# Towards 'Factory in a Box' for Personalised Emulsions on Demand:

## Harnessing Vortex based Hydrodynamic Cavitation

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## 'Factory in a Box' for Personalised Emulsions

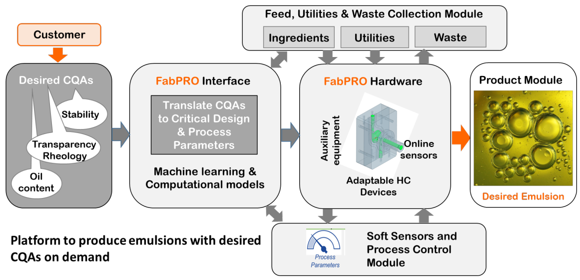
### Emulsions of Desired Quality Attributes

- **Physical:** Rheology, droplet size distribution, stability
- **Functional:** Personal care and health care, nutrition
- **Personal:** Appearance, feel, texture, smell and taste

Applications:

- Healthcare: Drug ingredients
- Food: Milk products, dressings
- Personal care: Cosmetics

### Distributed & On-demand Manufacturing




**Available tools for emulsion:** rotor-stator, micro – fluidization, hydrodynamic cavitation (HC), etc.

### Limitations of State of the Art

Technological limitations:

- Slow in responding
- Capital intensive
- Unsustainable methods
- Less flexibility
- None of the tools produce on-demand, scale of 1 LPH+

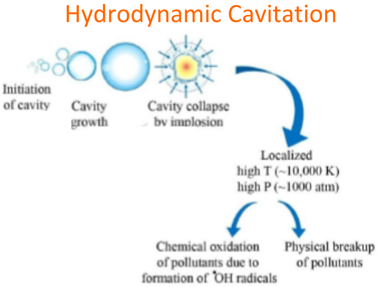
Limited understanding of HC

- Drop breakage by cavities
- Controlled cavitation
- Design optimisation of HC

First steps towards harnessing vortex based hydrodynamic cavitation for generating emulsions of controlled drop size distributions

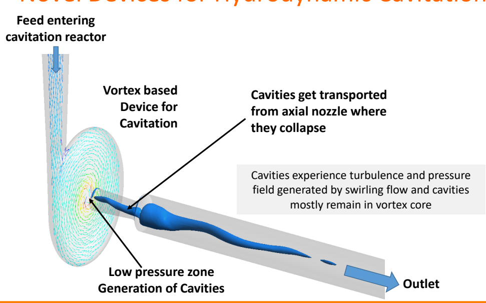
## Approach: Hydrodynamic Cavitation, Novel Devices, Computational Modelling

### Hydrodynamic Cavitation




**Benefits of HC:** Continuous process, easy to scale-up, High throughput

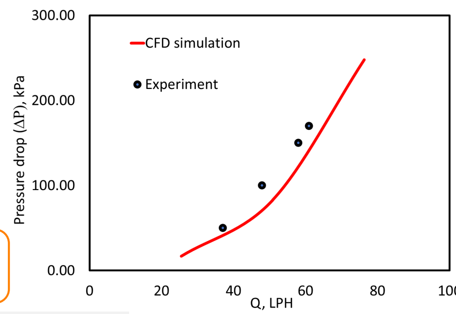
### Novel Devices for Hydrodynamic Cavitation




**Advantages:** No clogging, Early inception, less erosion, enhanced cavitation yield

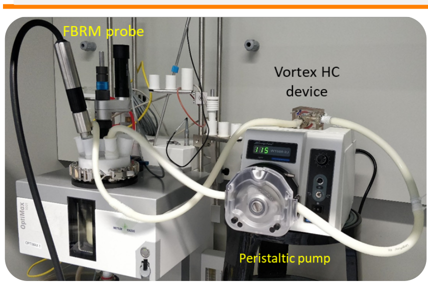
### Computational Modelling

RANS turbulence model: Two-equation SST-k-ω
Cavitation model: Singhal et al.



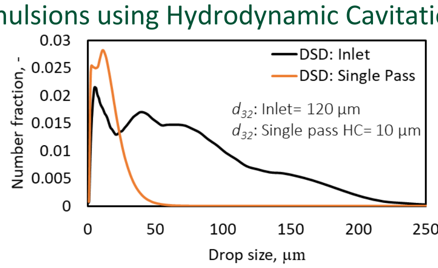

CFD used to predict cavitation inception conditions and device power input.

Choice of turbulence model & mesh refinement important factors in cavitation inception prediction. Unsteady RANS calculations are necessary.

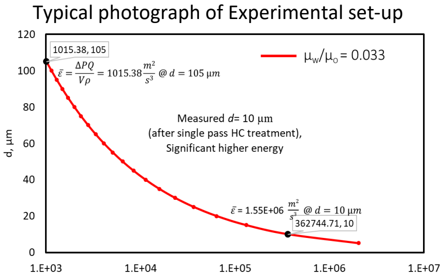



Typical photograph of Experimental set-up

## Emulsions using Hydrodynamic Cavitation

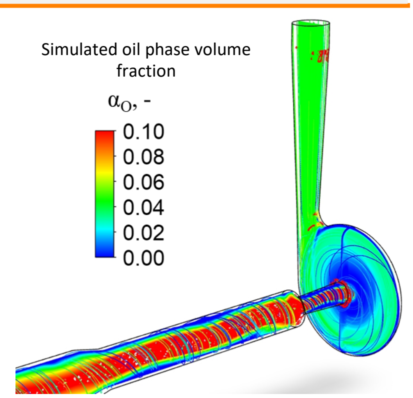


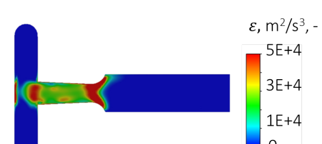

Comparison of Initial and single pass HC treated DSD




| Sl. No. | Name of the fluid | Density (kg/m³) | Viscosity (kg/ms) |
|---|---|---|---|
| 1 | Demineralized water (DW) | 998 ± 2 | $8.5 \times 10^{-4}$ |
| 2 | Rapeseed oil (1 - 20 vol%) | 915 ± 2 | $3.0 \times 10^{-2}$ |

- Interfacial tension: 0.035 N/m
- Surfactant: TWEEN 20 (1 -10 wt%)
- Total volume: 500 ml
- Total system volume: 150 ml
- Batch experiments total time: 2 hours
- Mode of experiment: Single pass and continuous measurements
- Pressure drop across the device: ΔP = 50, 100 and 150 kPa




Contours of Rate of energy dissipation

- A single-pass through vortex-based cavitation device produced droplets of ~10 μm. Droplet size estimated from average energy dissipation is one order of magnitude larger than this (~100 μm). This demonstrates the role of concentrated energy dissipation zones due to cavities
- The present approach, novel cavitation devices, computational models and results will provide a sound basis for harnessing hydrodynamic cavitation for manufacturing personalised emulsions with desired critical quality attributes in a truly distributed way

**Vortex based Cavitation Devices & Models will pave the way towards 'Factory in a Box' platforms for emulsions**