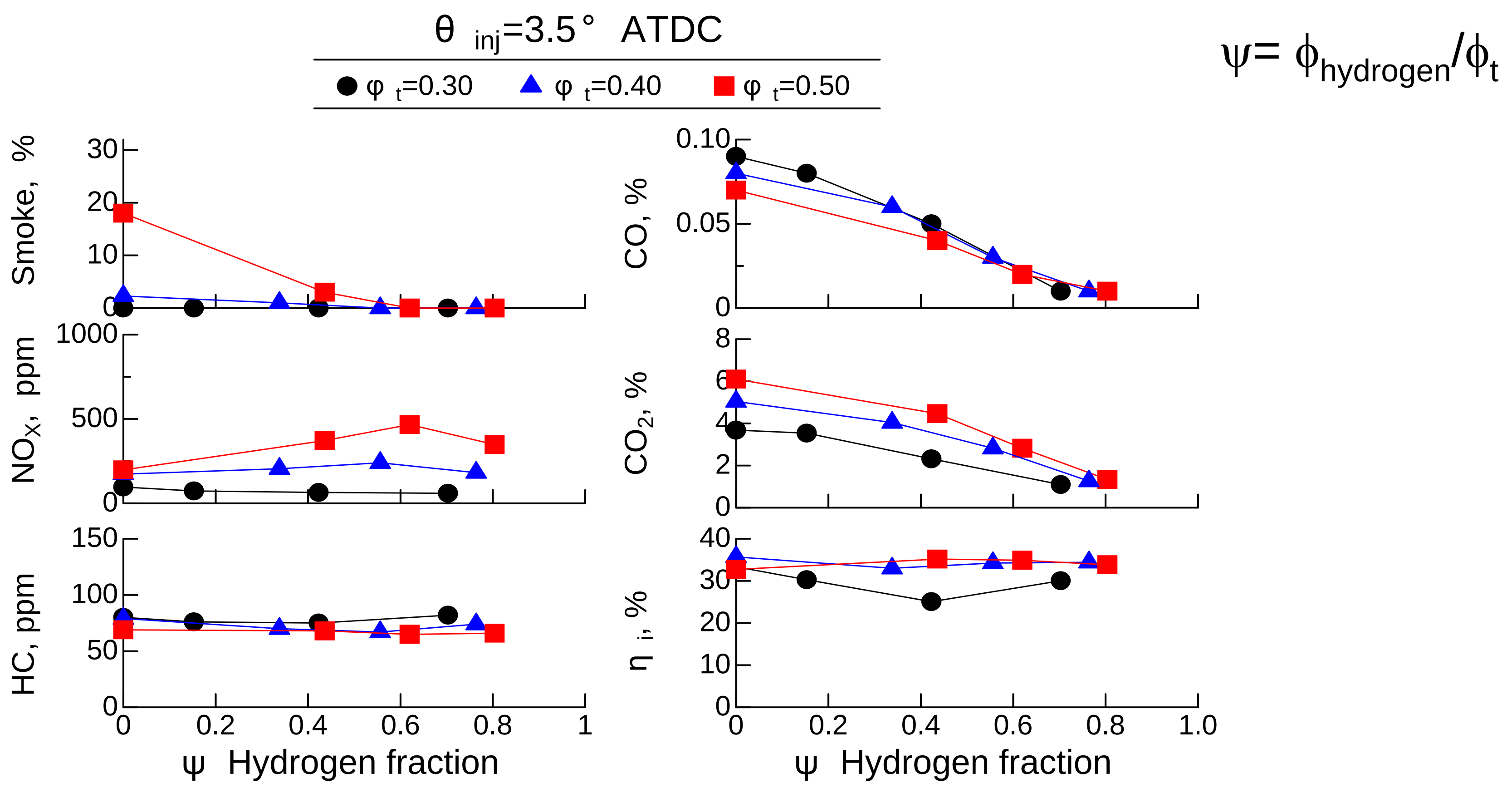
Hydrogen & gas oil





θ_{inj}=50deg.BTDC
No smoke, Very low NOx

Effect of injection timing on exhaust emissions etc.



With increasing ψ,

----> Smoke: decreased.

HC: similar values

CO_2 : decreased

CO: decreased.

η_i : a little bit larger than straight diesel

Effect of hydrogen fraction on exhaust emissions etc.

