Conference or Workshop Item:
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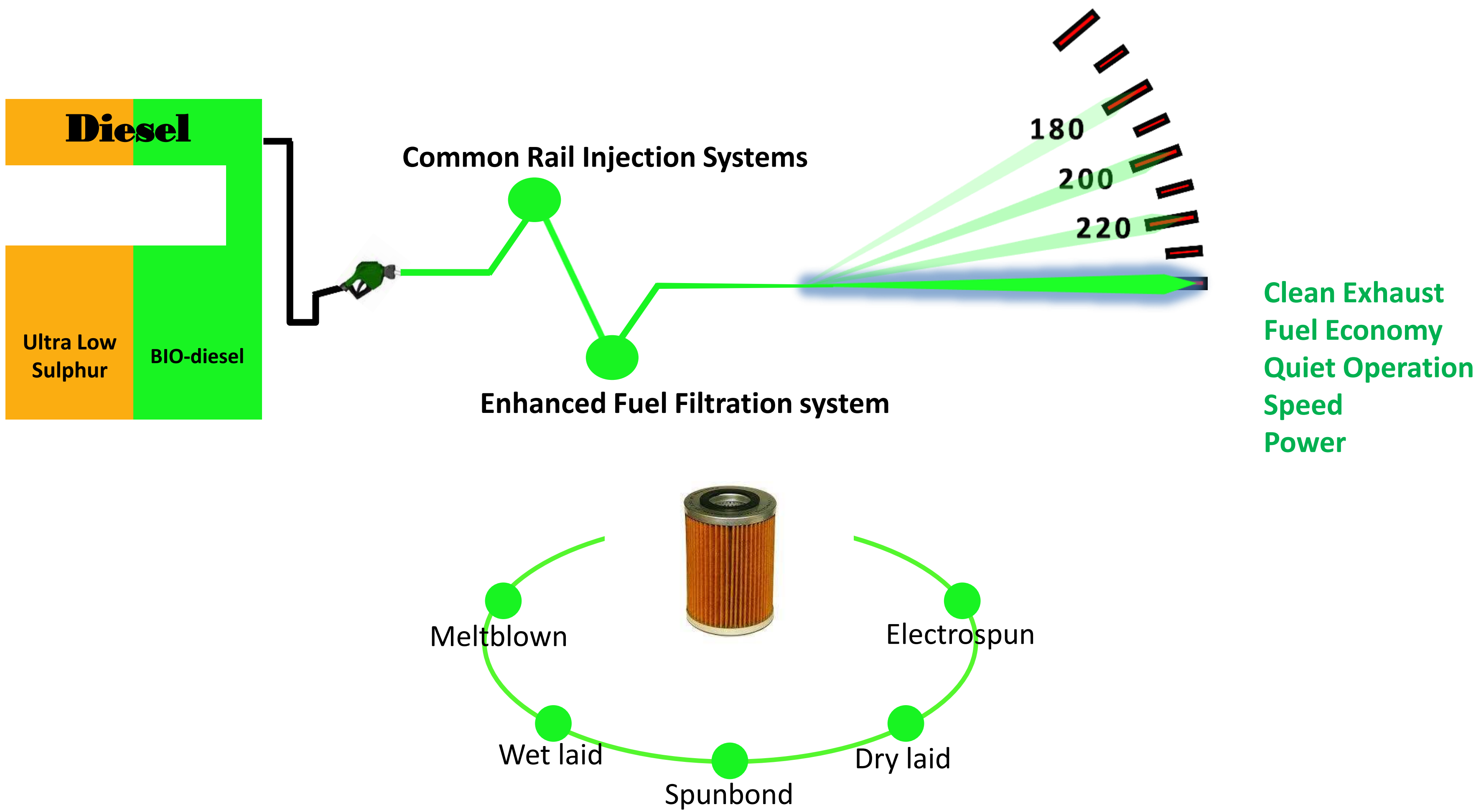
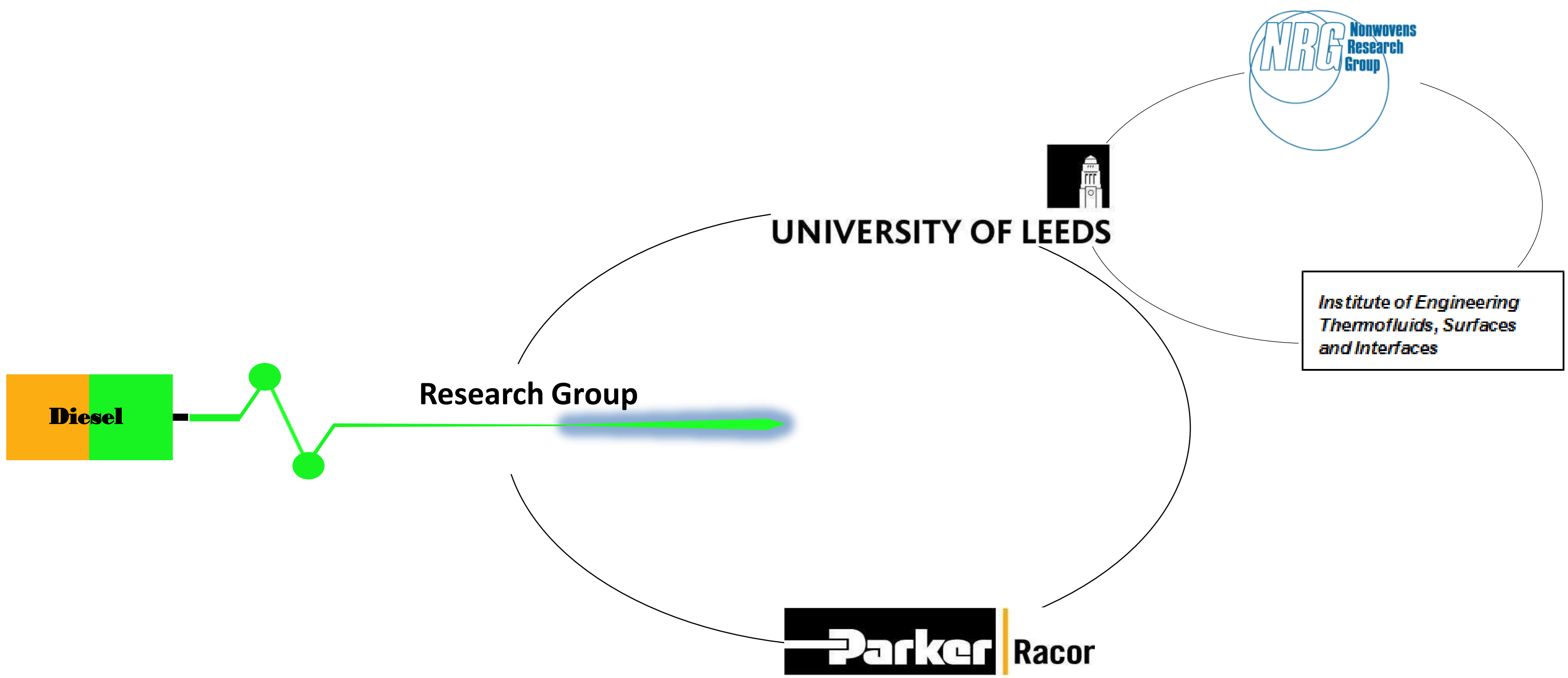
Enhanced water/fuel coalescing filter media for diesel engines: *overview and future directions*

