NUMERICAL AND EXPERIMENTAL STUDY ON DETAILED MECHANISM OF H2 / AIR FLAME JET IGNITION

Hajime BITOH Aoyama Gakuin University in JAPAN
Motoi SUETAKE Aoyama Gakuin University in JAPAN
Makoto ASAHARA Aoyama Gakuin University in JAPAN
Eisuke YAMADA Aoyama Gakuin University in JAPAN
A. Koich HAYASHI Aoyama Gakuin University in JAPAN

Outline

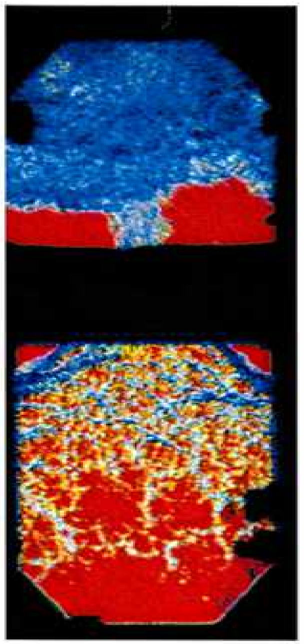
1. Background
2. Experimental tool and Initial condition
3. Result of experiments
4. Numerical method and Initial Condition
5. Result of simulation
6. Conclusion

Background

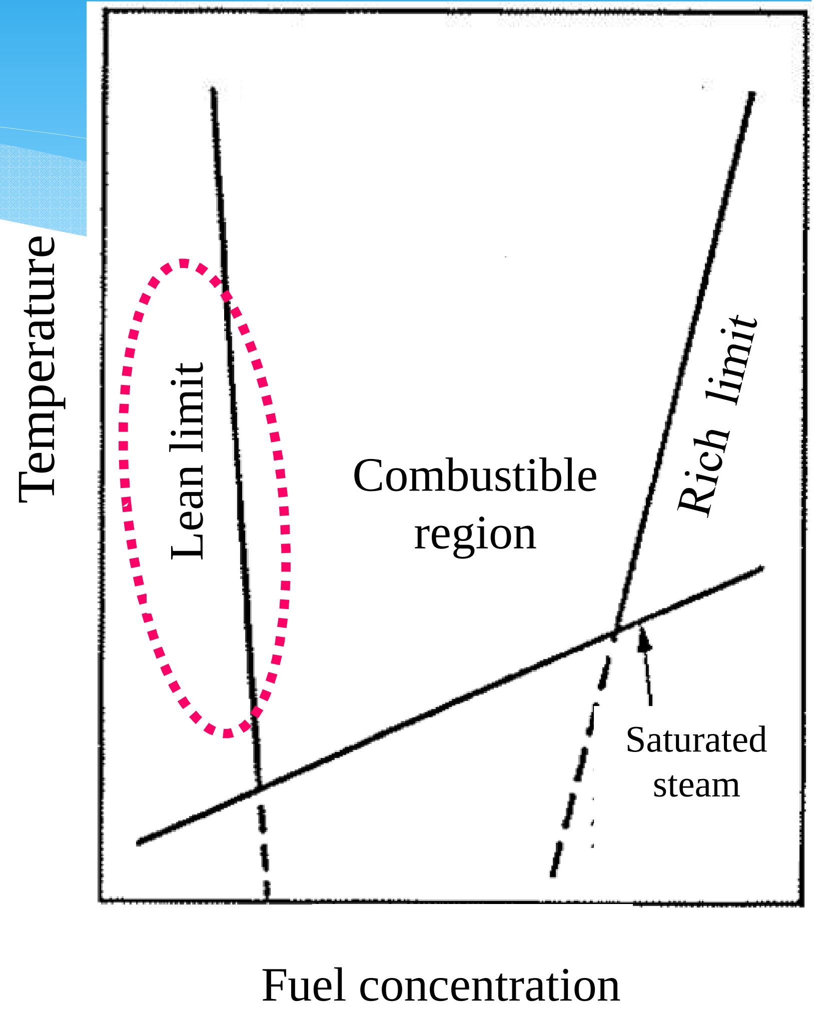
Jet ignition is a special type of combustion

Receiver Chamber (RC)

Driver Chamber (DC)



The Schlieren Photo of experiments by Suetake (1999)



Process of jet ignition

Process of Jet Ignition

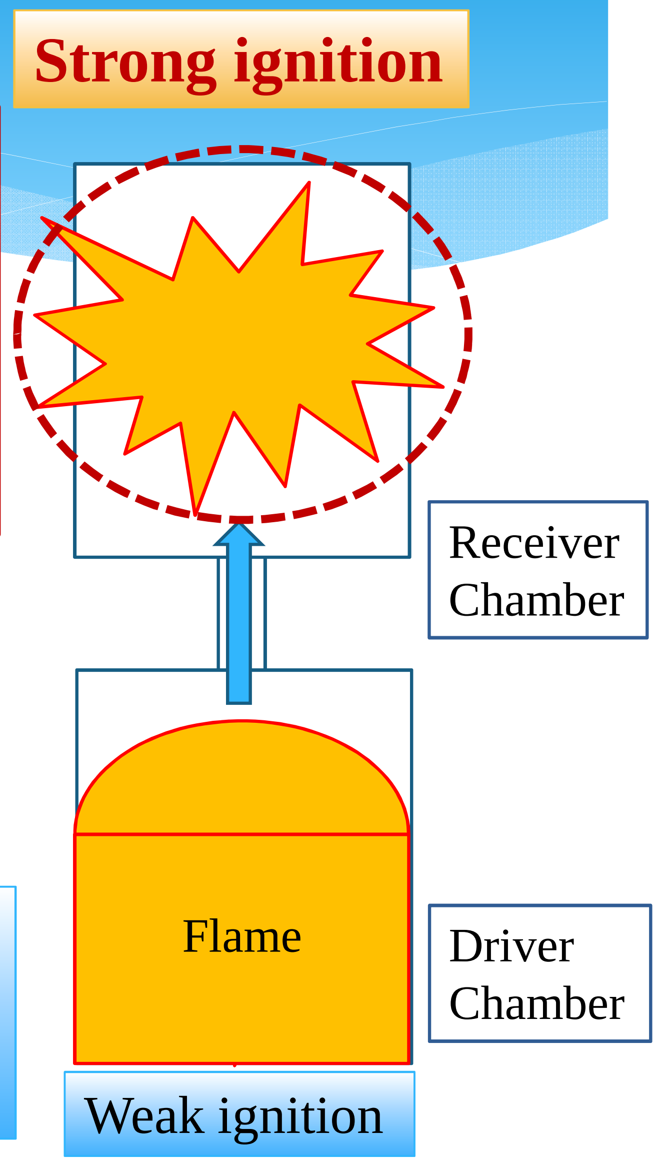
1. Flame is initiated by spark plug and propagates in DC
2. Flame extinguishes when it goes through the orifice
3. Fuel is reignited in RC

