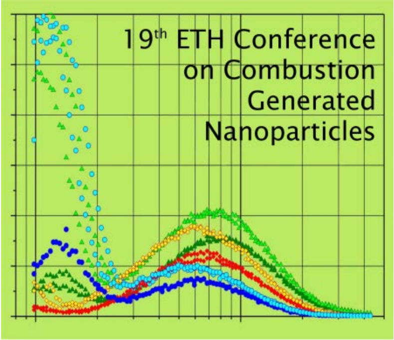
Comprehensive analysis of phenomena during catalyzed DPF active regeneration



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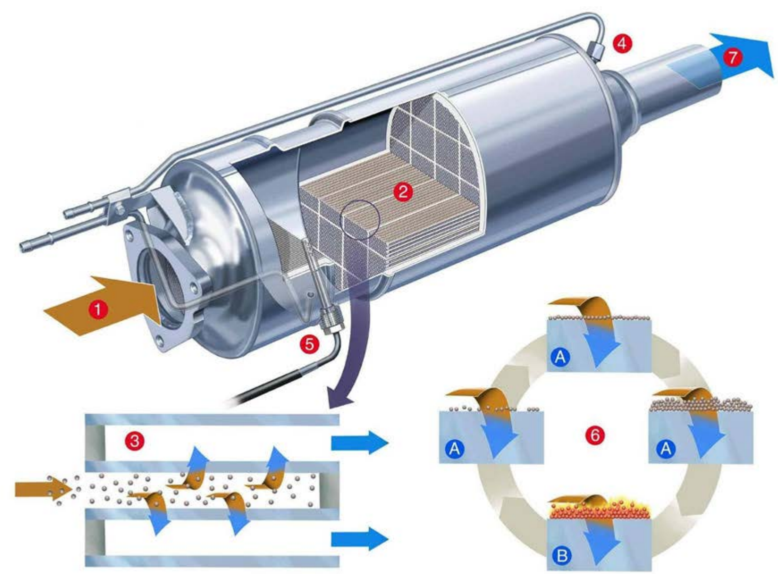
General context

Diesel Particulate Filter (DPF)

- All Diesel PC vehicle fitted DPF in EU since 2011
  - cDPF or FBC-DPF
- Sequential system:
  - 1st phase : Filtration
    - 300 – 1000 km
  - 2nd phase: Regeneration
    - Few minutes
    - Increase of DPF inlet T°C thanks to fuel post-injection



Source : GM Opel

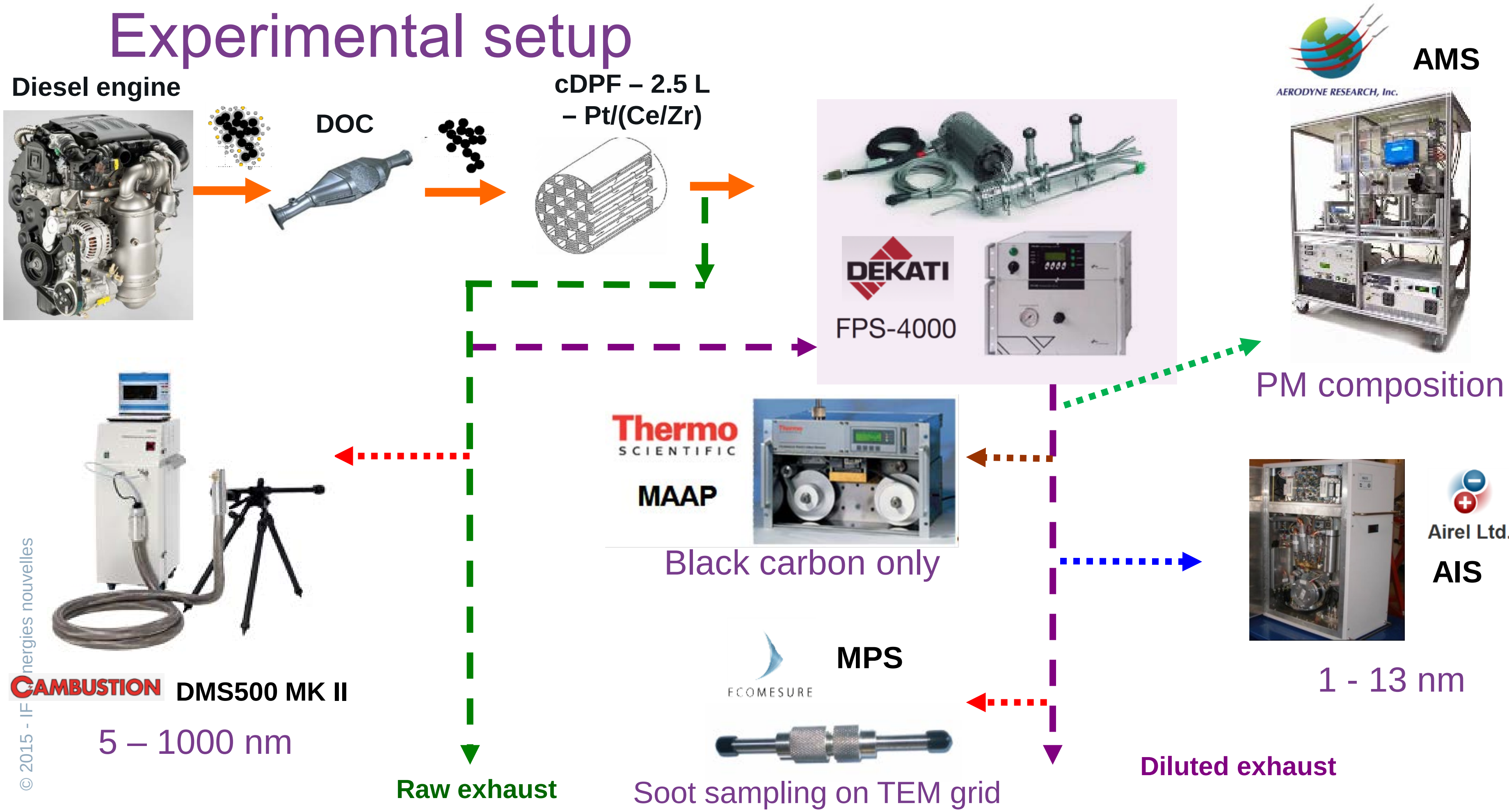
➢ Regeneration phase corresponds to around 1% of the total time of vehicle use