H. Arouni, K. Vengadasalam, U. Farooq, P. Goswami, M. Wilson, N. Kapur, S. J. Russell



Enhanced water/fuel coalescing filter media for diesel engines:
overview and future directions



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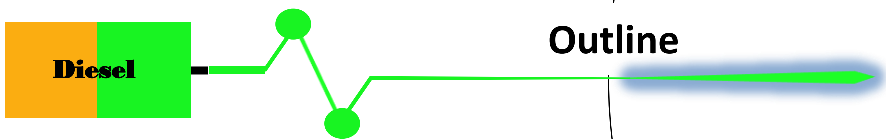
Enhanced water/fuel coalescing filter media for diesel engines: *overview and future directions*

Outline



- **Introduction**
  Fuelling systems and challenging fuel filtration
- **Design of water/fuel separation system**
  Emulsion, coalescence, fibrous structure
- **Future trends**
  Structure-property relationship and Future trends

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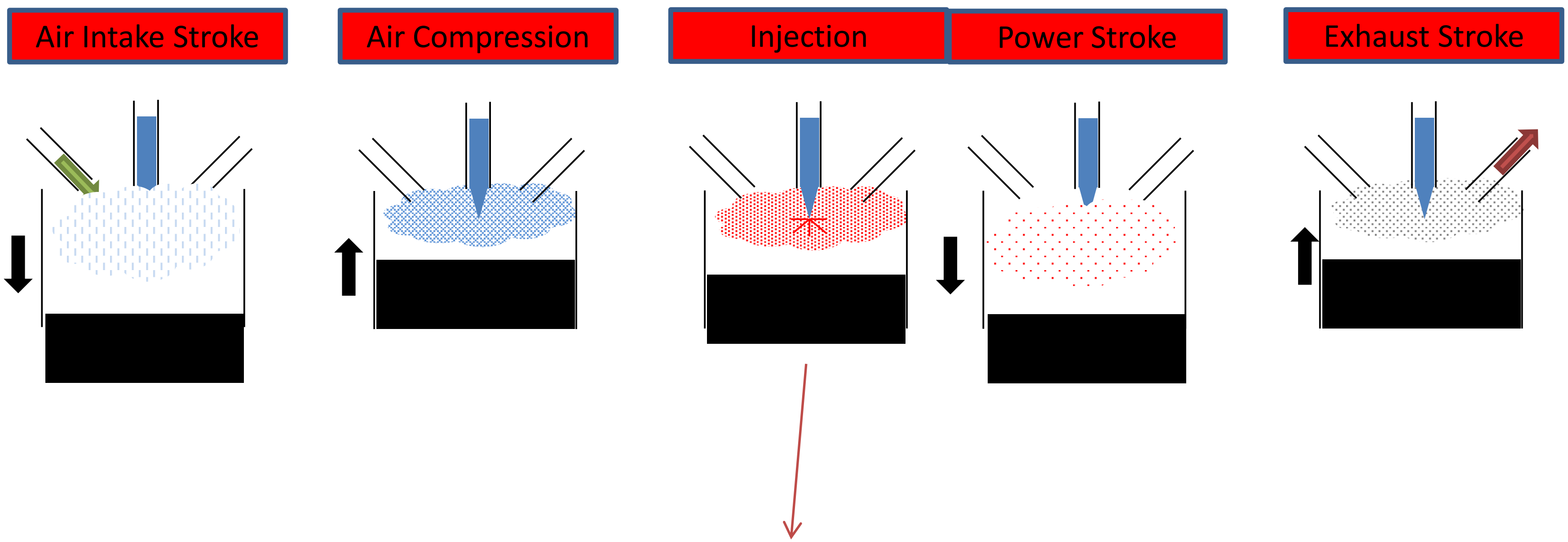
Enhanced water/fuel coalescing filter media - *Introduction*