Jet Ignition has **many advantages**

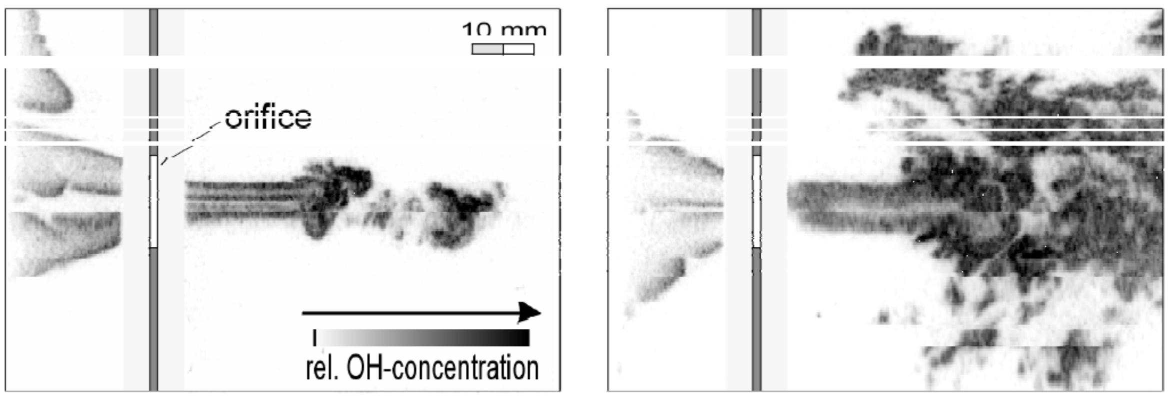
- **A little heat loss**
- **Good thermal efficiency**

Jet Ignition is **very powerful** and **dangerous**

- Higher pressure
- Faster flame speed



Past Study



Experiments by M. Jordan et al.

D. N. R. Mittiniti et al. compared **Plasma Jet Ignition** (PJI) and **Flame Jet Ignition** (FJI) (1985)

- FJI is possible to **ignite smaller energy than PJI**
- FJI is also possible to ignite **in very lean condition**

J. A. Maxon and A. K. Oppenheim studied the base of Pulsed Jet Combustion (1990)

Suetake performed the experiments of hydrogen / air flame jet ignition using a Schlieren photographic method (1997, 1999)

M. Jordan and F. Mayinger clarified the jet ignition area for the equivalent ratio and orifice diameter

Target of this study

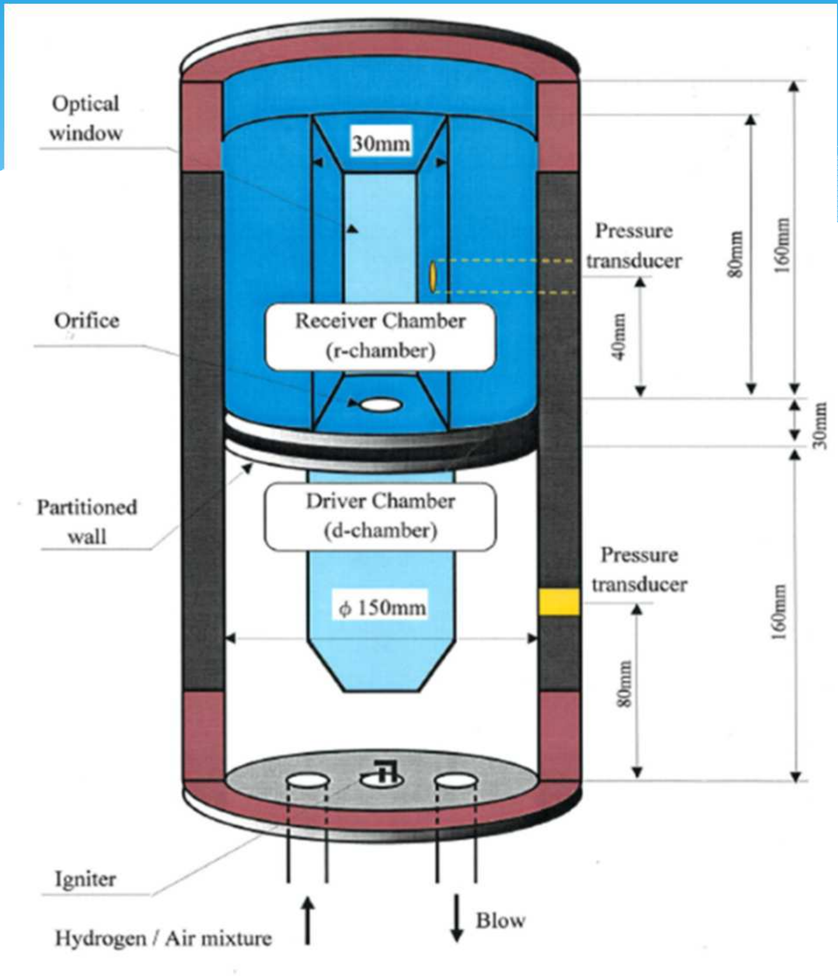
A detailed mechanism for jet ignition has not been clarified yet

However, it depends on equivalence ratio and the orifice diameter

To using a numerical simulation to clarify the detailed ignition mechanism on jet ignition

Experiments

Experimental Tools and Initial Condition



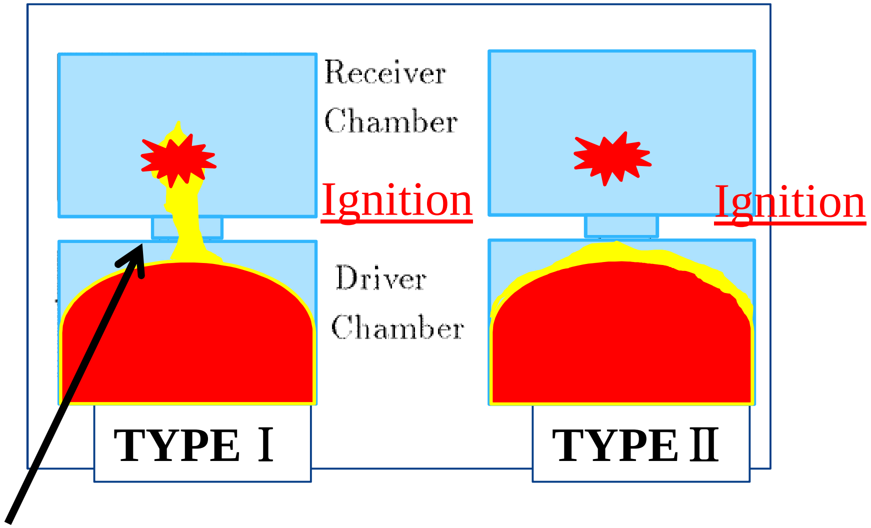
		Orifice diametar [mm]				
		5	8	10	12	14
ϕ	0.235	1	2	3	4	5
	0.250	6	7	8	9	10
	0.257	11	12	13	14	15
	0.264	16	17	18	19	20
	0.272	21	22	23	24	25
	0.279	26	27	28	29	30
	0.294	31	32	33	34	35
	0.309	36	37	38	39	40
	0.325	41	42	43	44	45
	0.340	46	47	48	49	50
	0.356	51	52	53	54	55