Objectives

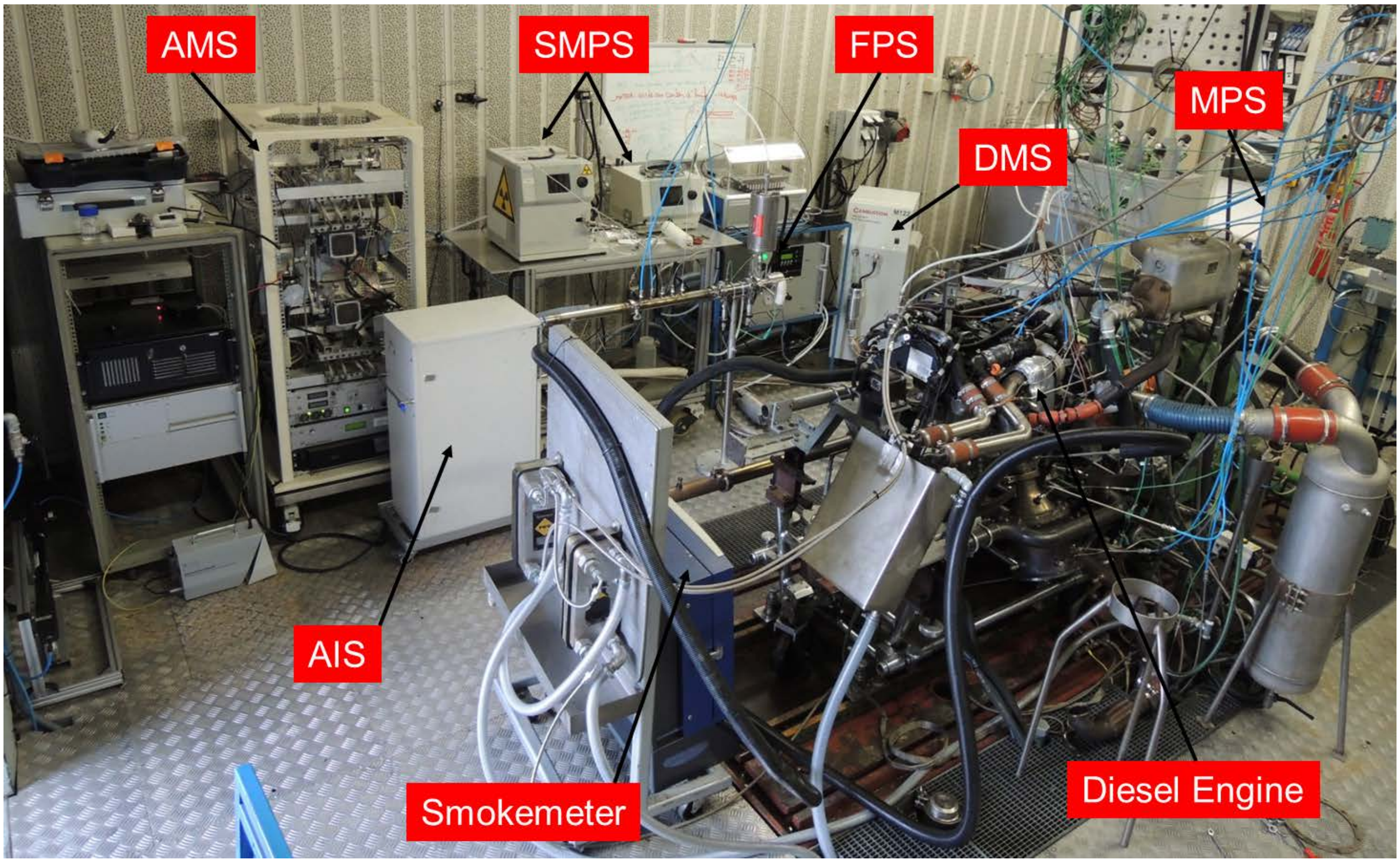
- To improve understanding of phenomena occurring during catalyzed DPF active regeneration
- To provide guidelines to reduce gaseous and particulate emissions during active regeneration
- To pave the way for future cDPF devices