Four Stroke Diesel Engine Operation



Combustion due to injection of fuel into compressed hot air

⚠ Compression-ignition engines are sensitive to any fuel contaminations

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Enhanced water/fuel coalescing filter media - *Introduction*

Common fuel contaminations

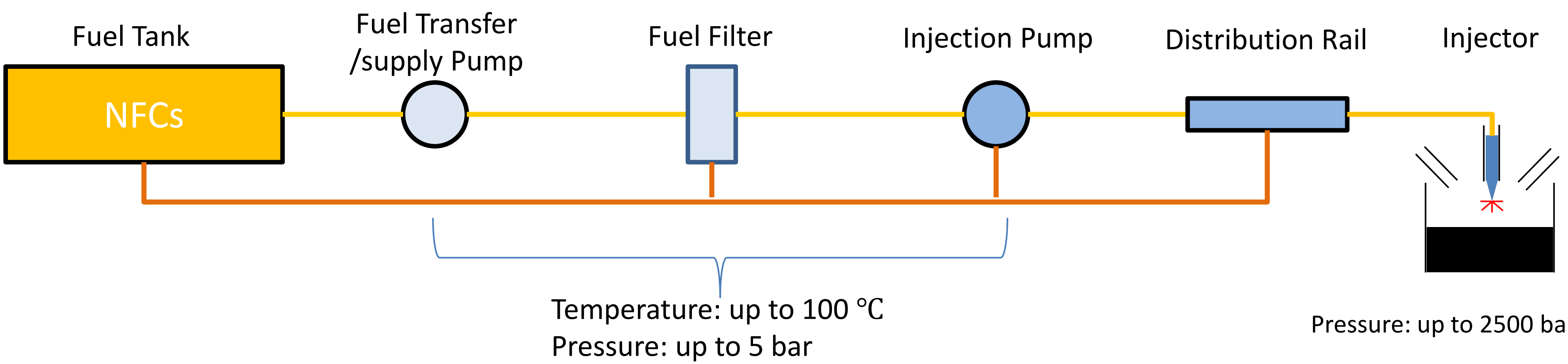
Water:
- rain
- air humidity

Solid particles:
- Dirt
- Fuel impurity
- Other contaminants

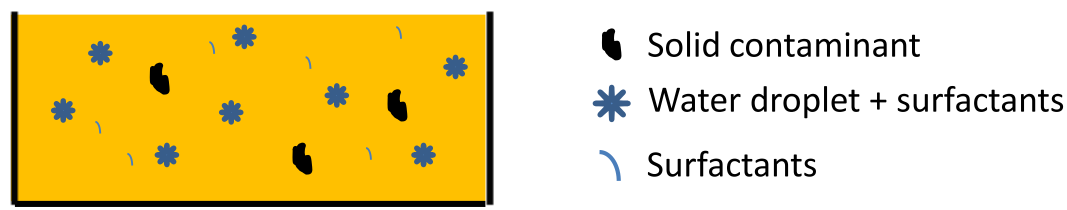
Sensitivity is intensified when High-pressure Common Rail fuelling systems (HPCR) is operating on new fuel components (NFCs)