Experimental Results

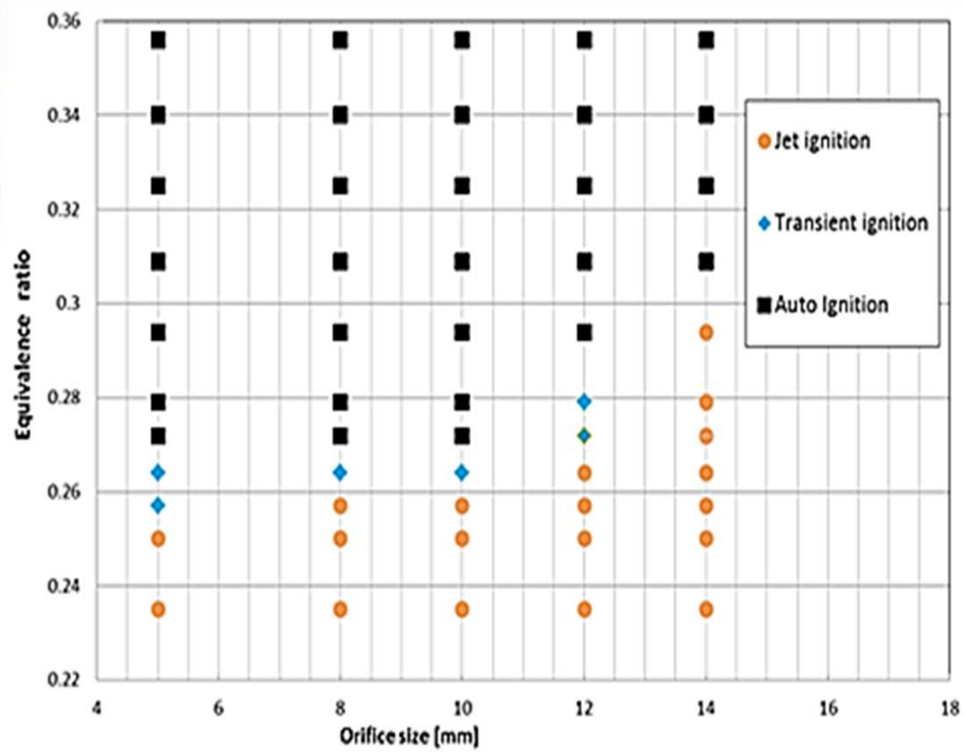
Type of Ignition

There are 3 type of jet ignition

TYPE Ⅰ : Jet Ignition
TYPE Ⅱ : Auto Ignition
TYPE Ⅲ : Transient Ignition
(It is mixed TYPE Ⅰ and TYPE Ⅱ)

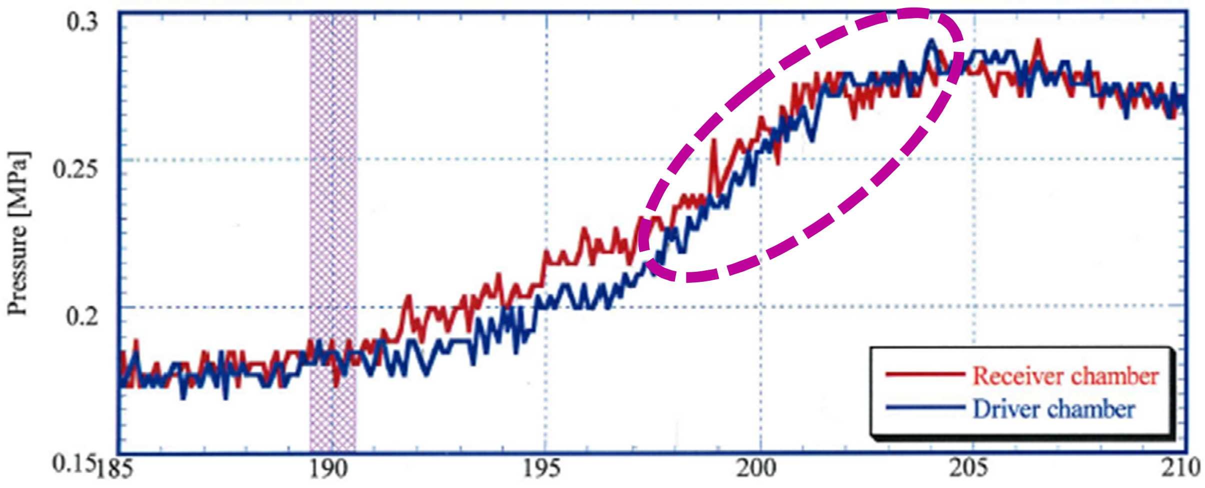


Burned gas passes through the orifice



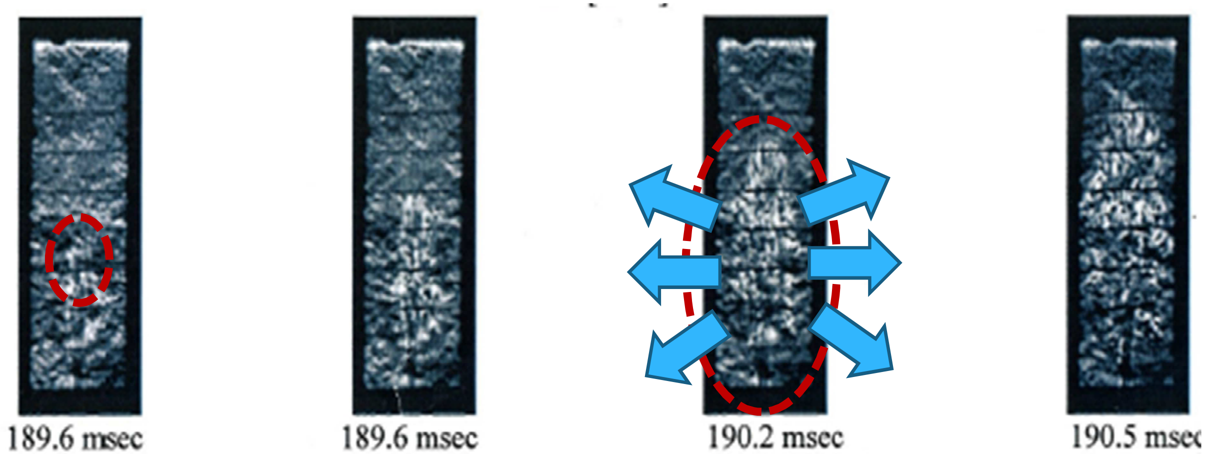
Ignition depends on the **equivalence ratio and orifice diameter**