Particles characterization during active regeneration

Experimental setup



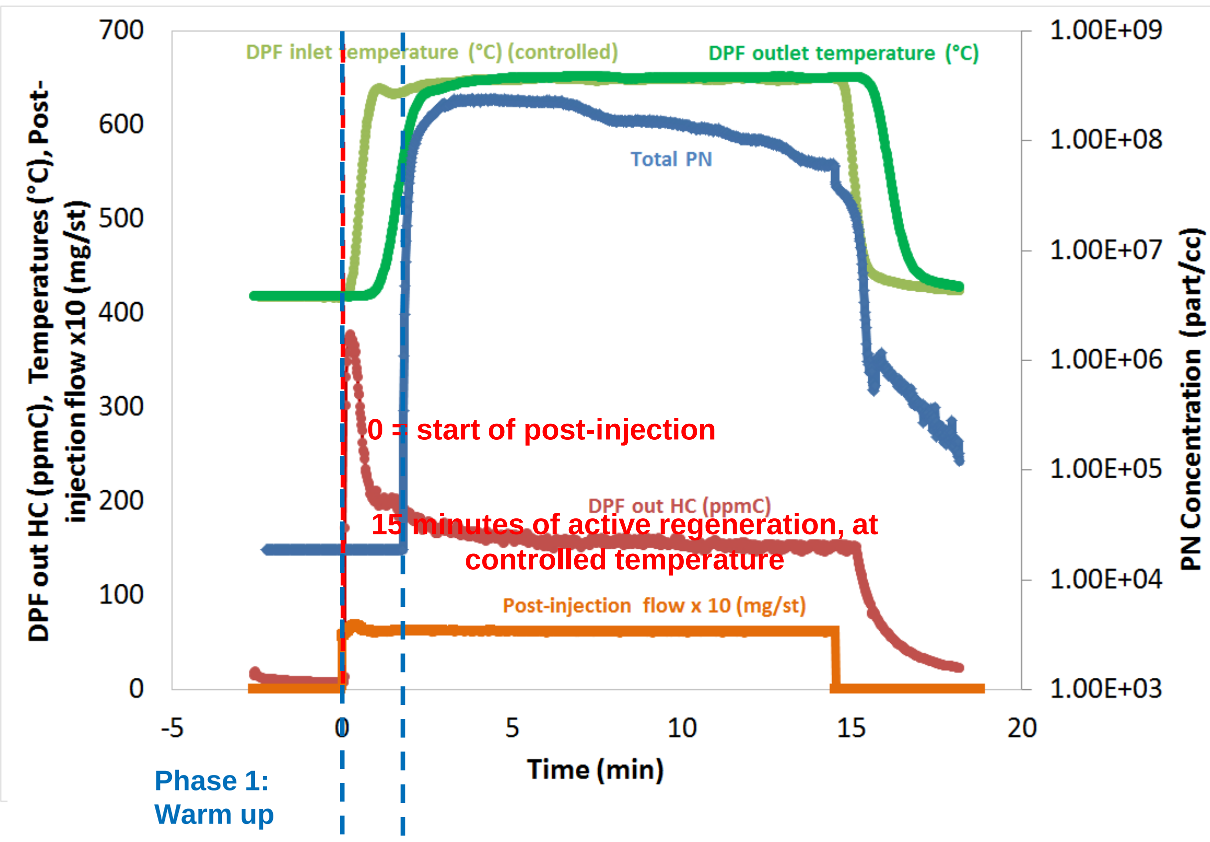
Particles characterization during active regeneration