Enhanced water/fuel coalescing filter media - *Introduction*

HPCR/NFCs fuelling systems



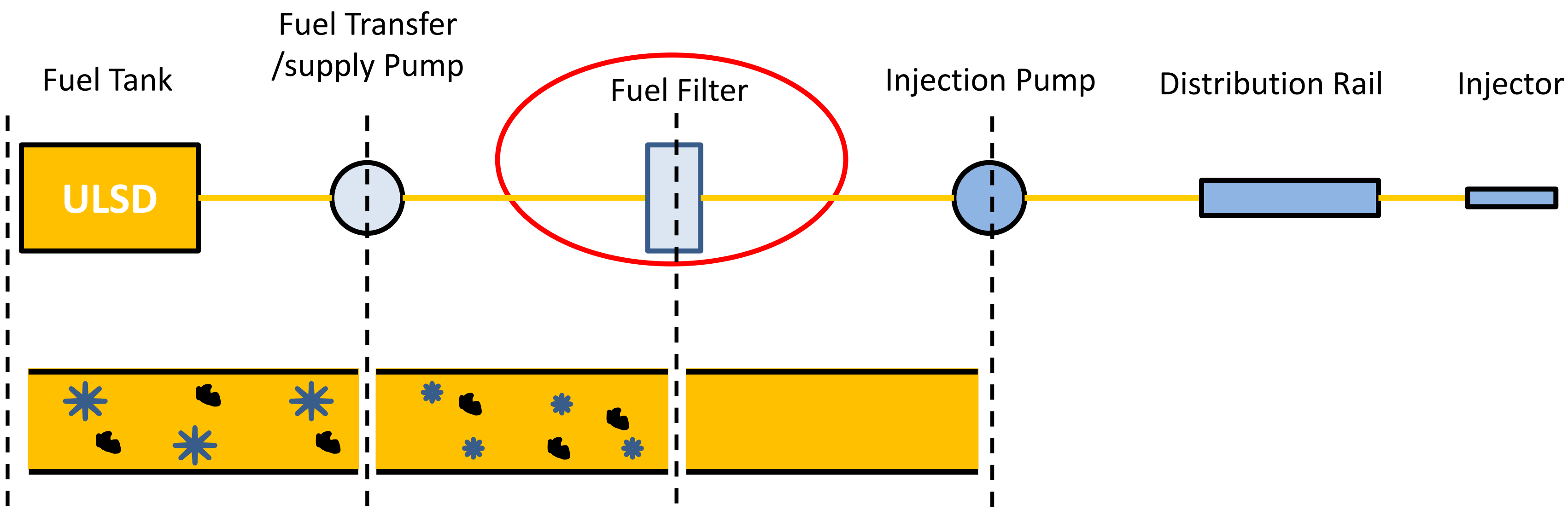
Conventional Diesel fuel



Ultra-Low Sulphur Diesel (ULSD) and Bio-diesel blends

Enhanced water/fuel coalescing filter media - *Introduction*

HPCR/NFCs fuelling systems - Challenging filtration



- HPCR is highly sensitive to both water and solid contaminants, as such the fuel introduce to the system should be **pure**
- Presence of surfactants disarms conventional filter media to separate emulsified water from the fuel

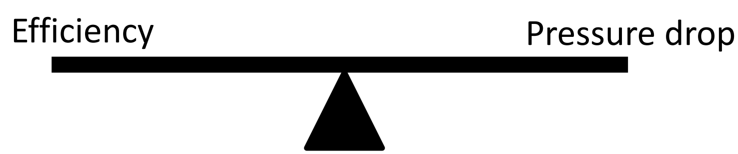
Enhanced water/fuel coalescing filter media - *Introduction*

Quality fuel filtration

- Efficiency (e) $e = \frac{M_{dU} - M_{dD}}{M_{dU}} \times 100$

$\mathrm{M_{dU}}$: Upstream particle count/amount for particles of diameter d or greater
M_{dD}: Downstream particle count/amount for particles of diameter d or greater

- Capacity



- Flow rate/Pressure drop (ΔP)

- Quality Factor $QF = \frac{-\ln(1-e)}{\Delta P}$

Enhanced water/fuel coalescing filter media – *Filter Design*

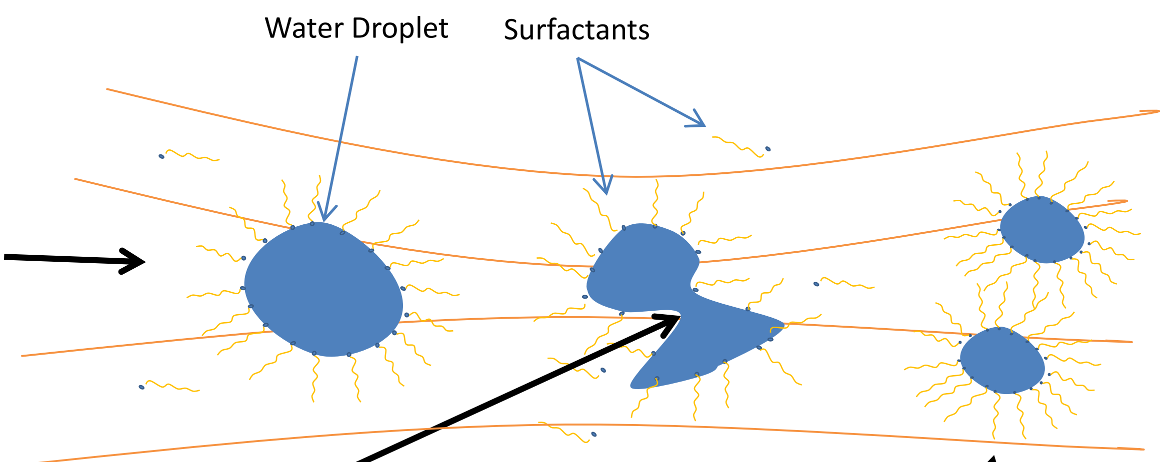
Design of Water/fuel Separation System

- ❖ Fuel/water emulsion
- ❖ Coalescence process
- ❖ Fibrous filter media

Enhanced water/fuel coalescing filter media – *Filter Design*

Fuel (ULSD/bio-diesel) – water emulsion

High pressure fuel pump
(high input energy)