No pressure jump case (Jet Ignition)



The ignition started at the top head of the flame jet

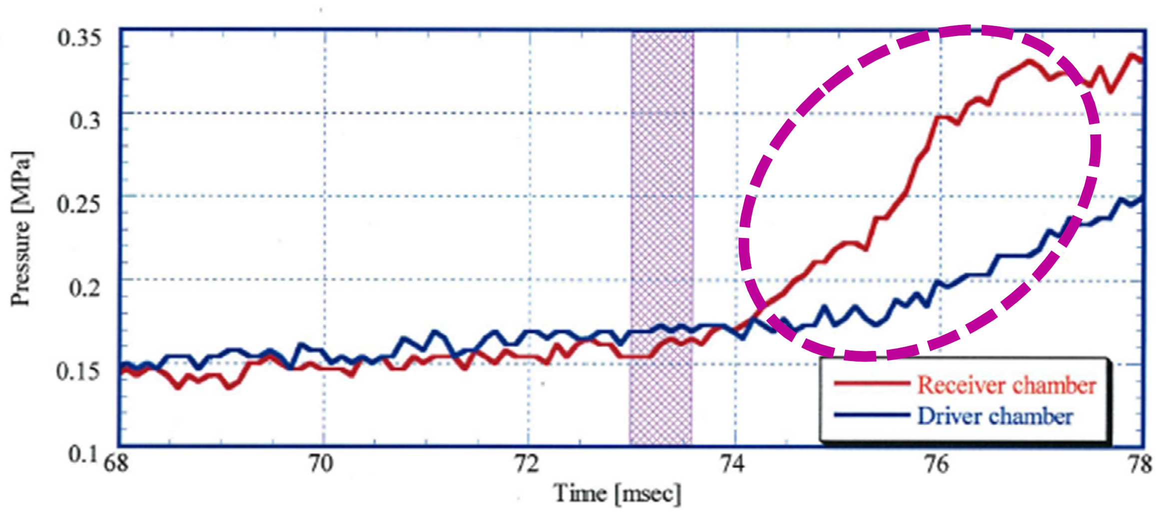
The flame structure expanded to the radial direction with an umbrella shape.



Pressure jump wasn't seen immediately when flame grew in the RC.

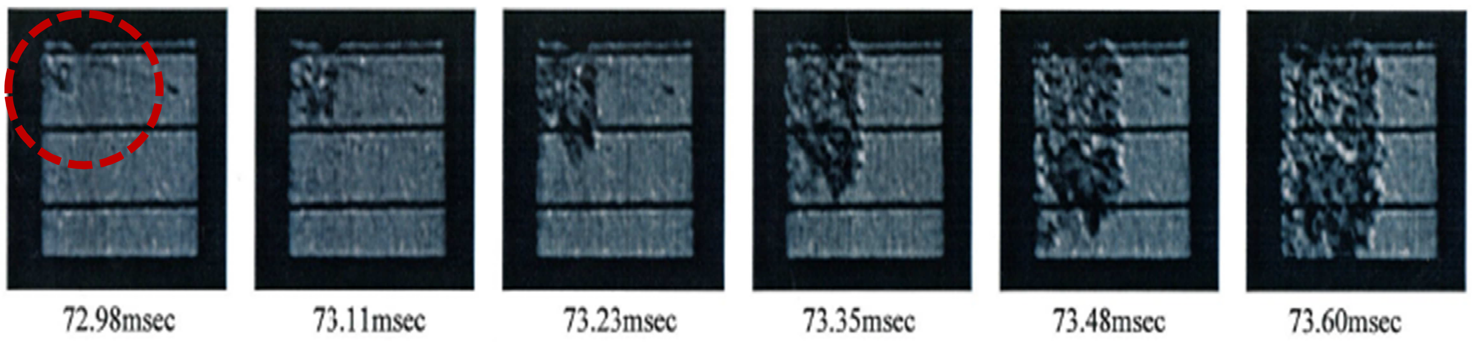
Schlieren photograph (Equivalent ratio 0.250, orifice diameter 10mm)

Pressure jump case (Auto Ignition)



Ignition happens near the right corner of the top wall in RC.

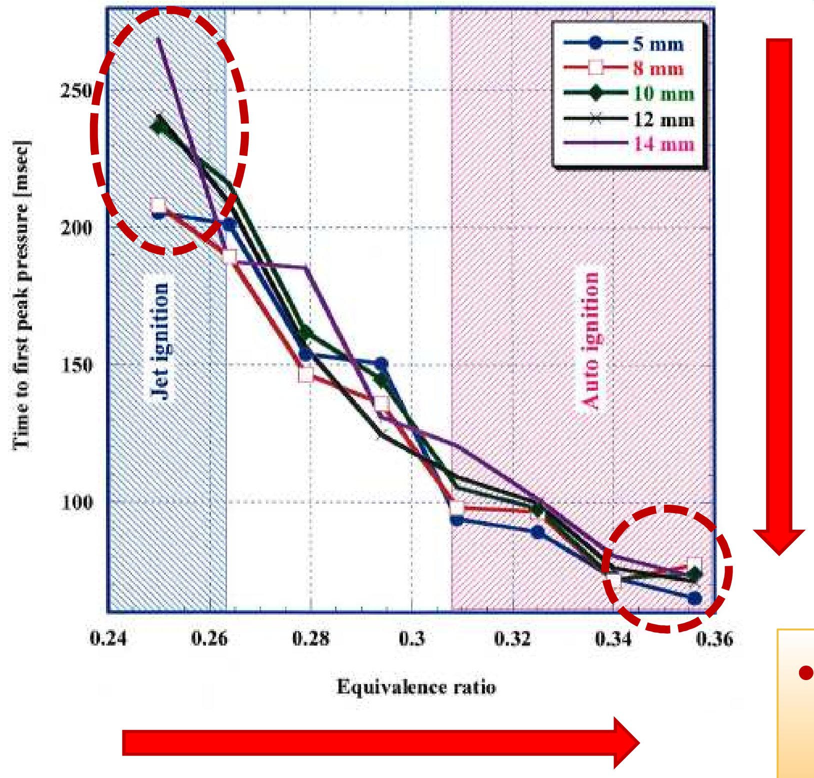
Pressure jump was seen immediately when flame grew in RC.