Particles characterization during active regeneration

Nearly empty DPF (0 – 0.5 g/L) – 630 °C

- Phase 1 { t = 0 → t ~ 2 minutes }: cDPF warm-up phase

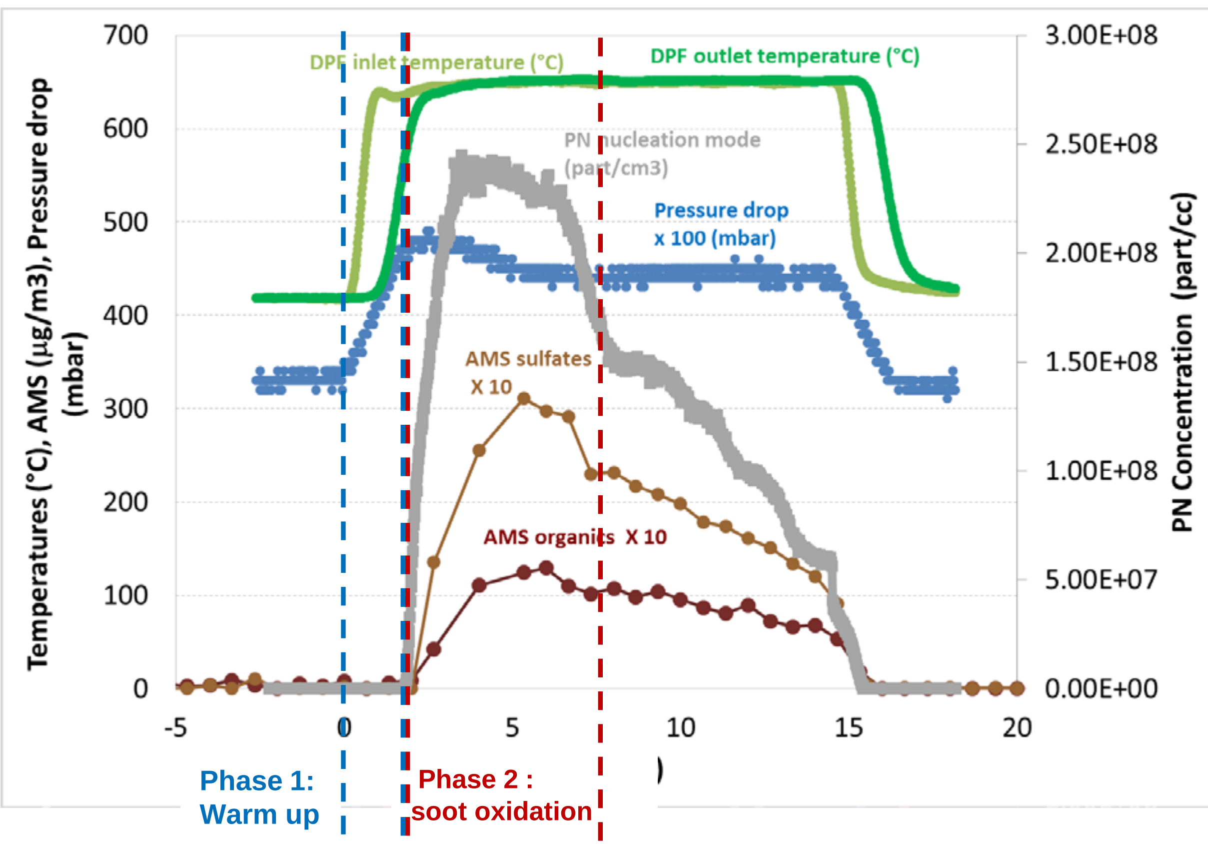


- No particulate emissions during the phase 1 despite of the massive HC post-injection