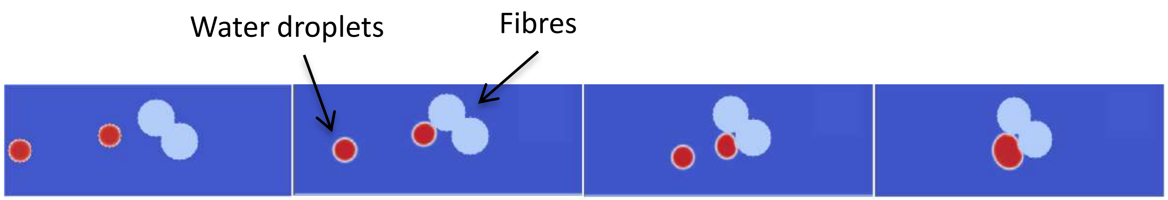


Low interfacial tension (IFT)
Easy rupture of bigger droplets

low kinetic for fine and stabilised dispersed phase

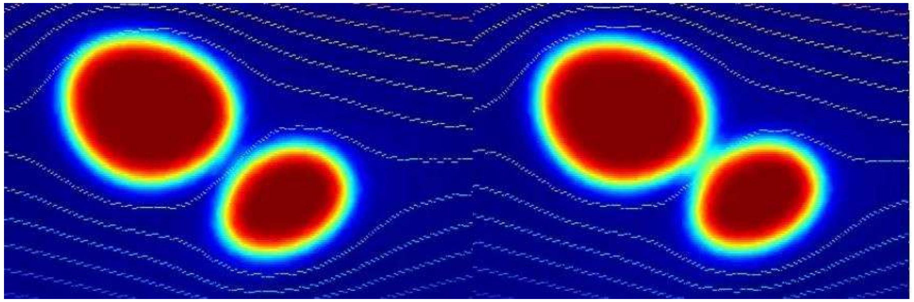
Enhanced water/fuel coalescing filter media – *Filter Design*

Coalescence process



Film Drainage model

- The time two droplets stay together
- Intermolecular forces along with external forces



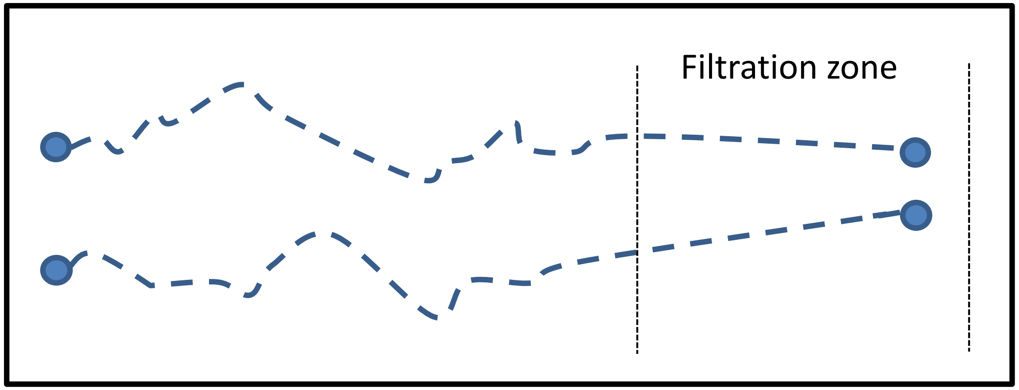
Critical Approach Velocity model

- Velocity difference between two droplets (external forces dominate intermolecular forces)

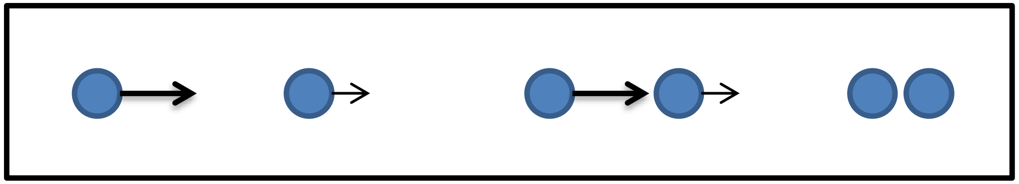
Enhanced water/fuel coalescing filter media – *Filter Design*

