Effect of carbon black nanoparticles on methane/air explosions: Influence at low initial turbulence

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CONTEXT

Nanoparticles used to modify:

- Resistance
- Surface modification
- Rheology
- Magnetization

High Specific Surface

→ **Advantageous on :**

- Catalysis
- Biomaterials
- Biological applications

Necessity of studies on the toxicity and explosion hazards of combustible nanoparticles

EXPLOSION OF NANOPARTICLES

Previous works have shown:

- The ignition sensitivity can increase for nano-dusts
- Similar explosion severity for µm- and nanoparticles

→ Dispersion of a highly loaded cloud → Utopic

→ Fast agglomeration / enhancing sedimentation

Unlikely to occur at normal industrial conditions

However… Simultaneous gas/vapor and dispersed nanoparticles

→ Hybrid mixture explosion

1. Could the explosion be modified by the presence of nano-dust at low turbulences levels?

2. Could an initial concentration of carbon black nanoparticles increase the severity of a hybrid mixture explosion?

PRESENTATION CONTENTS

Materials & Methods

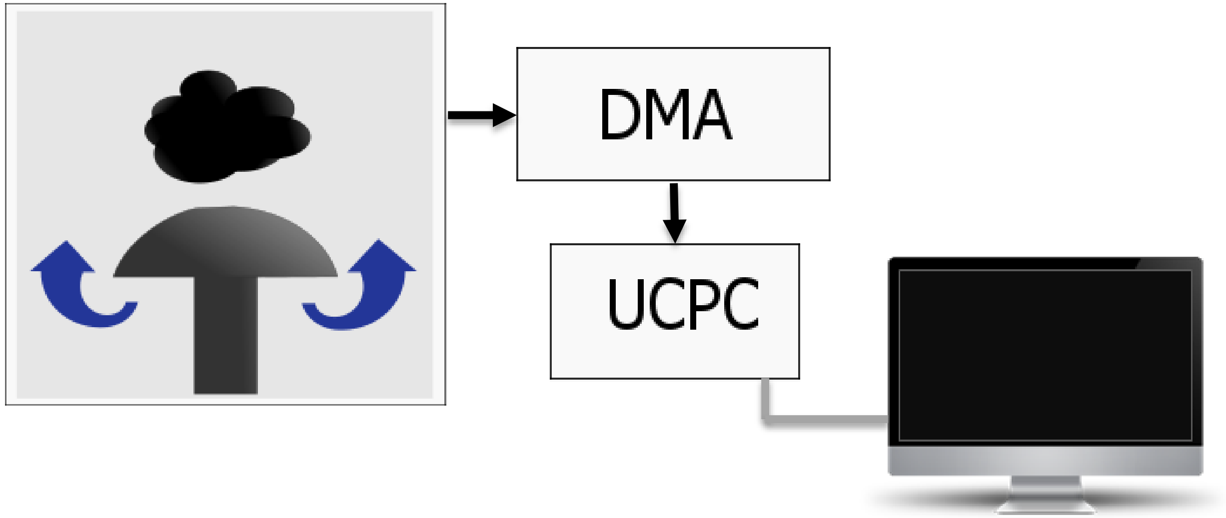
Results

1. DISPERSION STABILITY
2. EXPLOSION SEVERITY – Influence of dust concentration
3. EXPLOSION SEVERITY – Influence of turbulence