Schlieren photograph (Equivalent ratio 0.356, orifice diameter 10mm)

The time to reach the first peak pressure (TRFPP)

50 ms at maximum difference among orifice diameters at the case of jet ignition

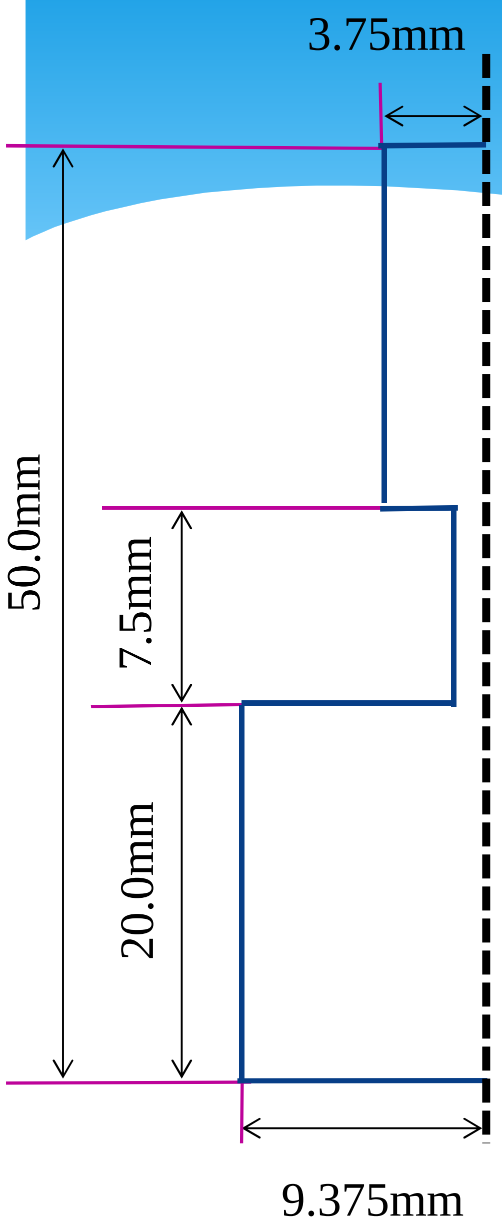


Higher equivalence ratio, there is a tend to reach auto-ignition

- **Jet ignition case heavily relies on flame propagation in RC**.
- The flame propagation velocity is dependent upon the orifice size.

Numerical Simulation

Numerical method and Initial Condition



Governing equation : Navier – Stokes equations
Convection term : TVD Scheme
Chemical reaction model : 9 species and 18 reaction

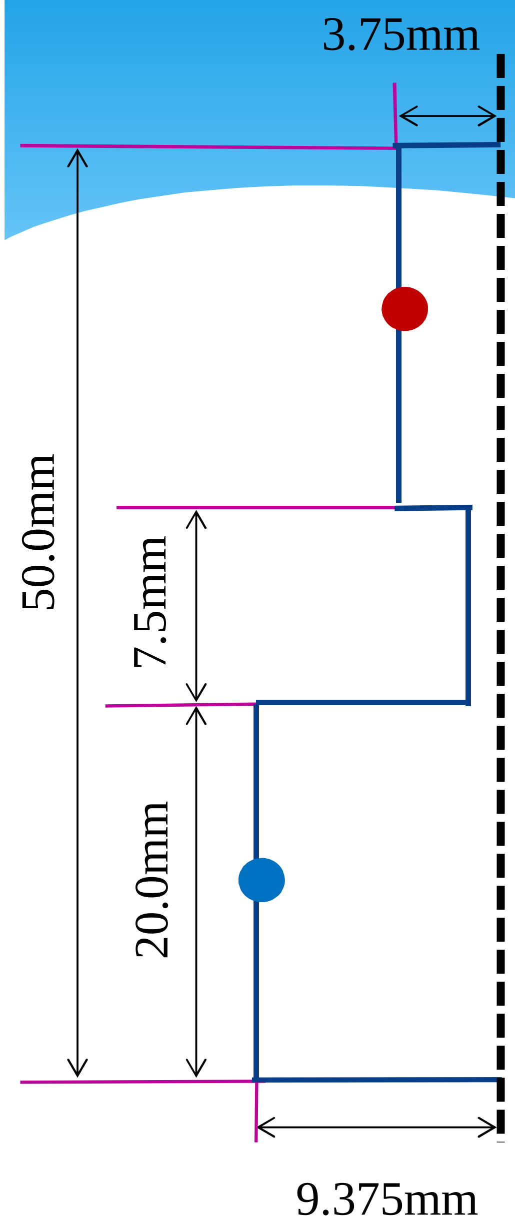
The model is developed by Petersen and Hanson

Total number of grid points : about 800,000
Basic calculation cell : 20μm×20μm

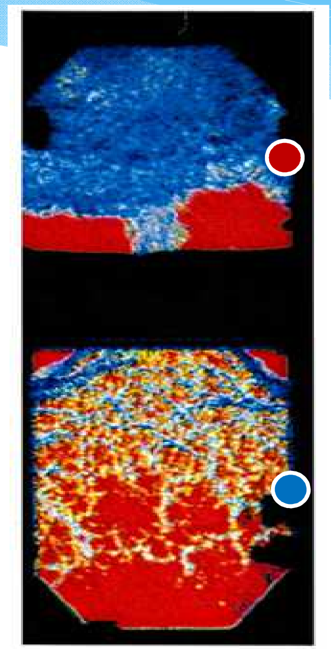
	Case 1	Case 2
Initial pressure [MPa]	0.100	0.100
Initial temperature [K]	293	293
Equivalence ratio	1.00	0.306

Numerical Results

Pressure measuring method



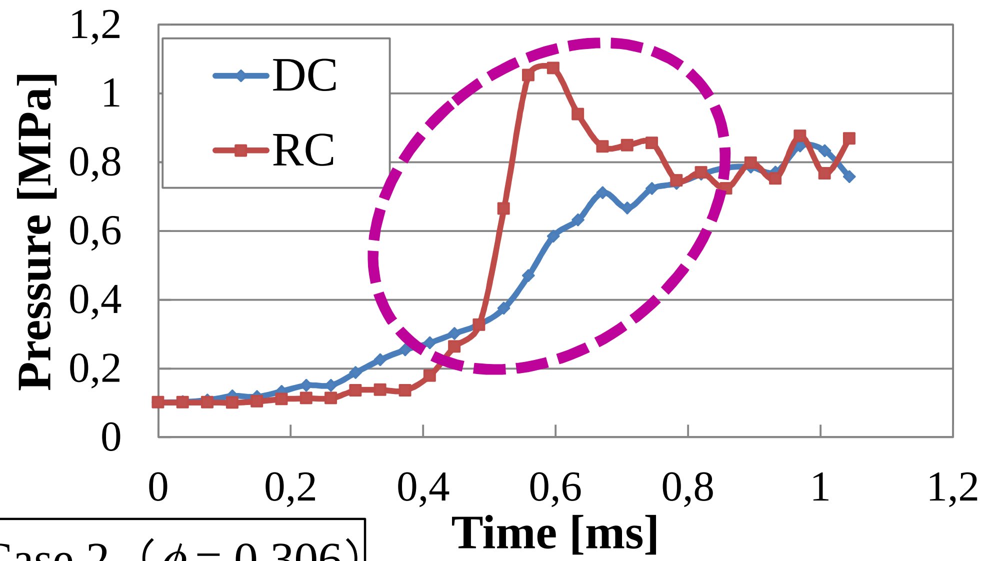
Measure the pressure in the right side of the half-height RC and DC



