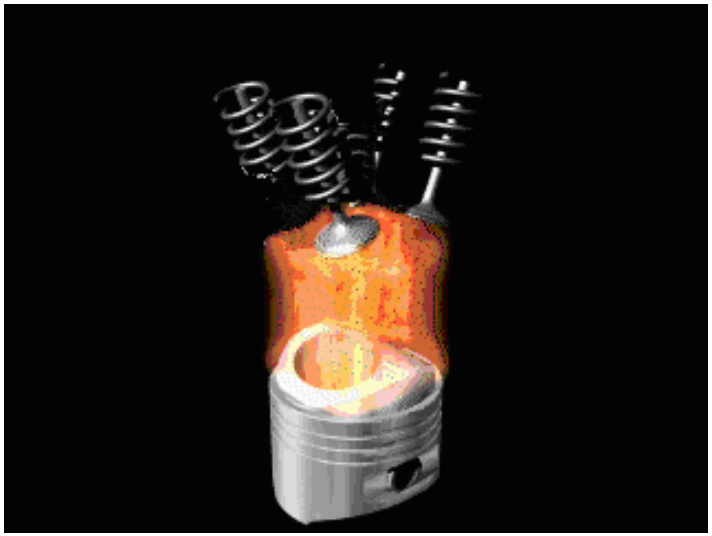

Experimental Combustion Analysis of HCCI Engine

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HCCI Engine

- High efficiency and ultra low emission w.r.t conventional Diesel engine.
- To achieve near zero NOx and soot emission to achieve latest Euro Norms (E6)
- To reduce fuel consumption, greenhouse gas emission.

(**Law of Diesel HCCI – Every one percent increase of diesel HCCI car saves 90 million liters of fuel per year. This corresponds to emission saving of some 210000 metric tones of Co2 -- SAE**)

What Is HCCI?

- HCCI is a combustion process. HCCI is not an engine concept. HCCI must be incorporated in an engine concept.
- HCCI is a low temperature chemically controlled (flameless) combustion process.
- HCCI can be considered as a hybrid form between the diesel and Otto combustion process.
- However combustion process is different. So there is neither Diffusion flame (as in a diesel engine) nor a flame front traveling through a premixed charge (as in SI engine).

What is HCCI ?