Conclusions

EXPERIMENTAL SETUP

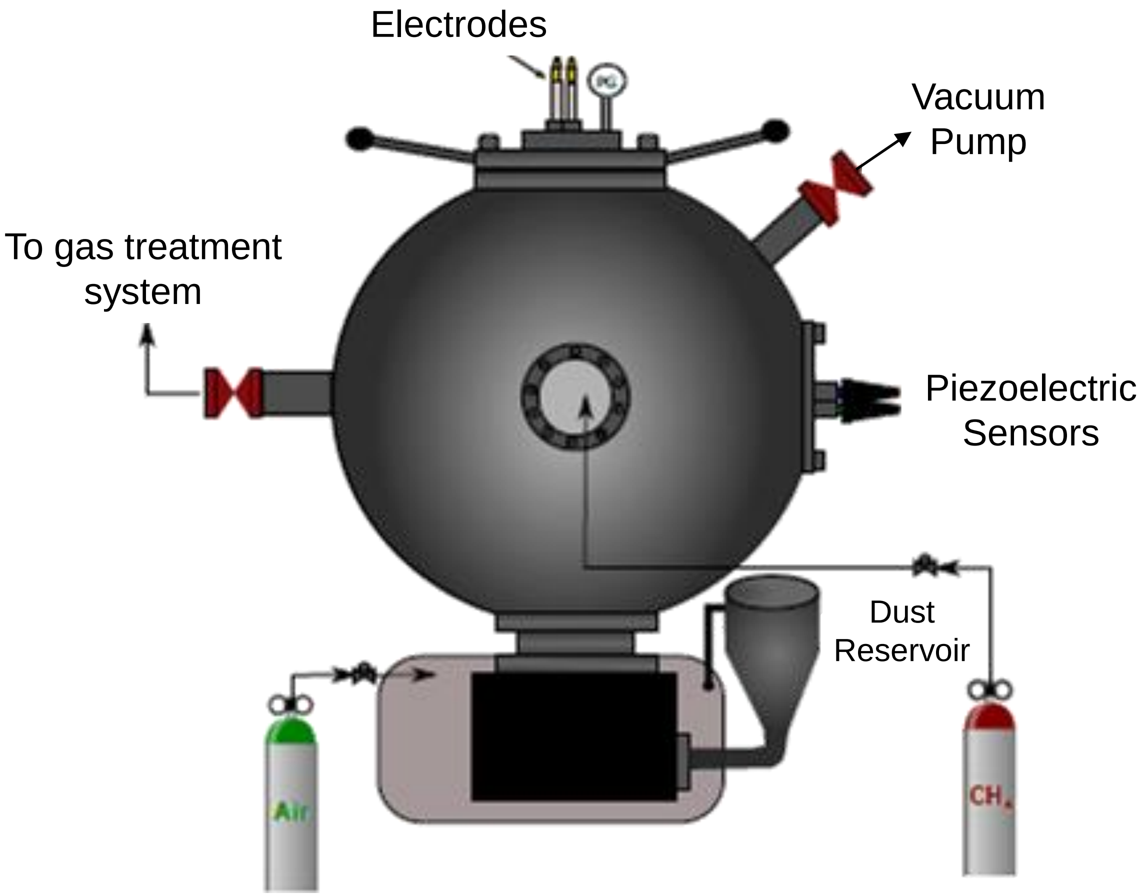
Dispersion Stability



Tested by:

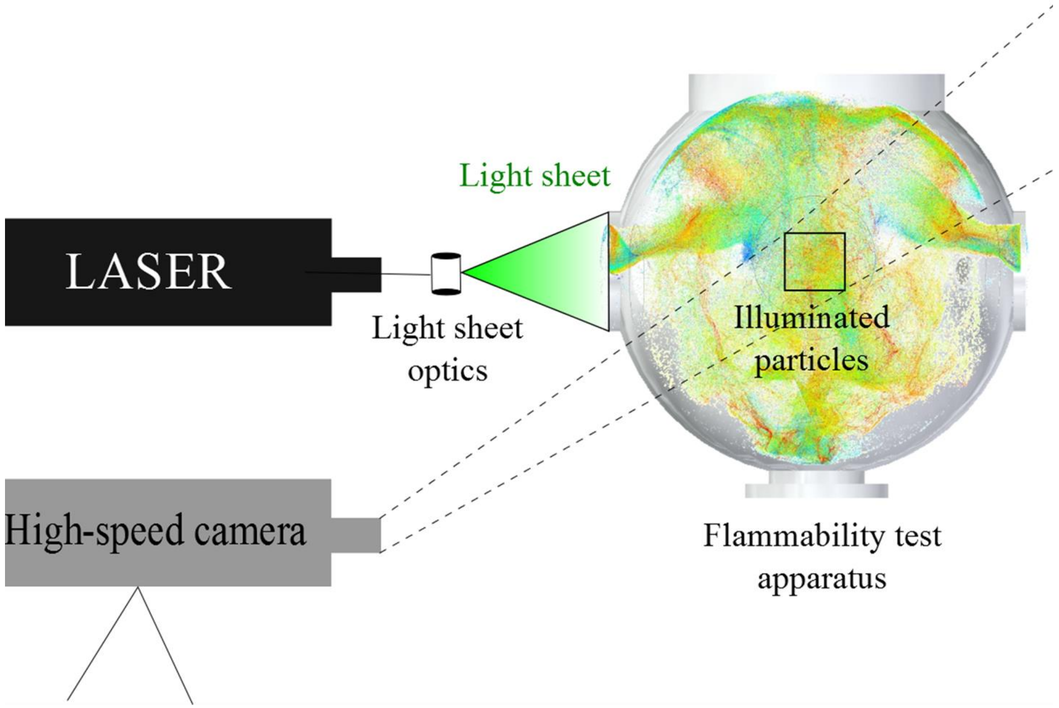
- Differential Mobility Analyzer (DMA)
- Ultrafine Condensation Particle Counter (UCPC)