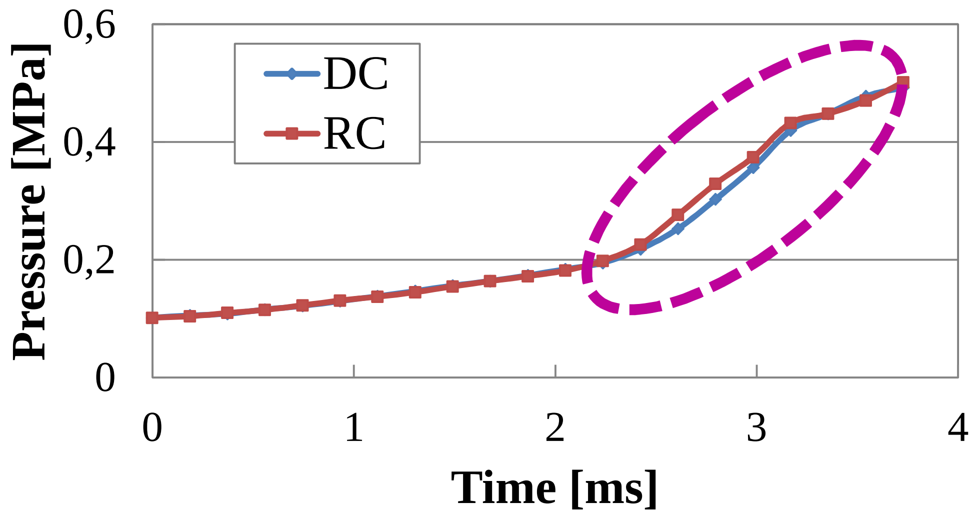
The Schlieren Photo of experiments by Suetake(1997)

Pressure history

Case 1 ($\phi = 1.00$)



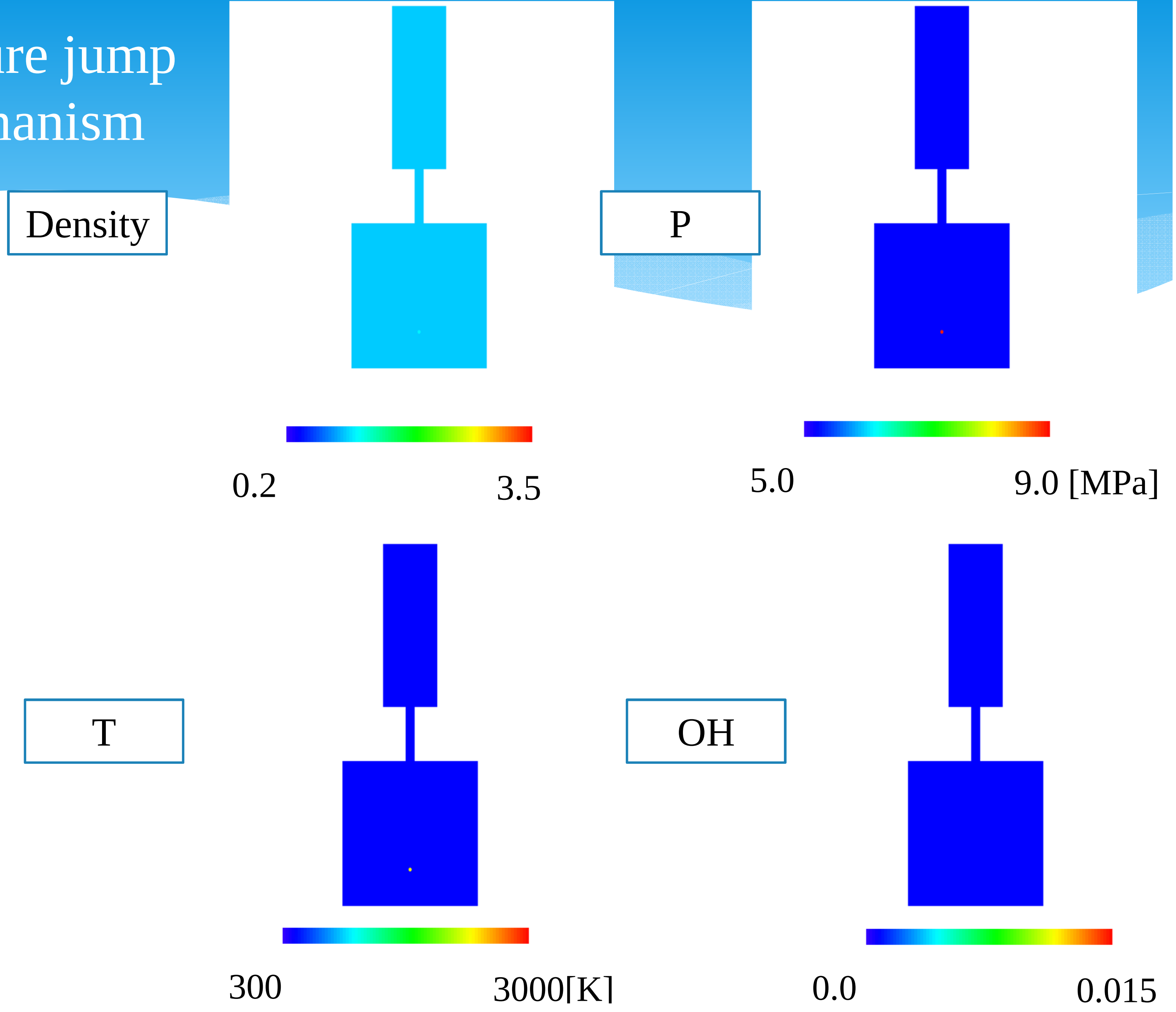
Case 2 ($\phi = 0.306$)



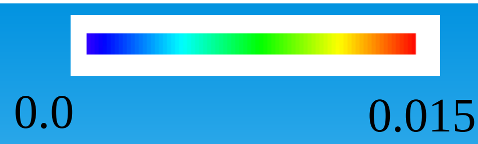
- In Case 1 sudden pressure jump was seen and the max pressure in RC is about **1.1MPa**.
- Pressure in the RC at its maximum is about **0.5MPa higher than DC .**