Particles characterization during active regeneration

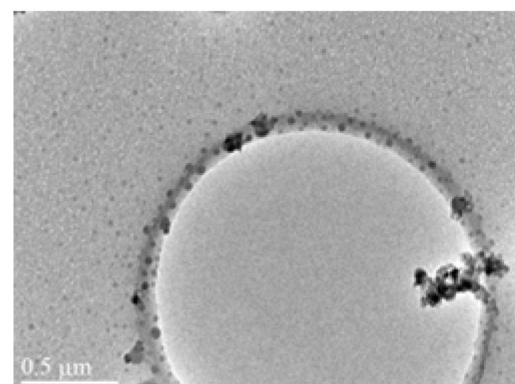
Nearly empty DPF (0 – 0.5 g/L) – 630 °C

- Phase 2 { t = 2 minutes → t ~ 7 - 8 minutes }: soot oxidation



➤ Phase 2 : Particulates peak in nucleation mode:
  - Sulfates + organic compounds

Confirmed by TEM analysis



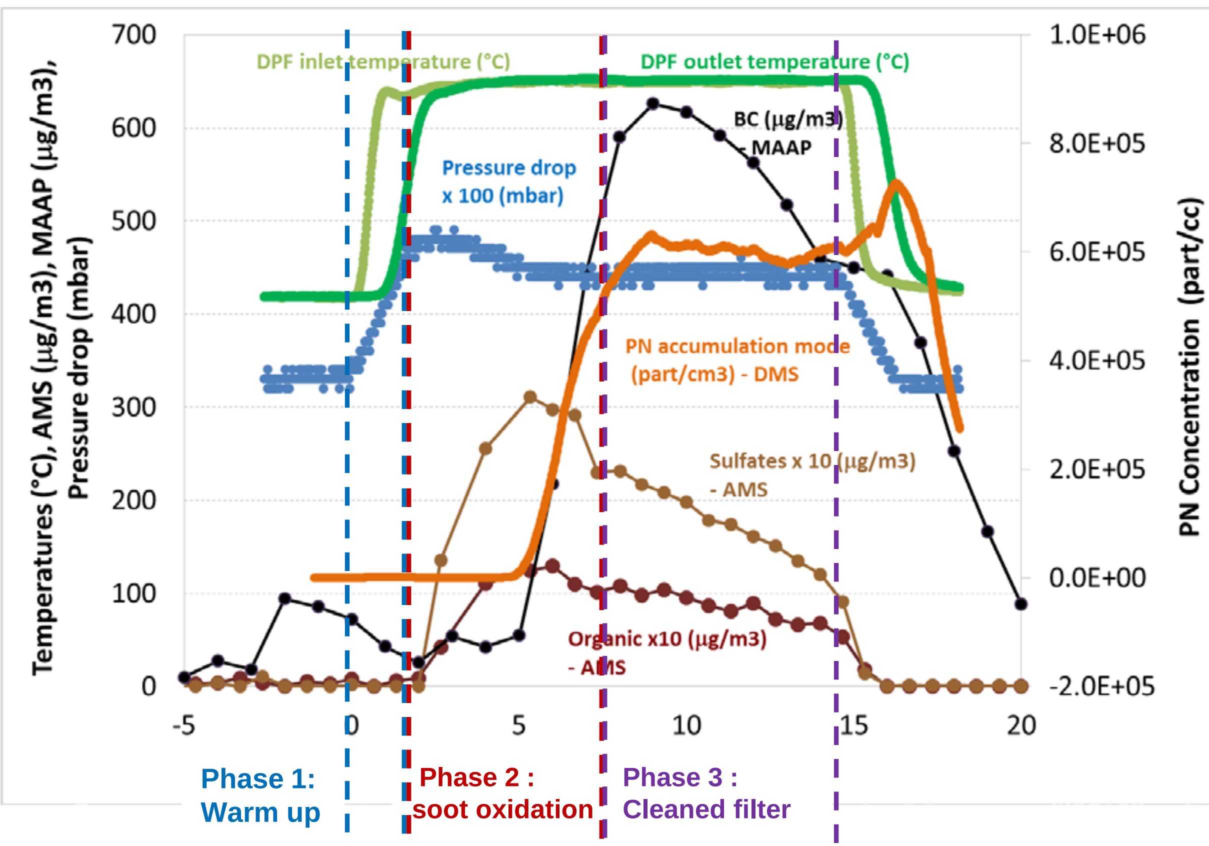
IFP Energies nouvelles

INSTITUT CARNOT IFPEN Transports Energie

Particles characterization during active regeneration

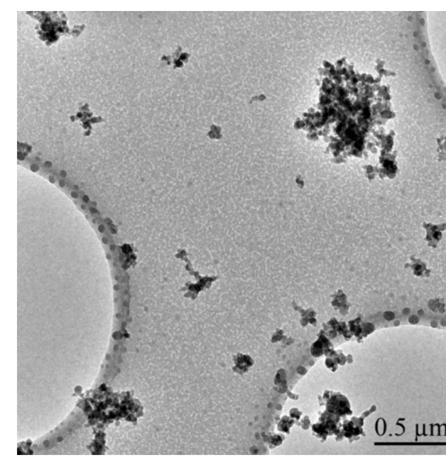
Nearly empty DPF (0 – 0.5 g/L) – 630 °C