P_{max} & $\frac{dP}{dt}_{max}$



Burnt gases were analysed by µGC

IGNITION DELAY TIME - TURBULENCE

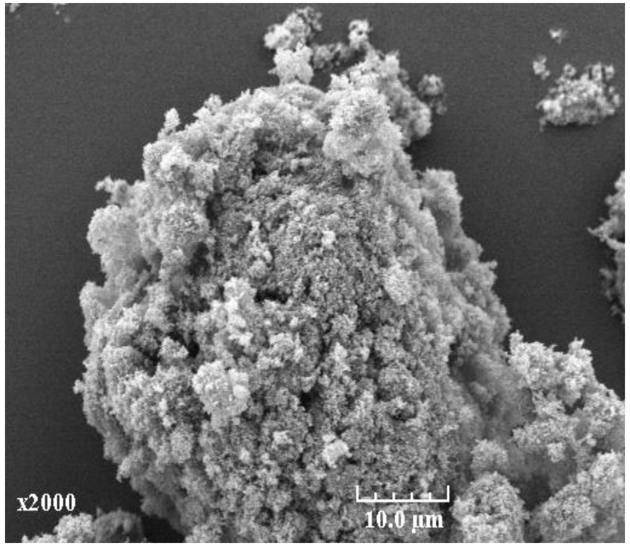


Particle Image Velocimetry (PIV)

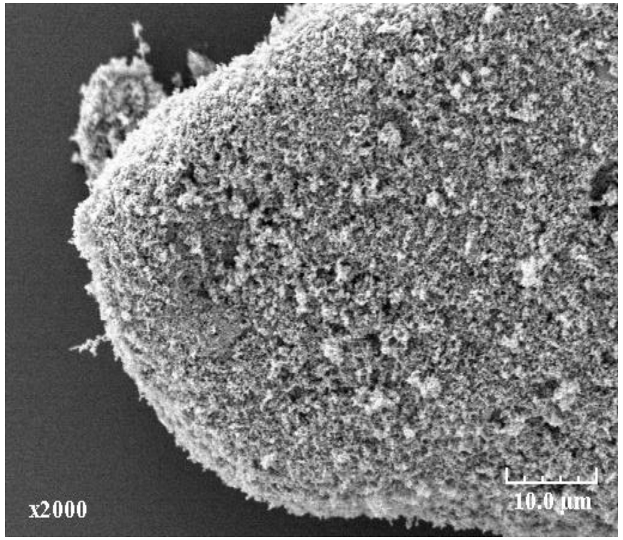
Ignition delay tv (ms)	Intensity of velocity fluctuations u' (m.s^{-1})	
	Sphere (this study)	Sphere (Dahoe 2000)
0	0	0
60	3.40	3
120	1.05	0.9

Standard Value

CARBON BLACK PARTICLES



PRINTEX XE2



CORAX N550

Ignition delay tv (ms)	Powder concentration (g/m³)		
	0	0.5	2.5
0	Gas Concentration (%v.): 5.5 - 7 - 8 - 9 - 12		
60			
120			