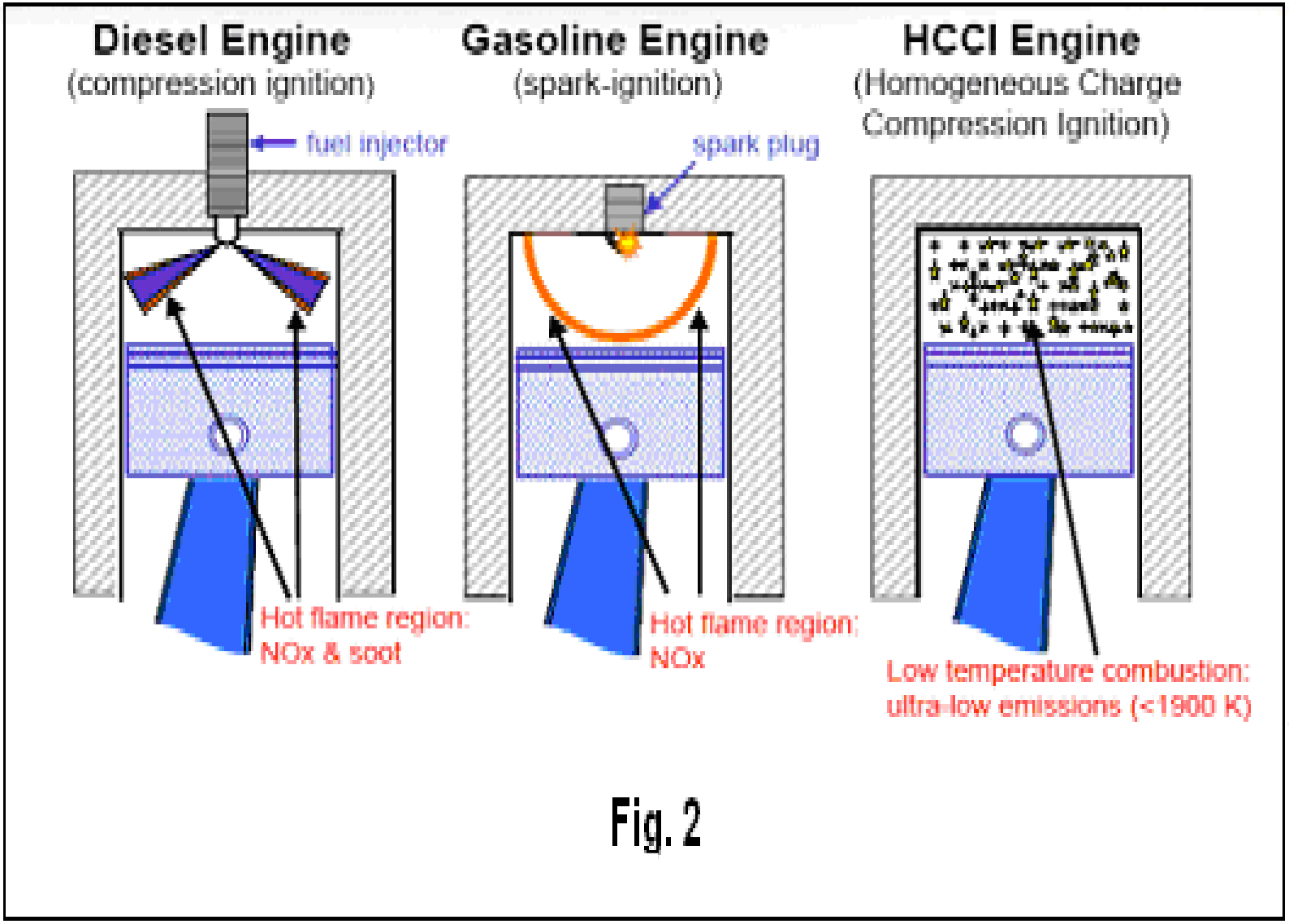


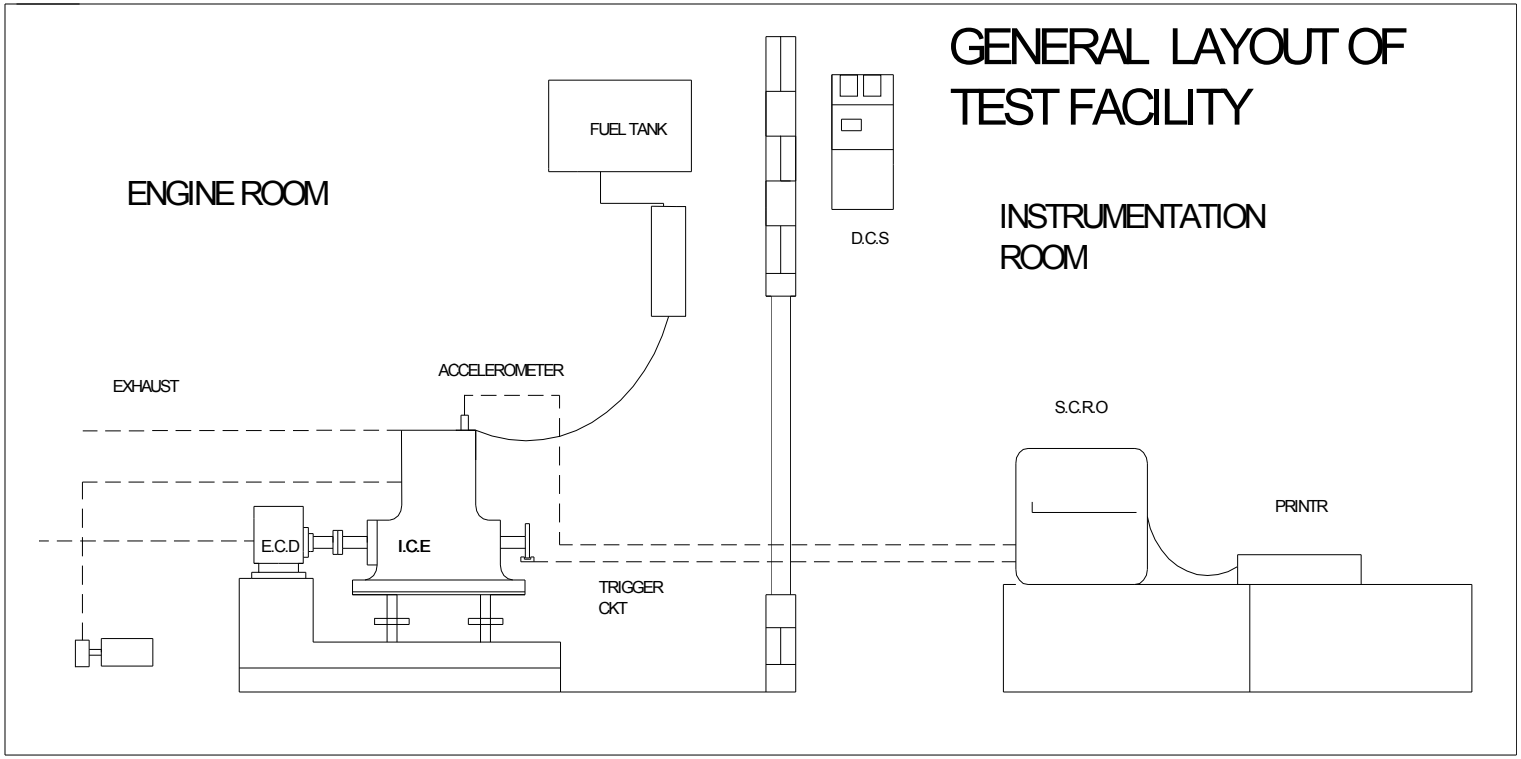
Fig. 2

Low Temperature Reaction

Process Divided in to following steps-

- Initiation-radicals are formed, reacts with fuel molecule
- Chain Propagation- Hydrogen Peroxides(H2O2) formed
- Degenerate Branching process- H2O2 divided in to two radicals of OH with fuel molecule , initiates combustion process