- Phase 3 { t = 5 - 6 minutes → t ~ 15 minutes }: cleaned filter



- Phase 3 : Particulates peak in nucleation mode **AND** in accumulation mode

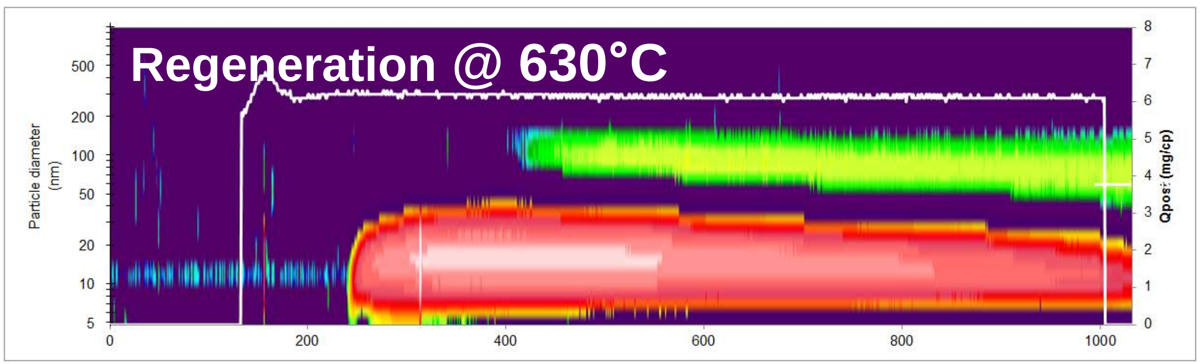
Confirmed by TEM analysis

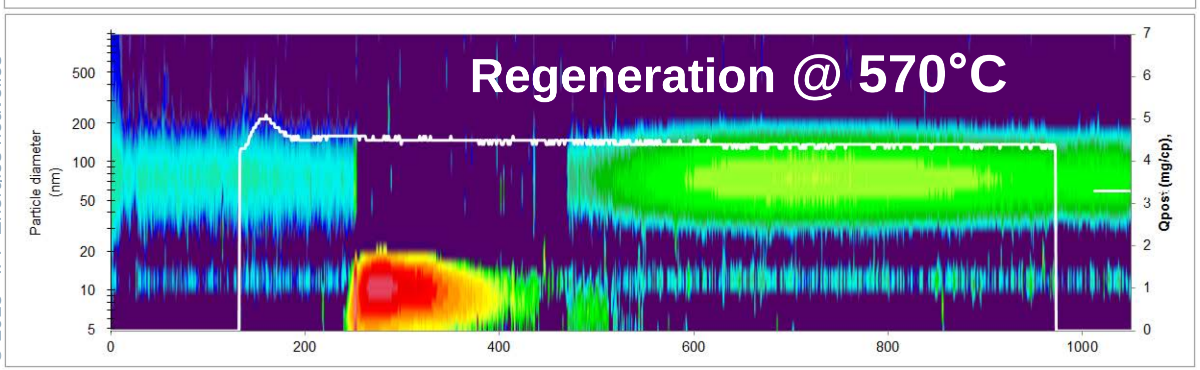


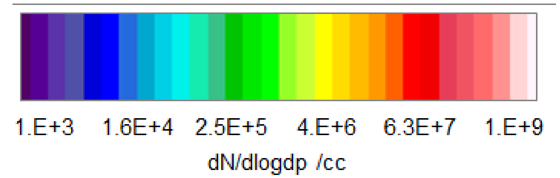
Particles characterization during active regeneration

Effect of regeneration temperature

- Higher regeneration temperature ⟷ higher quantity of HC (post injection)
- Higher regeneration temperature → more sulfate emissions