Factors in successful droplet coalescence

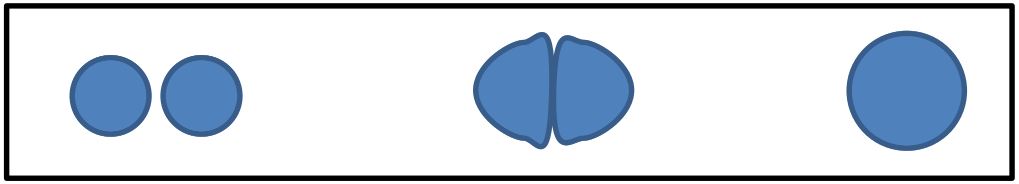
Control on movement of droplets



Control on velocity of droplets



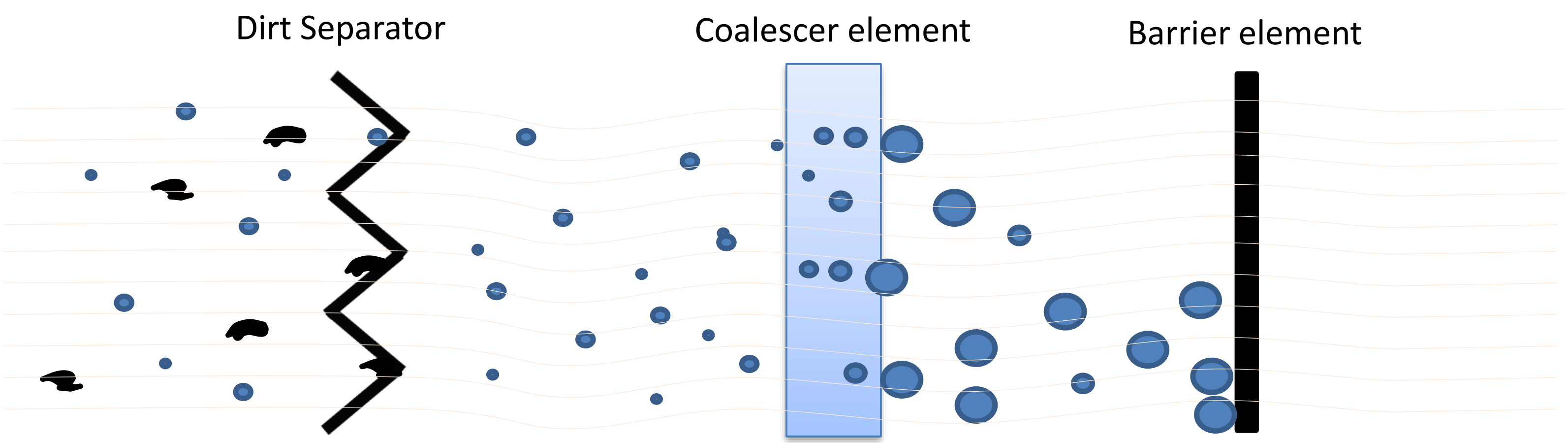
Sufficient impact/residence time



Enhanced water/fuel coalescing filter media – *Filter Design*

Fibrous filter media: Media configuration

- Dirt separator media:
  - Single/composite layer
  - multilayer
- Water separator media:
  - Coalescer element
    - Single/composite layer
    - Multilayer
  - Hydrophobic barrier element
    - Woven mesh /nonwoven



Enhanced water/fuel coalescing filter media – *Filter Design*

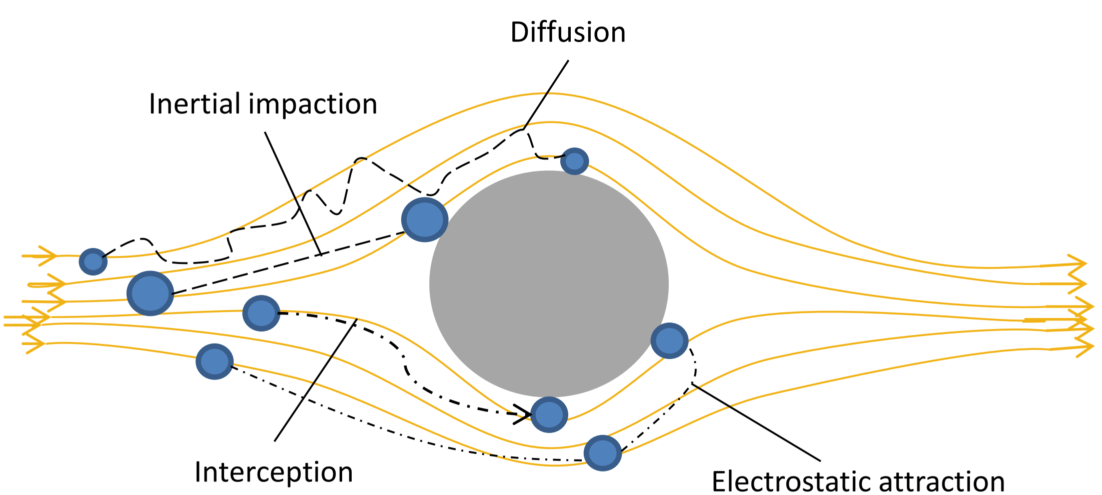
Fibrous filter media: Filtration mechanism