Experimental Set up

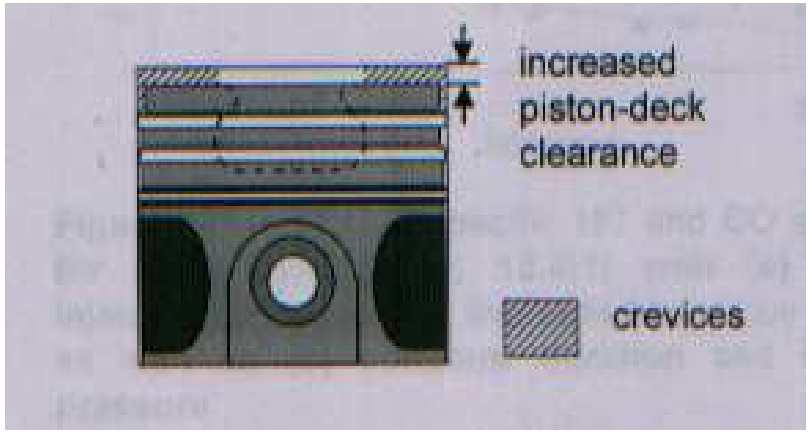


Four Cylinder Conventional DI Diesel engine converted in HCCI engine on Test Bed

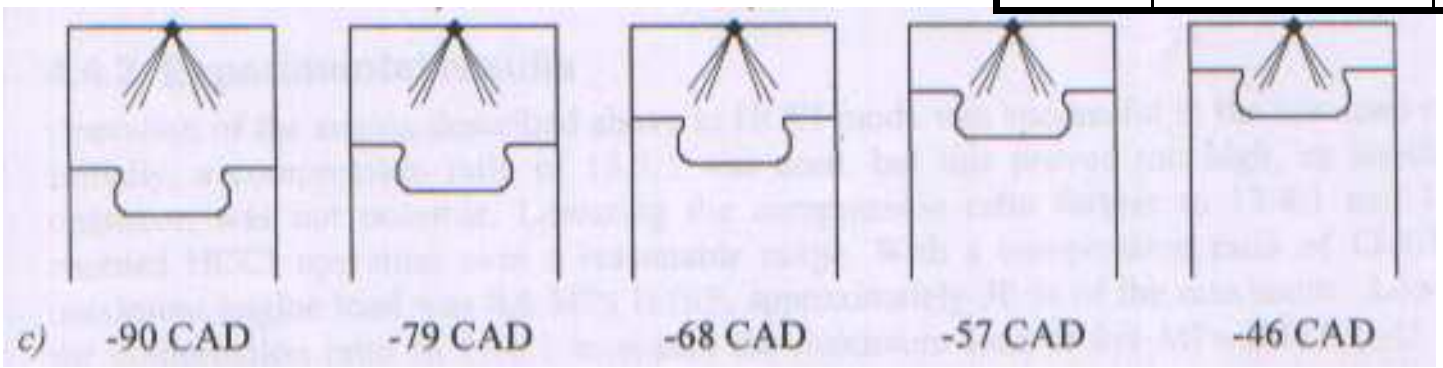
Make	Kirloskar
Bore	81 mm
Stroke	92.3 mm
Compression Ratio	17
Displacement	80cc
Fuel	Diesel
Direct Injection	
Smoke Meter-AVL415S , Variable Sampling Volume	
Nox Meter-Ecophysics,CLD700EL	
CO2 meter-Horiba , EL435	

Injection Strategy

- Reading for Compression ratio (rc)= 15.4 (Experiments conducted at KPIT, Ahmednagar)



IMEP MPa	Press of fuel injected MPa	λ (lambda
0.2	**55**	**1.9**
0.3	**75.1**	**1.43**
0.4	**80.2**	**1.21**
0.5	**98.1**	**1.11**