2) Recent Research

a) Knock limit --- effects of temperature, pressure, residual gas, other gaseous fuel on combustion

b) Combustion of gasoline with hydrogen

(Spark-ignition engine)

Small amount of hydrogen is used.

c) Combustion of gaseous fuel including hydrogen

(Dual fuel engine)

Combustion characteristics and exhaust emissions of hydrogen blended fuel, for example, natural gas is mixed with hydrogen.

Biomass-gas or other gases including hydrogen are also burned in an internal combustion engine.

3) Tools : Test engines (SI engine and dual fuel engine)

a) Spectroscopic analysis of hydrogen flame in an SI engine

Optics of Cassegrain type is used for local spectroscopic analysis.

OH radicals are detected and combustion characteristics such as heat release rate, flame developing speed are analyzed.

b) Local gas temperature measurement using a small interferometry sensor system

Interferomerty technique is applied to measure temperature history of unburned and burned gas with a small sensor that is developed in my laboratory.

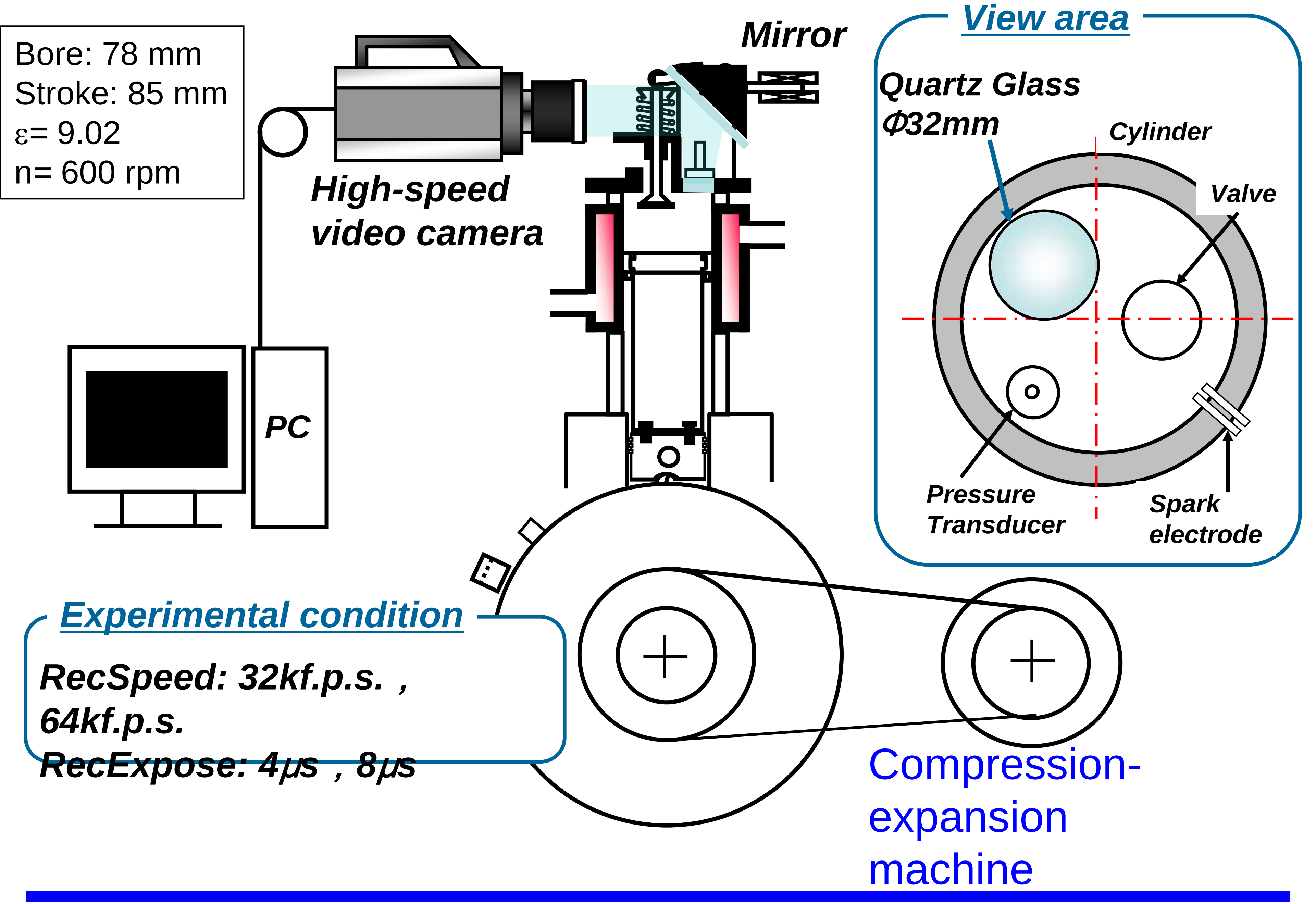
c) Visualization of knock phenomena

Auto-Ignited Kernels during Knocking Combustion in a Spark-Ignition Engine

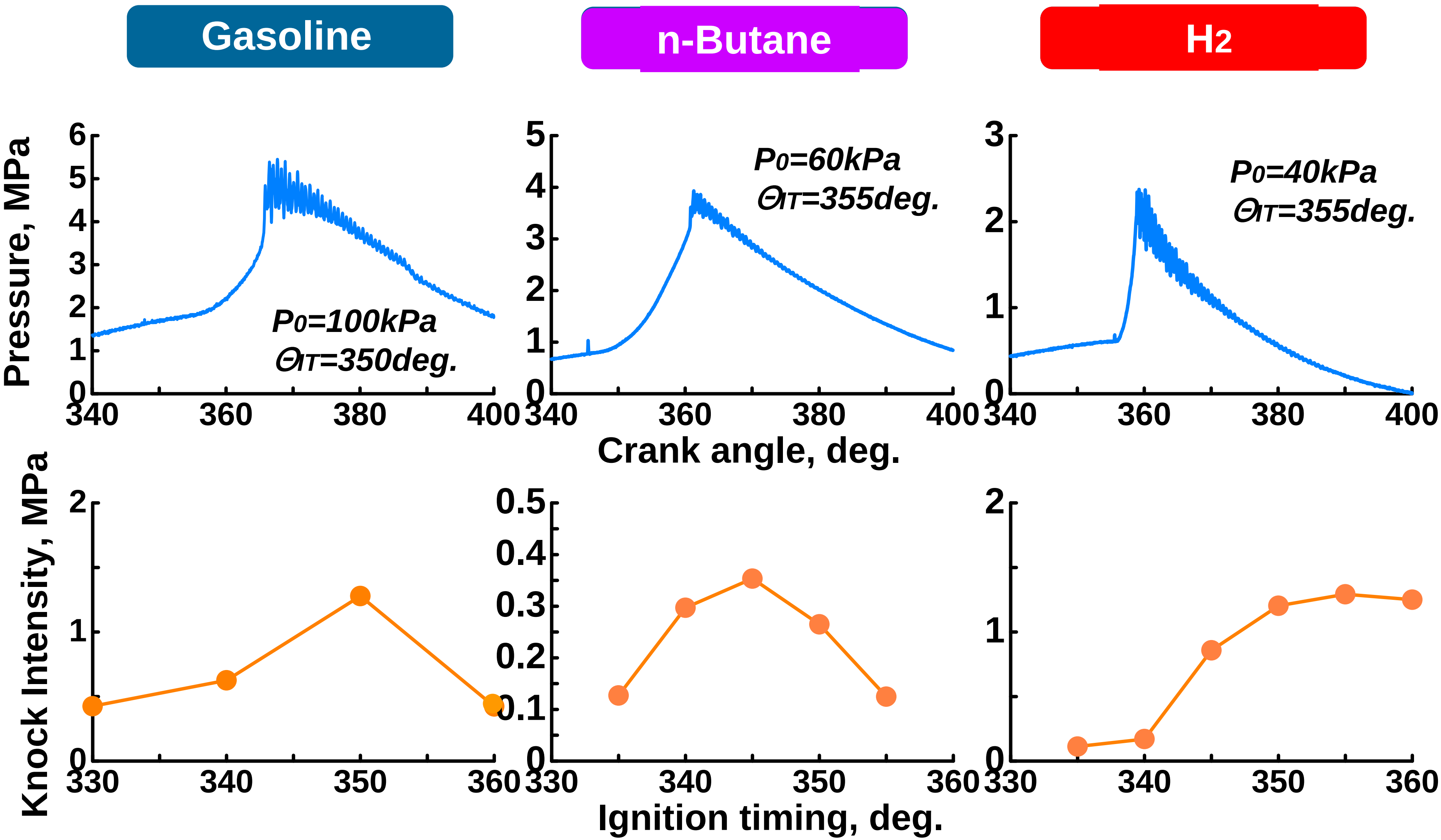
#2F01
Proceedings of the Combustion Institute,
Vol.31(2006)