Minimum Explosible Concentration (Carbon Black): 60 g/m³

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↓

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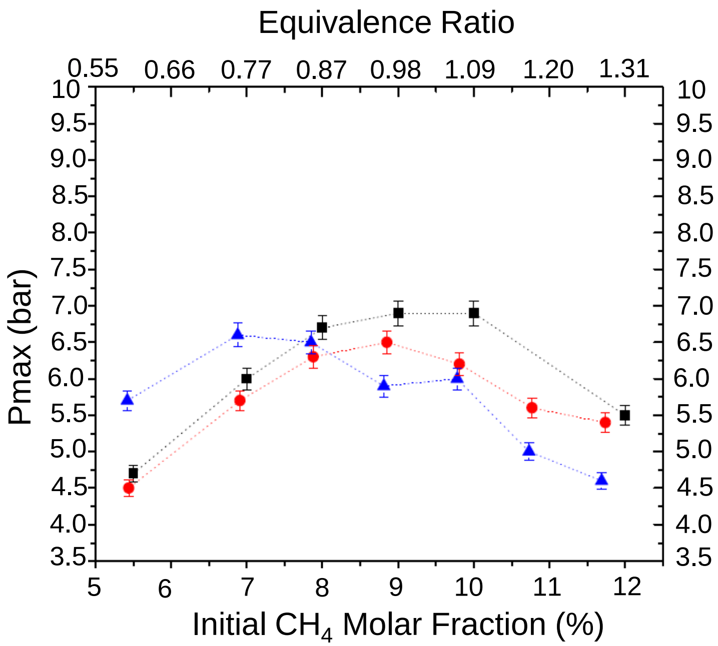
DISPERSION STABILITY

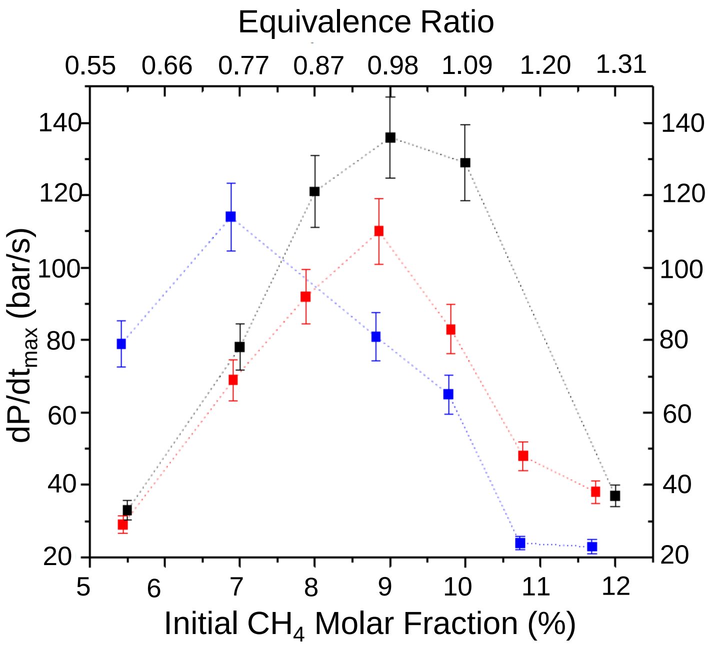
Nanopowders	Time after dispersion (s)	Mean Mobility Diameter (nm)	Concentration (particles/cm^3)	Ambiance Concentration (particles/cm^3)
Printex XE2	20	245	2.1×10^5	6×10^3
	190	241	1.5×10^5	
Corax N550	20	346	2.4×10^5	
	180	350	1.5×10^5	

1. Similar mobility diameter after 20 and 190 seconds
2. Agglomeration phenomena is limited because of the low powder concentration
3. A stable dust cloud of agglomerates is generated
   Ignition delay times (t_v)→ Present @ 60 & 120 ms