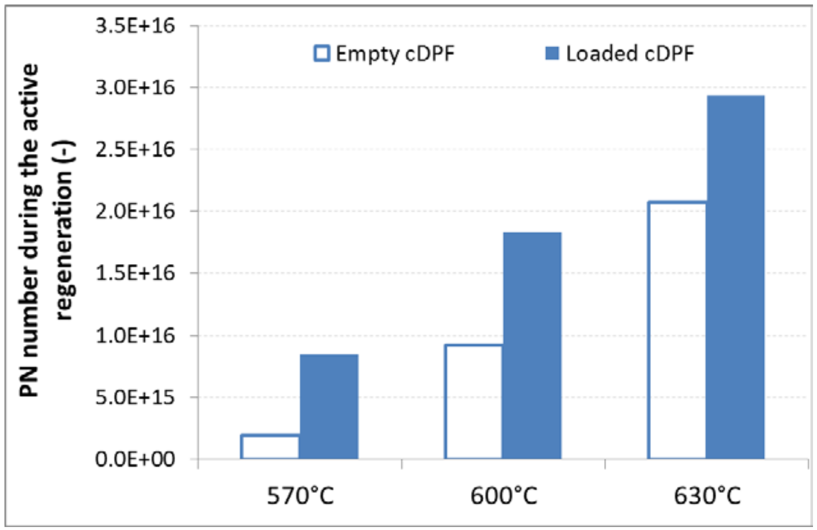




- The higher the temperature regeneration is, the higher the particulates emission level in nucleation mode.

Particles characterization during active regeneration

Effect of soot loading



- Higher PN during active regeneration with loaded filter :
  - Mainly due to the bigger nucleation mode
  - Probably not related to the soot cake
  - Sulphur storage during loading phase

Particles characterization during active regeneration

Conclusions (1/2)

- **Significant particulate emissions were measured during active regeneration :**
  - In nucleation mode during the first minutes (2 – 7 minutes)
    - Nucleation is thermically activated : simultaneously observed by DMS, AMS and AIS measurements.
    - High temperatures (> 600°C) cause the sulfate species desorption from the catalytic supports (DOC and DPF catalysts)
    - Nucleation could come from the simultaneous presence in the gas phase of sulfate species and volatile organic compounds (fuel post-injection) : this volatile fraction cannot be adsorbed on the solid soot surface because no emission of solid particles were detected during the early stage of the active regeneration .
  - In accumulation mode after 5 minutes
    - Linked to the removal of the soot cake

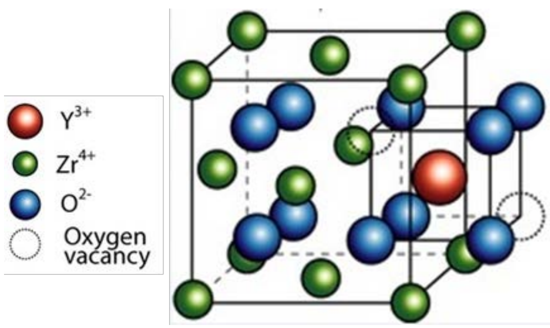
Particles characterization during active regeneration

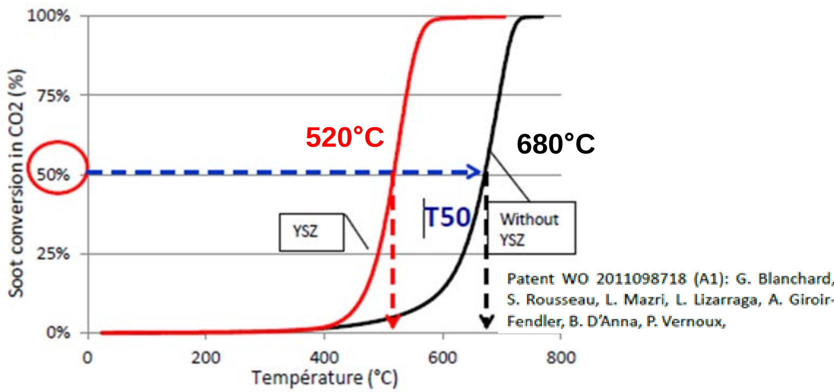
Conclusions (2/2)

- **Some ideas to reduce particulate emissions during active regeneration :**
  - **Reduce the PGM loading in catalysts : PGM promotes the sulfate desorption in the temperature range of the DPF regeneration (600-650°C). Once desorbed, sulfates species act as nucleation seed.**
  - **Reduce the temperature of regenerations : shorter post-injections (less organic compounds) and any or few desorption of sulfates.**
  - **Control the regeneration duration : must be finely controlled to avoid solid particulates emissions after soot cake destruction.**

Development of innovative cDPF in the framework of the PIREP2 project

- Development of a self-regenerating DPF able to continuously burn the soot without any PGM
  - Use of ceramics with ionically conducting ceramics like YSZ