Nobuyuki Kawahara
Eiji Tomita
Yoshitomo Sakata

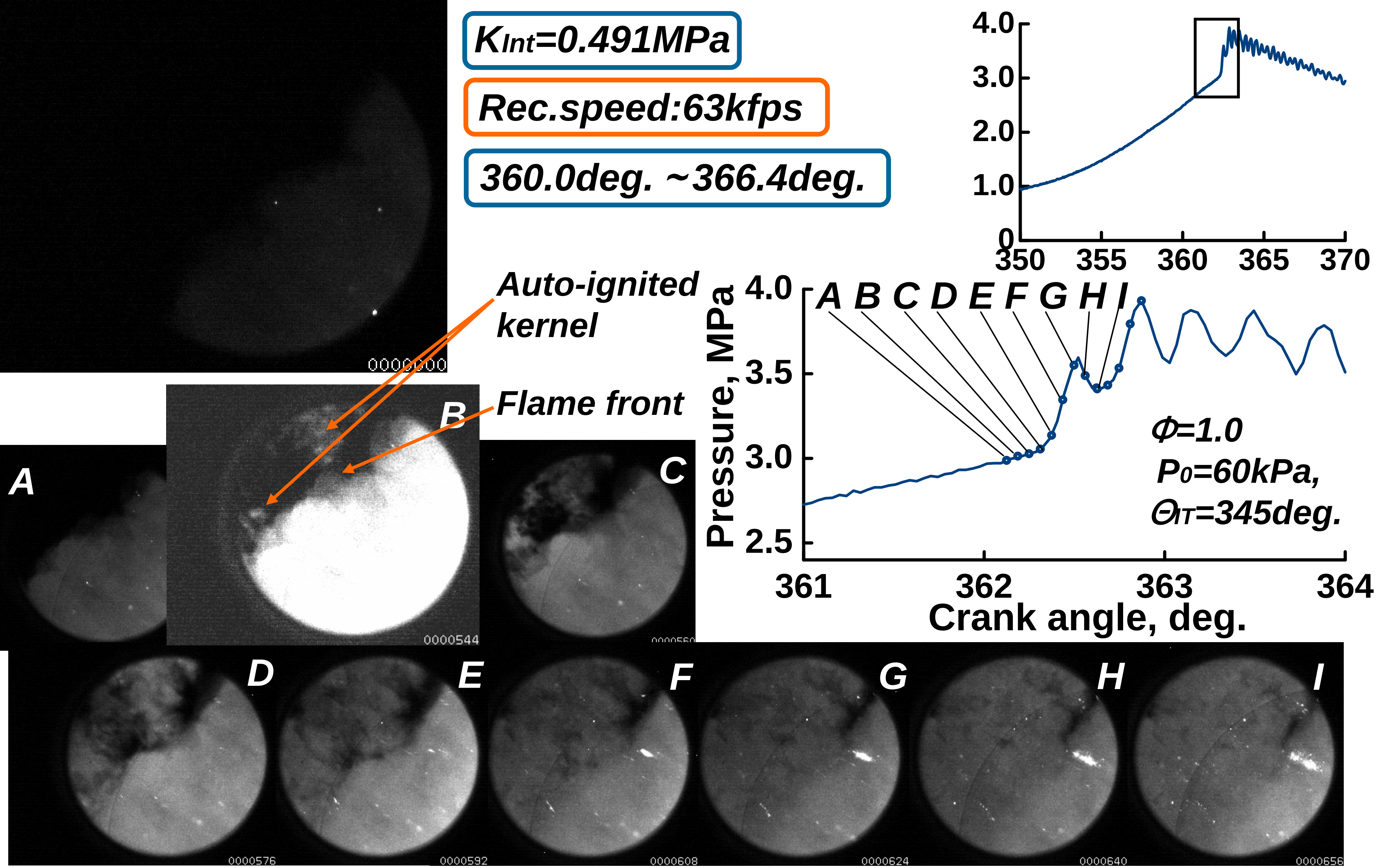
Okayama University (Japan)