INFLUENCE OF CB CONCENTRATION



Methane/Printex XE2/Air



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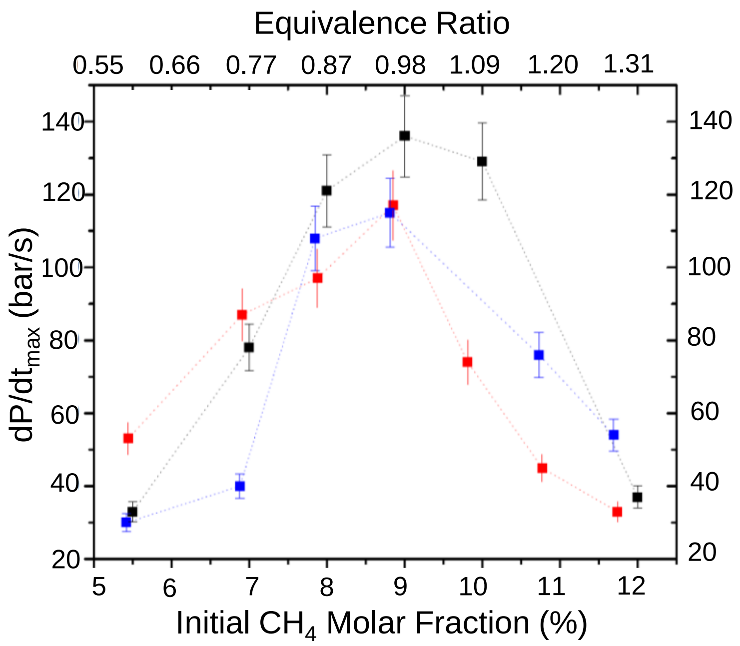


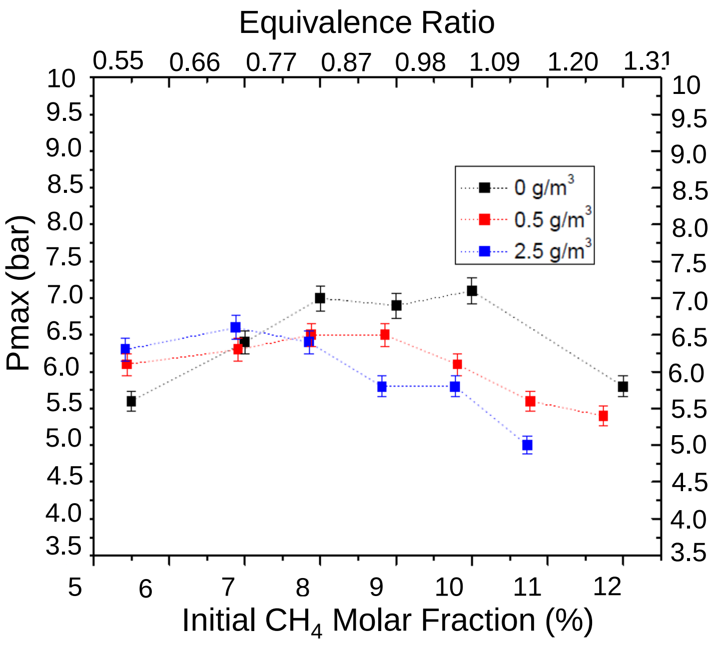
Methane/Corax N550/Air

■ **0 $g.m^{-3}$** ● **0.5 $g.m^{-3}$** ▲ **2.5 $g.m^{-3}$**

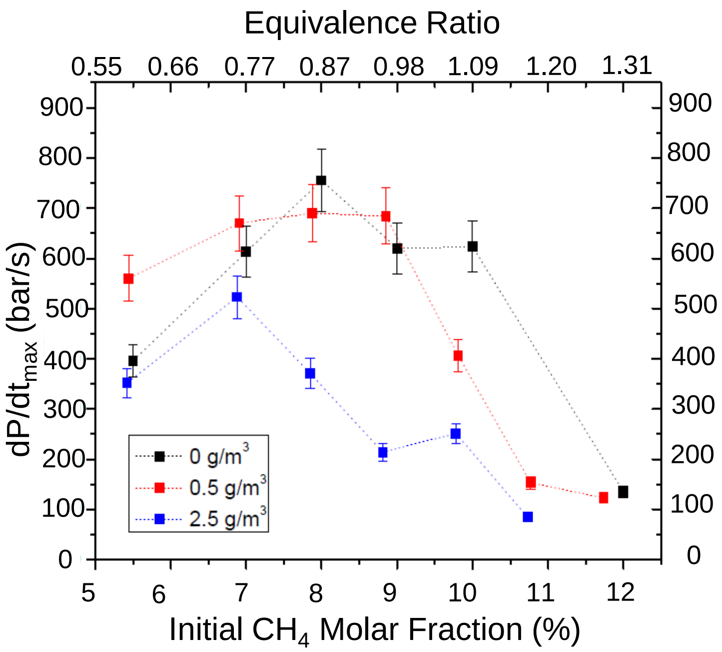
At quiescent conditions (not dispersed at high pressure):