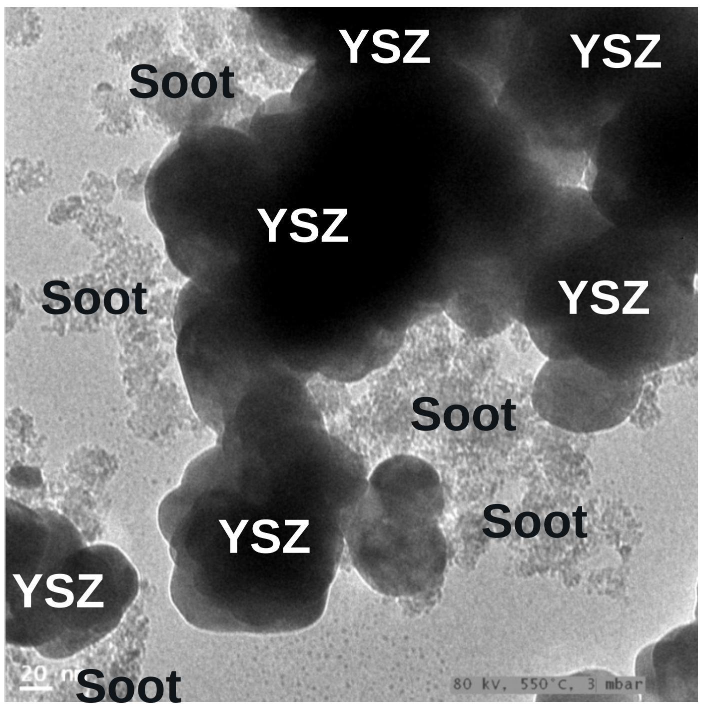
E.Obeid, IC^3 conference, 2013

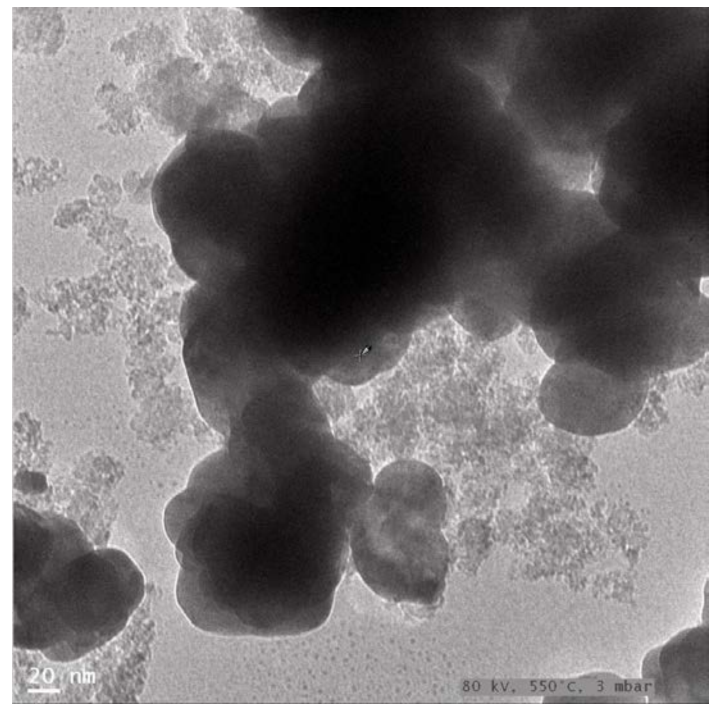
  - Reduce or cancel the need of the active regeneration :
    - Less / no post injection → less volatile HC
    - No PGM → no sulphate storage in the cDPF

➢ Probably less particulate emissions during regeneration

Development of innovative cDPF in the framework of the PIREP2 project

- **Oxidation test at the Environmental TEM (ETEM)**
  - Setup T°C = 525°C, 3 mbar O_2, speed x4





➢ **Tight contact between soot particulates and YSZ grains is the key driver of the oxidation reaction**

T.Epicier, ICEC conference, 2014

Acknowledgements

- This work has been partly funded by the French Research National Agency (ANR) within the Pirep 2 project

- Pirep 2 project's partners

Laboratoire d'Electrochimie et de Physicochimie des Matériaux et des Interfaces (LEPMI)

Laboratoire de Météorologie Physique (LAMP)

- French clusters

Horizon 2020 : Call GV-02-2016

Looking for project partners

- **GV-02-2016: Technologies for low emission powertrains**
  - **Assessment and reduction of particle emissions below 23 nm, particularly for direct injection gasoline and diesel engines**
  - **Development of the related measurement procedures down to 10nm**
  - **Characterization of particles from GDI and Diesel engines in the range 10 – 23 nm and below 10 nm to prepare the future regulations**

Thank you for your attention!

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