Injection strategy-

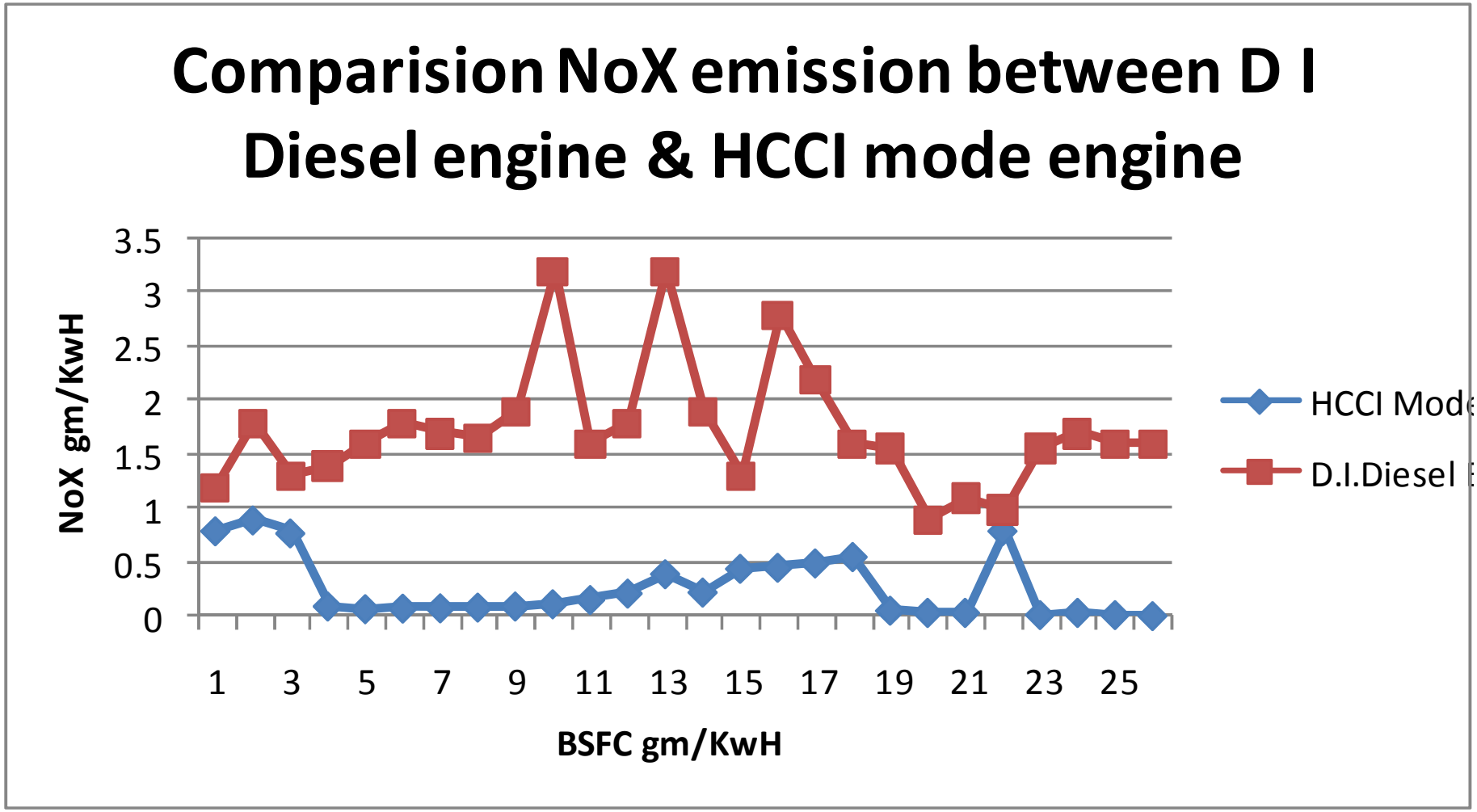
(Experiment conducted at Kirloskar Oil Engine Ltd, Ahmednagar)

- Fuel injectors with included angle of 60 deg instead of 45 deg were used to spray more downward.
- Penetration was calculated for each injection.

  Penetration=*[2.95({Pinj.-Pamb.)/density of air})^0.25x T inj.]* – ***Hirroyasus Expression***
- Fuel was injected in five sequential stages to achieve a uniform A:F mixture.
- At the early stage of compression ,air density is lower therefore penetration is much longer .
- The dwell between injection was set 11 CAD (Crank Angle Degree) to avoid interaction between the individual injections.
- To reduce droplet size of fuel, The No. of orifice on nozzle increase from 5 to 10 (size- 0.111mm to 0.120mm)

Experimental Result of HCCI Engine

(NoX emission)