1. Higher explosions severity for initial CH_4 fractions 5.5-8%
   → Same trends for Printex XE2 and Corax N550
2. Strong influence of Printex XE2 on the explosion severity

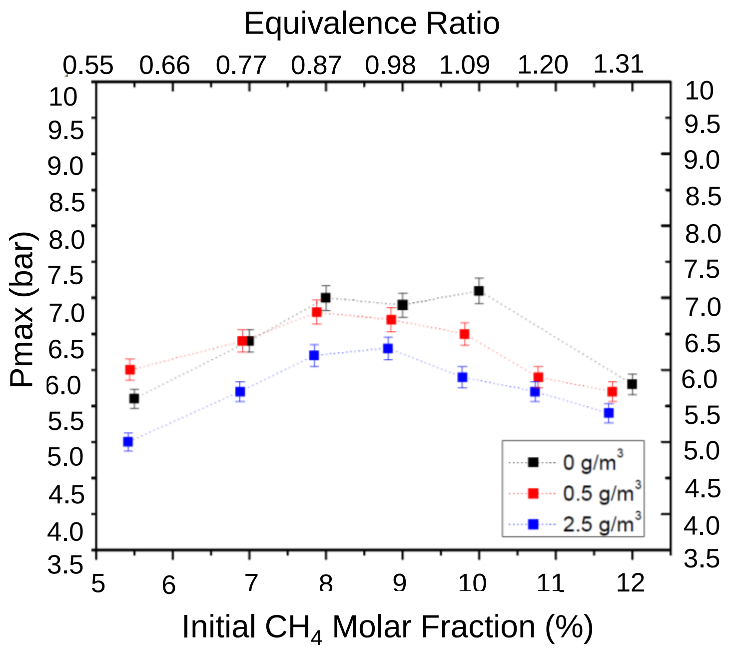
INFLUENCE OF CB CONCENTRATION



Methane/Printex XE2/Air



Methane/Printex XE2/Air



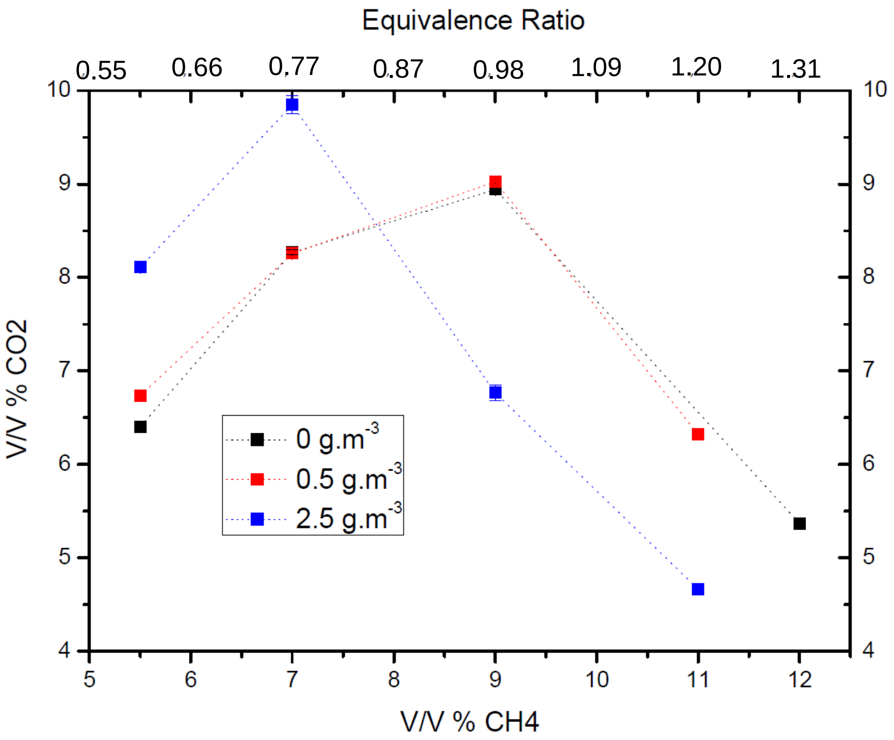
Methane/Corax N550/Air

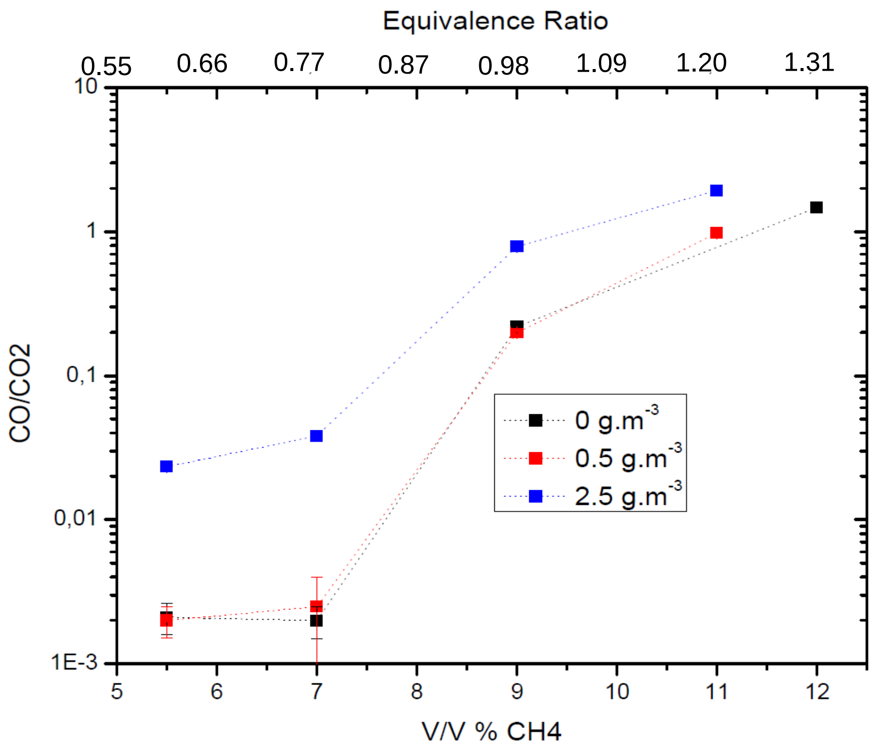
0 g.m^{-3} **0.5 g.m^{-3}** **2.5 g.m^{-3}**