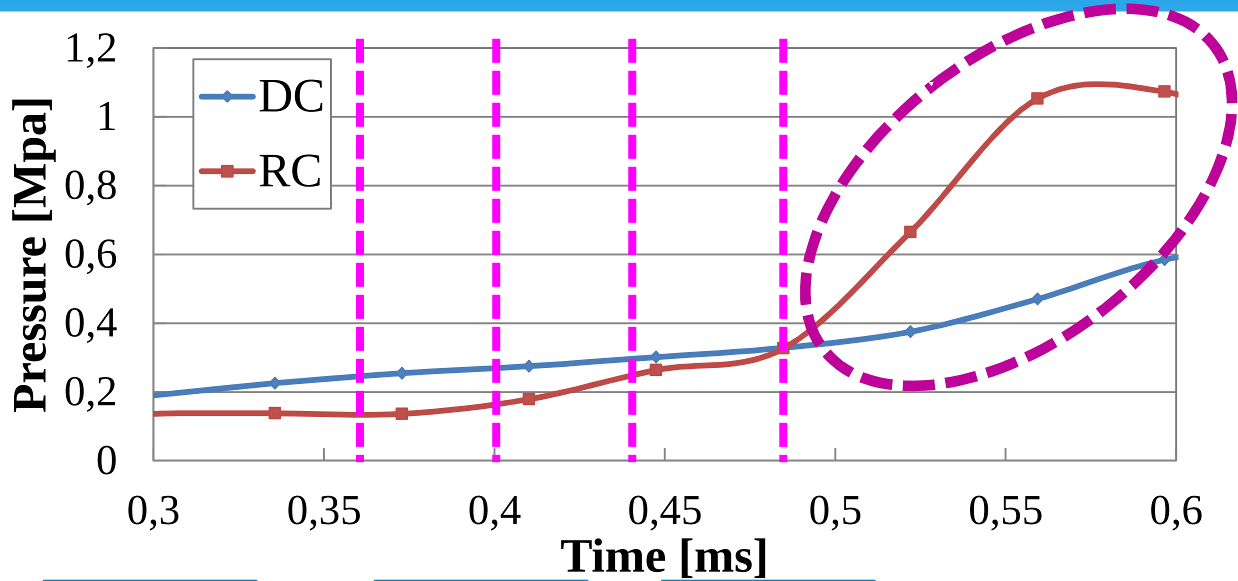
In Case 2 there is **no such pressure jump** and **little deference** between the pressure in RC and DC.

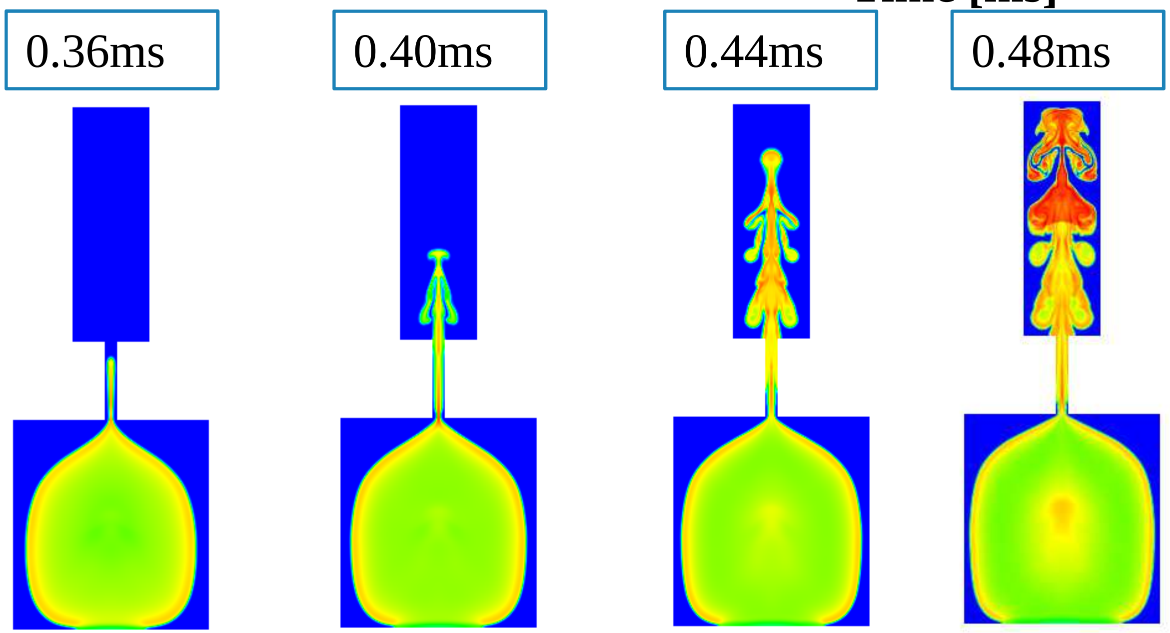
Pressure jump mechanism



Flame propagation (OH distribution)