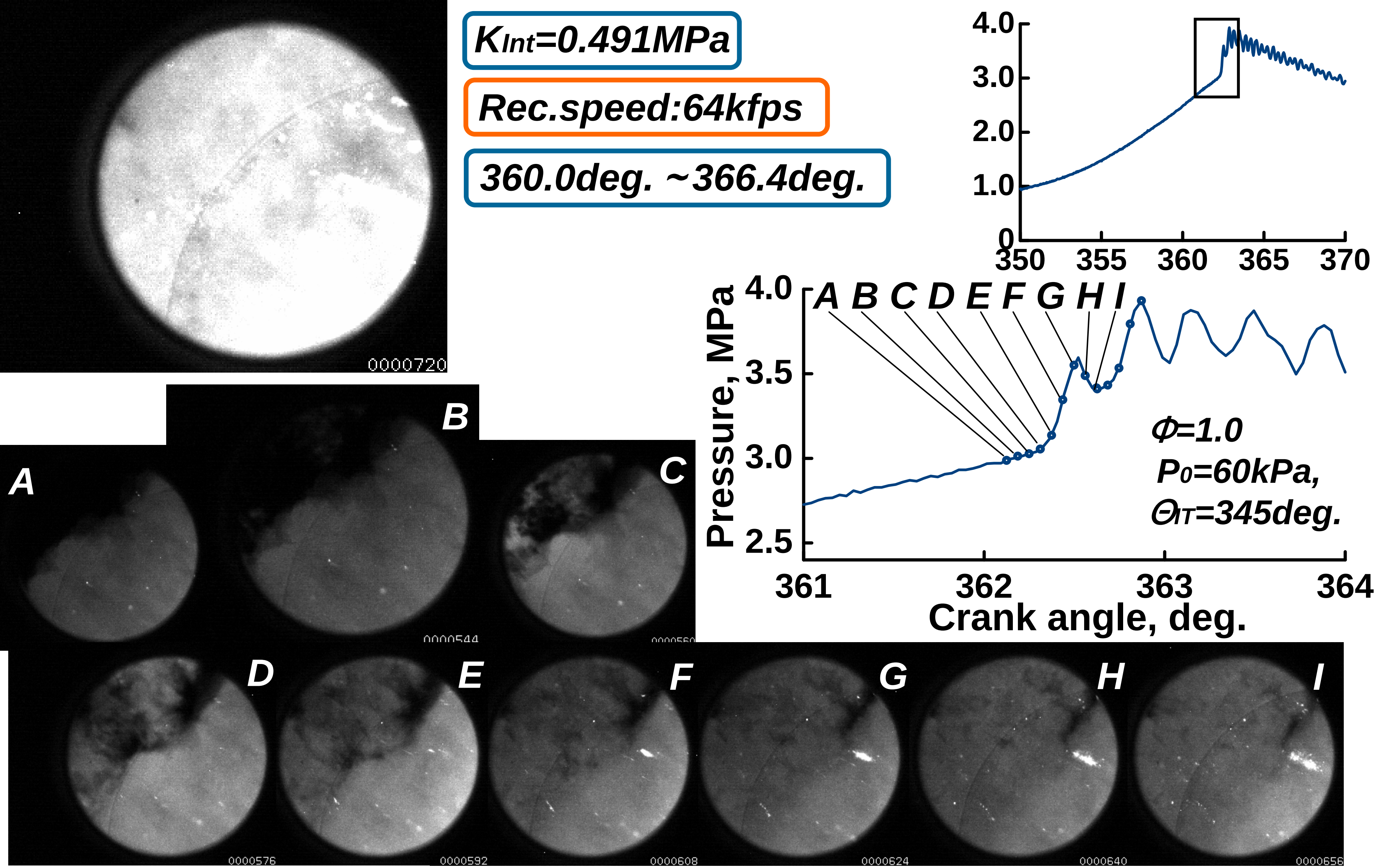
Visualization method



Pressure history and knock intensity



Relation between flame and pressure vibration



Relation between flame and pressure vibration

$H_2(\Phi=1.0)$

RecSpeed:64kf.p.s RecExpose:1/2