At u' = 1.04 m/s (t_v 120ms):

1. Similar trends compared to the quiescent system
   Higher influence at higher specific surface → Deagglomeration of powder
2. Turbulent quenching for Printex XE2 → No explosion at 12% v/v CH_4

INFLUENCE OF CB CONCENTRATION





Printex XE2/Methane/Air mixture under quiescent conditions.

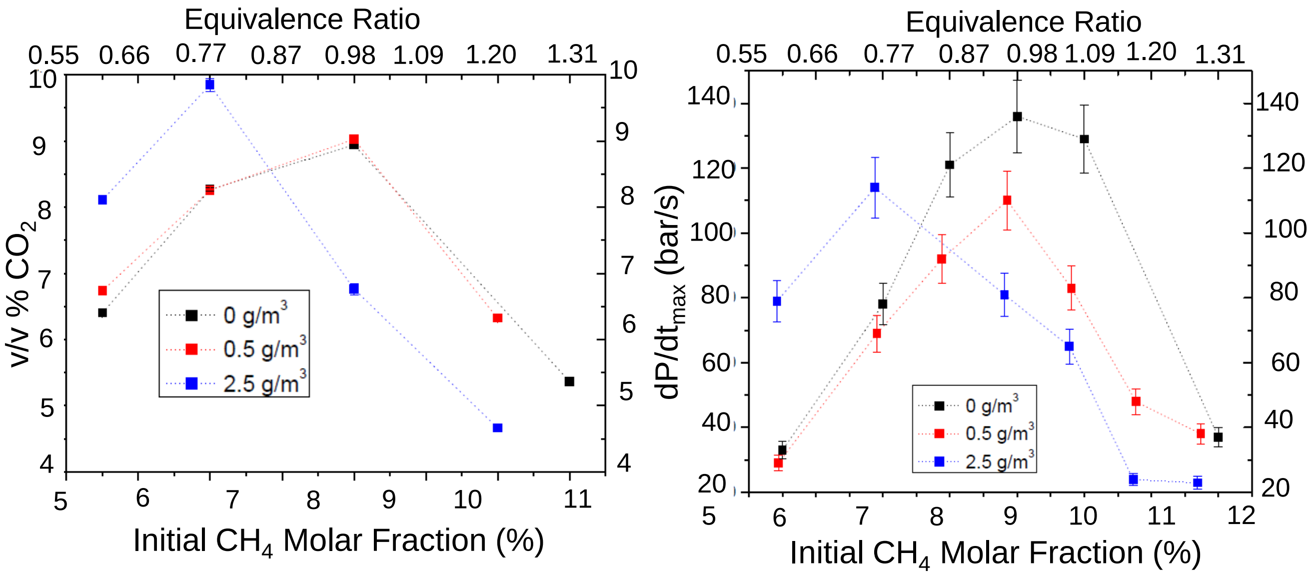
Dispersion of a cloud of carbon black affects the **combustion reaction**