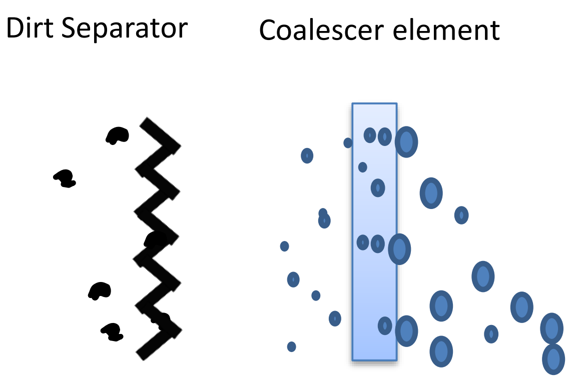
Particle capture:

- inertial impaction (mainly large particles, >1 μm)
- interception (>0.1 μm)
- diffusion
- electrostatic attraction

Particle separation:

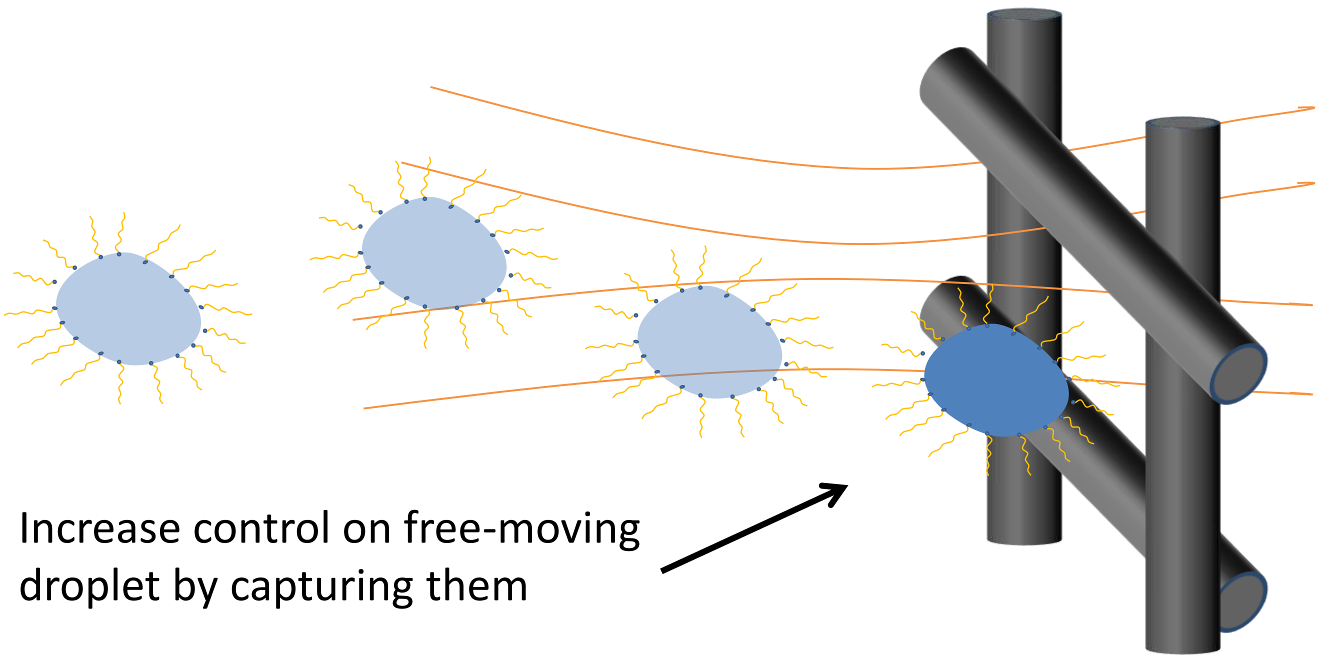
- Holding solid particles
- Enlarging droplets by coalescence and let them to be drained out





Enhanced water/fuel coalescing filter media – *Filter Design*

Role of fibrous media in successful droplet coalescence



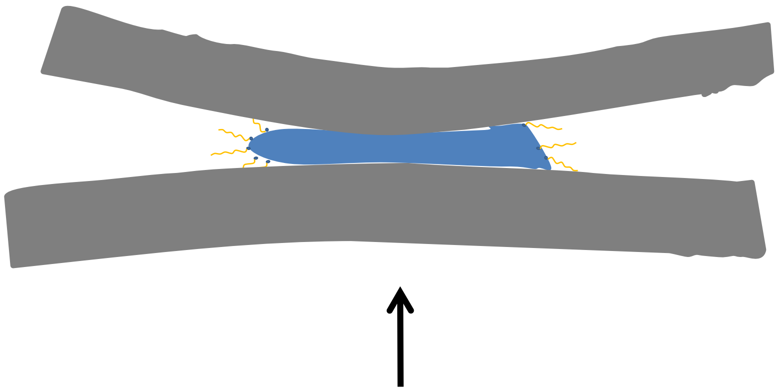
Increase control on free-moving droplet by capturing them