Combustion Phases OF HCCI

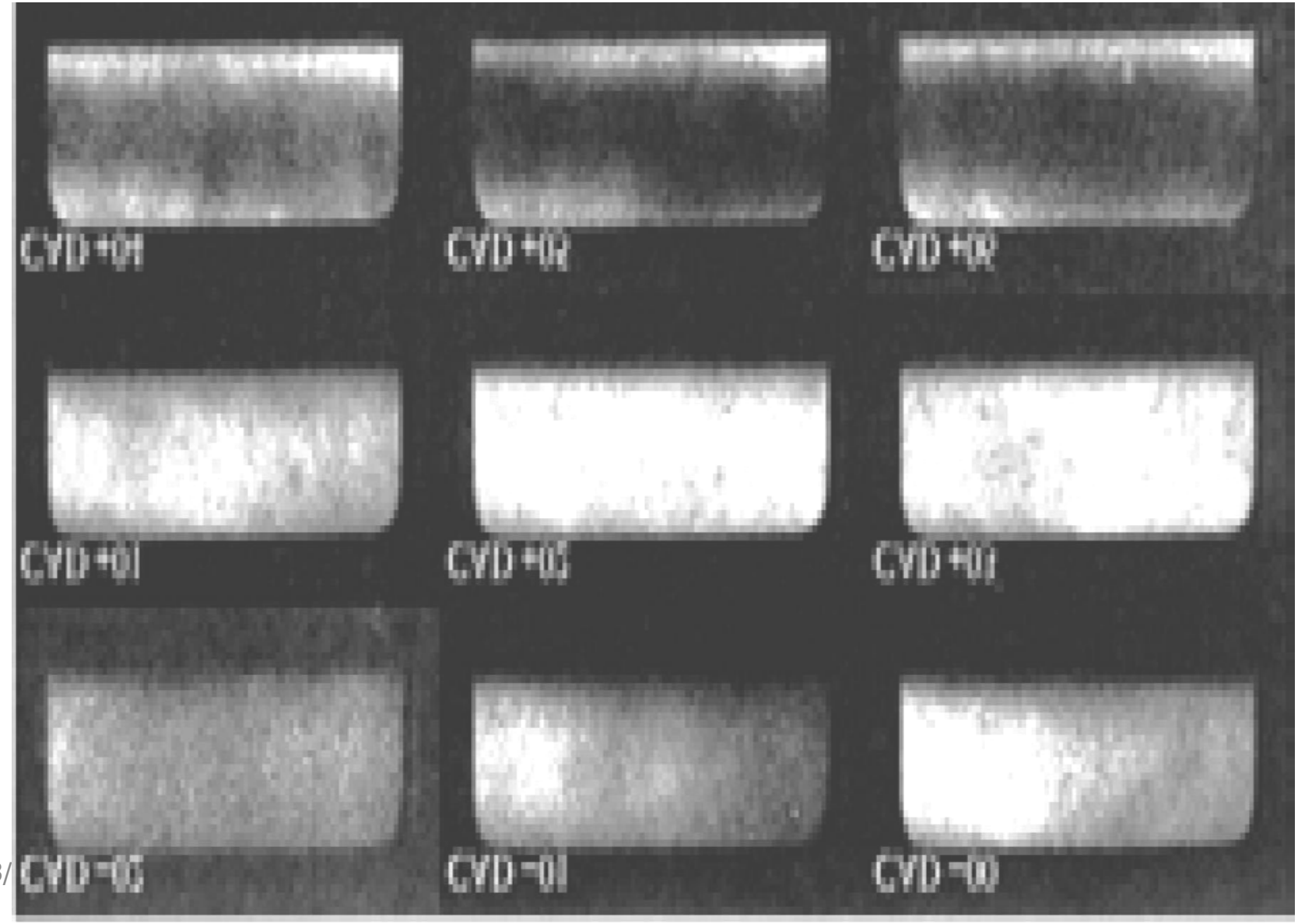
(By AVL- Endoscope)

- **Homogenous charge is drawn in to the cylinder during suction and compress to high enough temperature to achieve spontaneous ignition of the charge.**
- **As shown in the images by the camera(20 images per CAD) it can be seen that.**

1. **Combustion starts in almost whole volume of C.C Two degree before TDC (CAD- 02).**
2. **After Combustion initiation the temperature rapidly increases and whole fuel burn simultaneously (CAD 0 to CAD +03).**

- **As whole mixture burns simultaneously and no flame propagation , combustion temp. can be controlled less than 700 deg Centigrade and thus NOx formation is avoided.**

PHOTO SEQUENCE OF HCCI COMBUSTION, BASED ON 20 FP CAD CAMERA (AVL- Endoscope)



Experimental Setup At Government Polytechnic Ahmednagar by changing injection strategy

The main Challenges with Making HCCI Practically

- **Effective Control System for ignition timing .**
- **To achieve practically Variable Compression ratio.**
- **Injection strategy w.r.t load condition .**
- **extending the operating range to high loads**
- **limiting the rate of combustion heat release at high load condition**
- **achieving cold start**

Conclusion

- HCCI engines are more efficient than SI and CI engines.
- Lower emission of PM and NOx to meet future norms (Euro 6 Norms).
- It has fuel flexibility.
- HCCI engines will be cheaper than the presently used engines because of simplicity.

But

Control on Ignition timing is essential.

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Thank you