↳ Even at **low concentrations of dust**

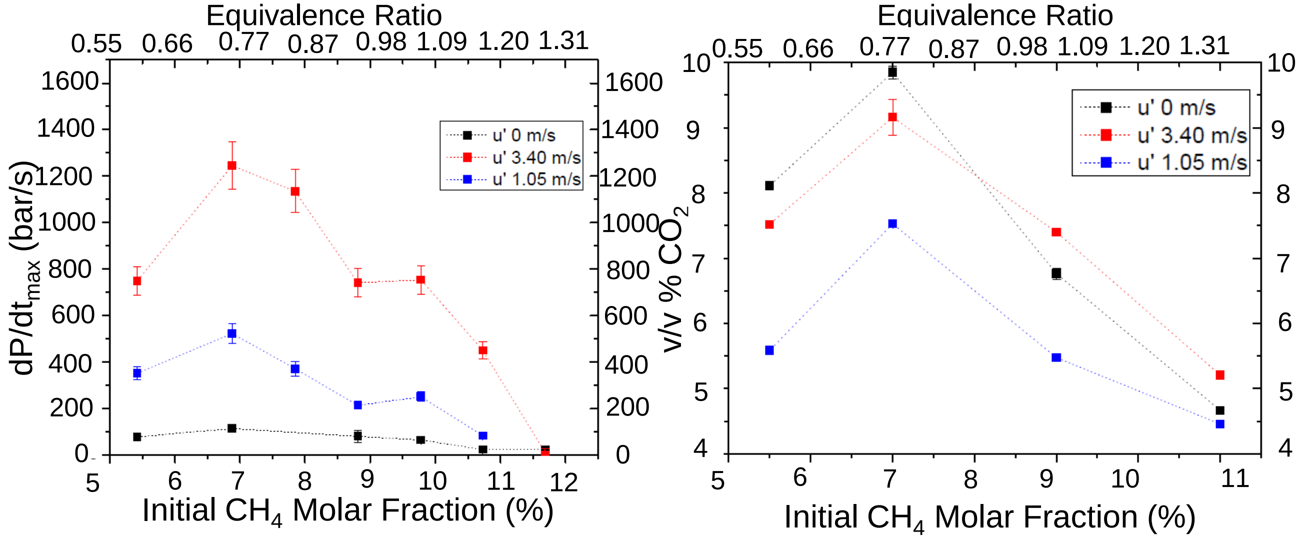
Modifications on the combustion reaction could be related to:

① Radiation heat exchange ② Flame surface changes

INFLUENCE OF CB CONCENTRATION



Printex XE2/Methane/Air mixture under quiescent conditions.



Printex XE2/Methane/Air mixture 2.5 g/m^3.

The **highest (dP/dt)max** is obtained

↳ Maximum conversion of **CO to CO_2**

Variables that promotes the conversion of CO_2

1. Carbon black addition for Fuel lean mixtures
2. Increase on the initial turbulence level

Complex interactions between the turbulence and the combustion reaction are evidenced

↳ Test on inert powder

CONCLUSIONS

- Dust clouds of the carbon particles studied remain highly stable after the dispersion

  → Mean mobility diameter

  Printex XE2 ~ 240nm
  Corax N550 ~ 370nm

  → Agglomeration phenomena is limited because of the low concentrations of powders

- Explosion severity of methane/air mixtures increases when low concentrations of carbon black nanoparticles are added

  Even at **low initial turbulence**

- The specific surface area of particles have a great influence on the explosion severity

  → Deagglomeration phenomena at high turbulence systems

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