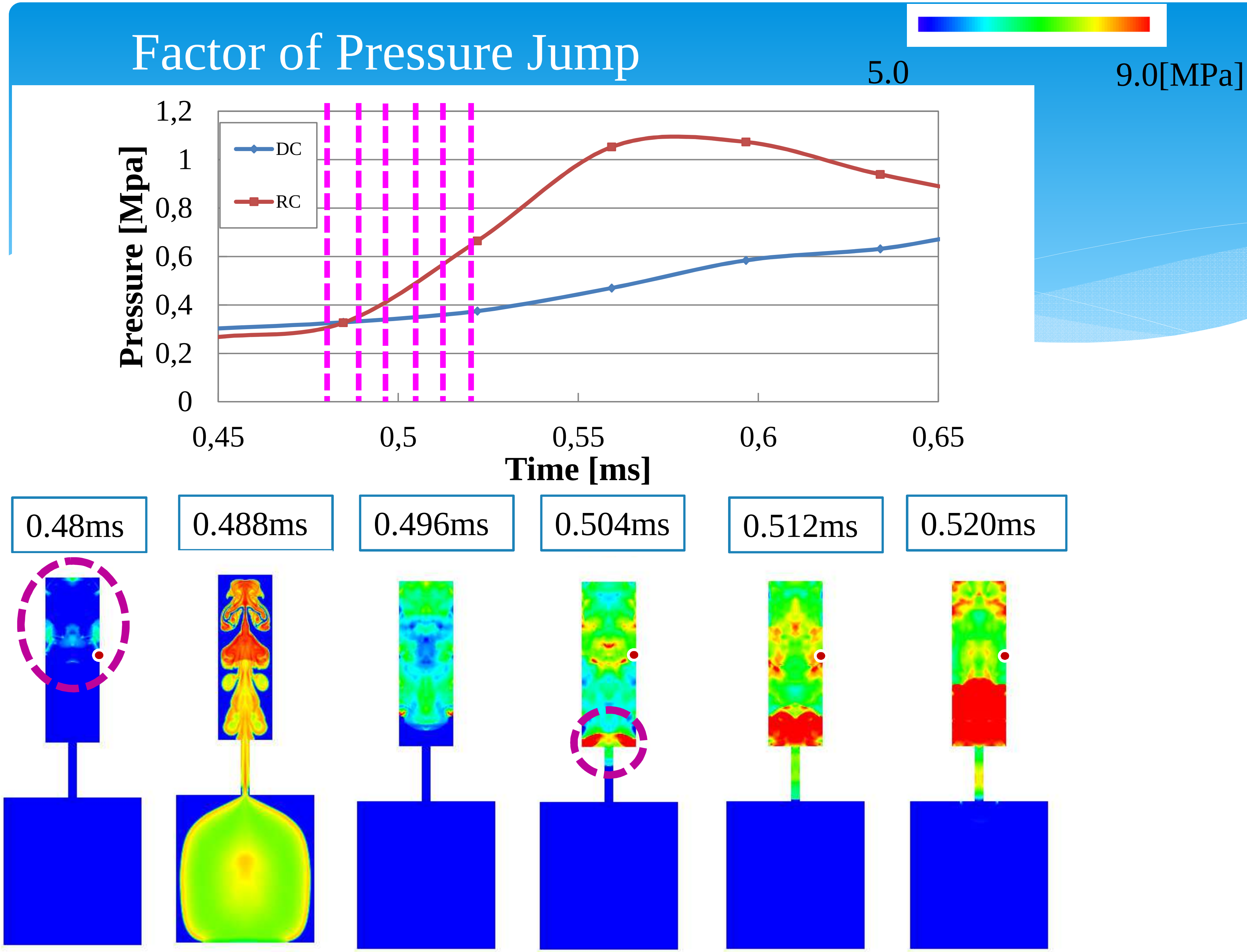




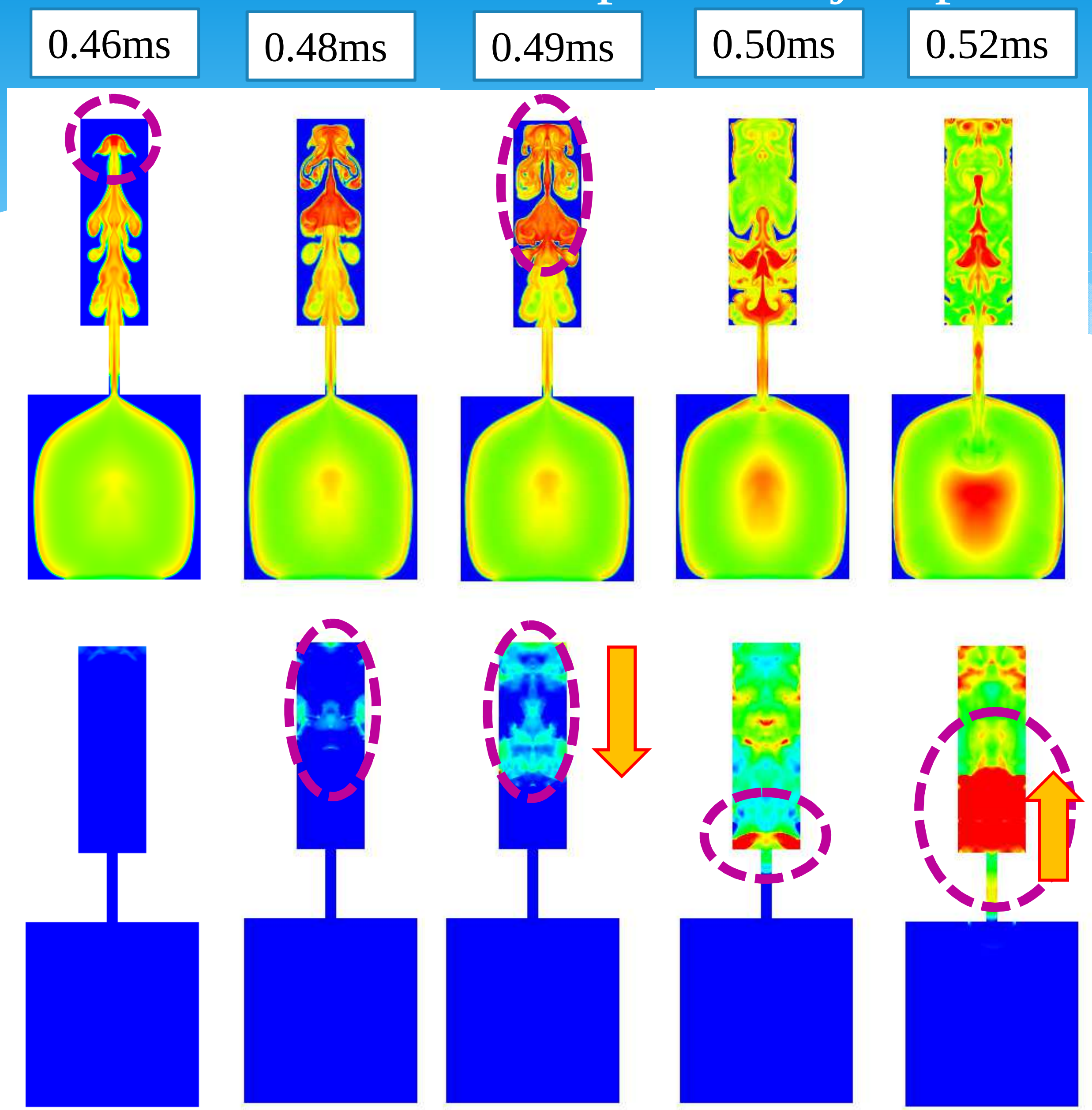


Pressure jump **wasn’t seen immediately** when flame grow in the RC.

Factor of Pressure Jump



The mechanism of pressure jump



Flame arrives near the top of wall.

Compressive waves are reflected and interacts with flame

Compressive waves are focused on the bottom corner of RC

Strong compressive waves reciprocate in RC

Conclusions

- Changing equivalence ratio and orifice diameter, it is divided 3 type of ignition that jet ignition, auto ignition, and transient ignition.
- There are difference for the pressure history in each cases.
- On jet ignition case, the pressure jump wasn't seen immediately when flame grew in the RC.
- On auto ignition case, the pressure jump was seen immediately when flame grew in the RC.
- The factor of pressure jump is the strong compressive waves produced by the interaction between compressive waves and flame reciprocates in RC.