- $W_{sl} > 0\ ;\ \gamma_{lv} + \gamma_{sv} > \gamma_{sl}$

  γ_{lv}: liquid surface tension
  γ_{sv}: solid surface tension
  γ_{sl}: solid-liquid interfacial tension

Enhanced water/fuel coalescing filter media – *Filter Design*

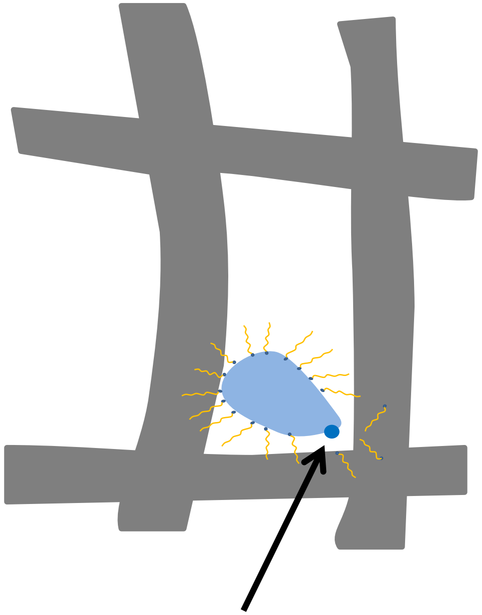
Role of fibrous media in successful droplet coalescence



Increase control on captured droplets by managing their movement

- $Ws > 0\ ;\ \gamma_{sv} > \gamma_{lv} + \gamma_{sl}$
- $P_c = \frac{2\gamma_{lv} \cos \theta_a}{r_e}$

  r_e : effective capillary radius



Contribute to induce surface tension gradient on the surface of droplets

- $Pl = \gamma \left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

  R1 and R2: radiuses of the curved interface

Enhanced water/fuel coalescing filter media – *Filter Design*

Design of water/fuel coalescing media

Operational Requirements → Required Properties → Technical Factors

Operational Requirements

- coalescing water droplets
- Structural stability
- Tolerable pressure drop
- inexpensive and universal application

Required Properties

- Managing water droplet movement
- Proper flex resistance
- Proper fluid permeability
- Material and production process

Technical Factors

- Surface area
- wettability
- Porosity, pore size, pore size distribution
- Physical, chemical, and thermal properties of material

Enhanced water/fuel coalescing filter media – *Summary*

- Surface area, wettability, pore structure, thickness, and macro-structure of the fibrous structure are being considered as the main properties of coalescing filter media.

- Inversely interrelated factors such as pressure drop versus pore-size, surface area, and wettability have made the media design very challenging and comprehensive study is needed to provide a clear profile for the factors.

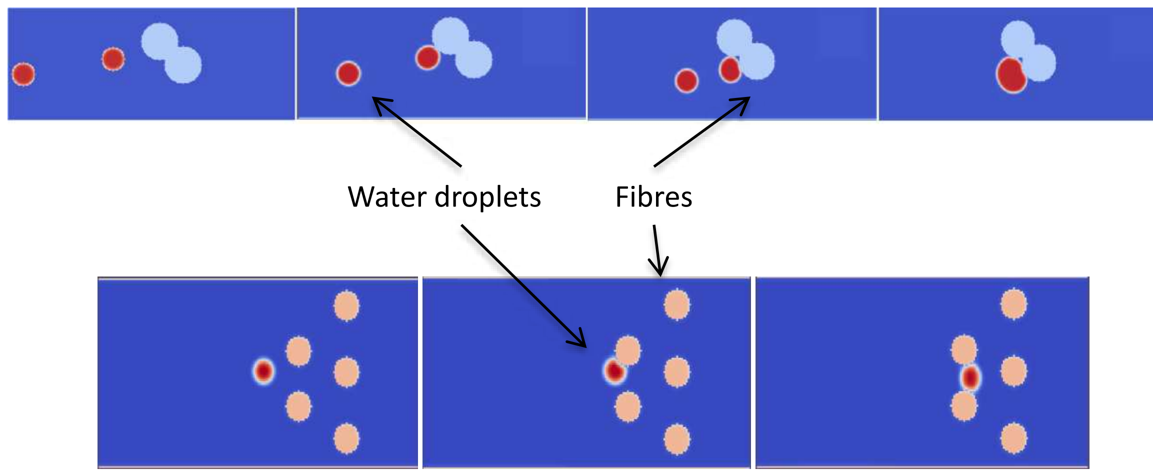
- Single layer and multilayer media are two main structural configurations for coalescing media.

- The future trend in this area might be focused on proper configuration and selection of materials in fibrous coalescing media to manage fibrous material properties to maximise fulfilment of the end-use requirements.

Enhanced water/fuel coalescing filter media

Our Facilities in Leeds to study, model, and design water/fuel separation systems

Water coalescence test rig



Water coalescence simulation

Thank you…

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