Incorporation of Fine Powders into a Liquid with an In-Line Rotor-Stator

James Bacon (J.C.Bacon@lboro.ac.uk)

Chris D. Rielly (C.D.Rielly@lboro.ac.uk)

N. Gül Özcan-Taskin (N.Ozcan-Taskin@lboro.ac.uk)

Department of Chemical Engineering

1. Introduction

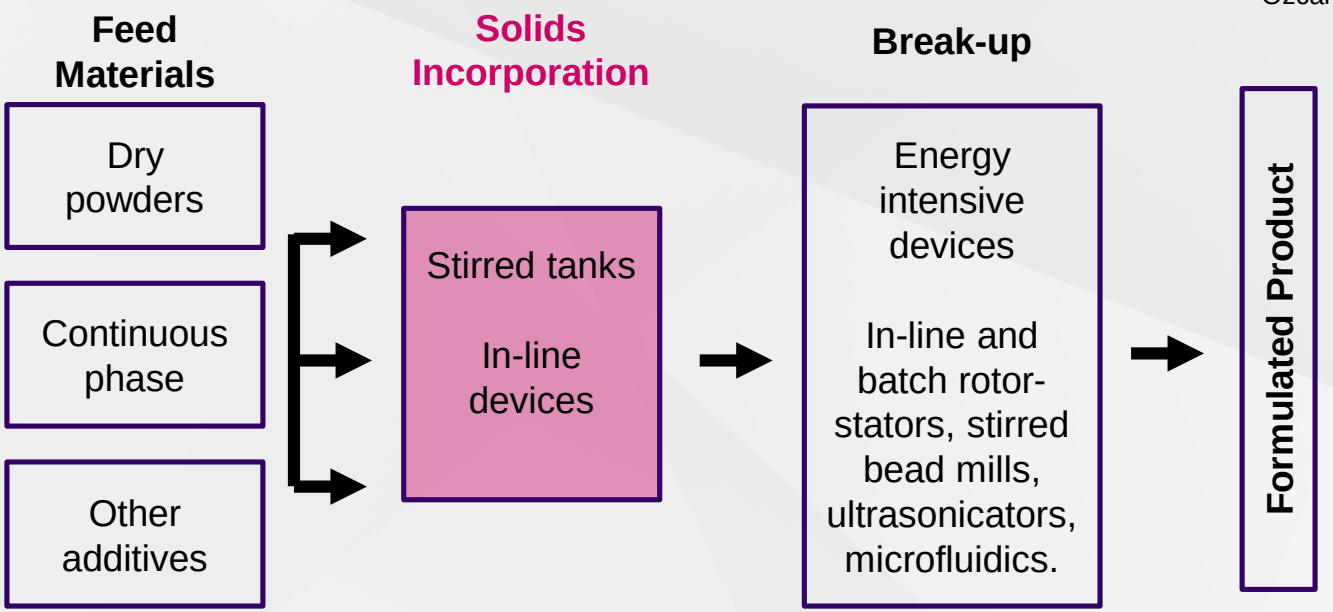
Novel products with nanoparticles in their formulation have superior **properties** and **performance:**

- Paints & inks,
- Scratch resistant coatings,
- Harder wearing fabrics
- Improved conductivity in electrical components
- Lighter weight and stronger materials

Some of these require the **dispersion** of nanoparticles in a liquid

1.1 Dispersion of Nanoparticles in Liquids

Özcan- Taşkin (2015)



Typically 2 stage process, requiring incorporation into a stirred tank

1.2 Powder Incorporation

Young-Dupré equation:

$$\Upsilon_{s/V} = \Upsilon_{s/L} + \Upsilon_{L/V}\, cos\theta$$

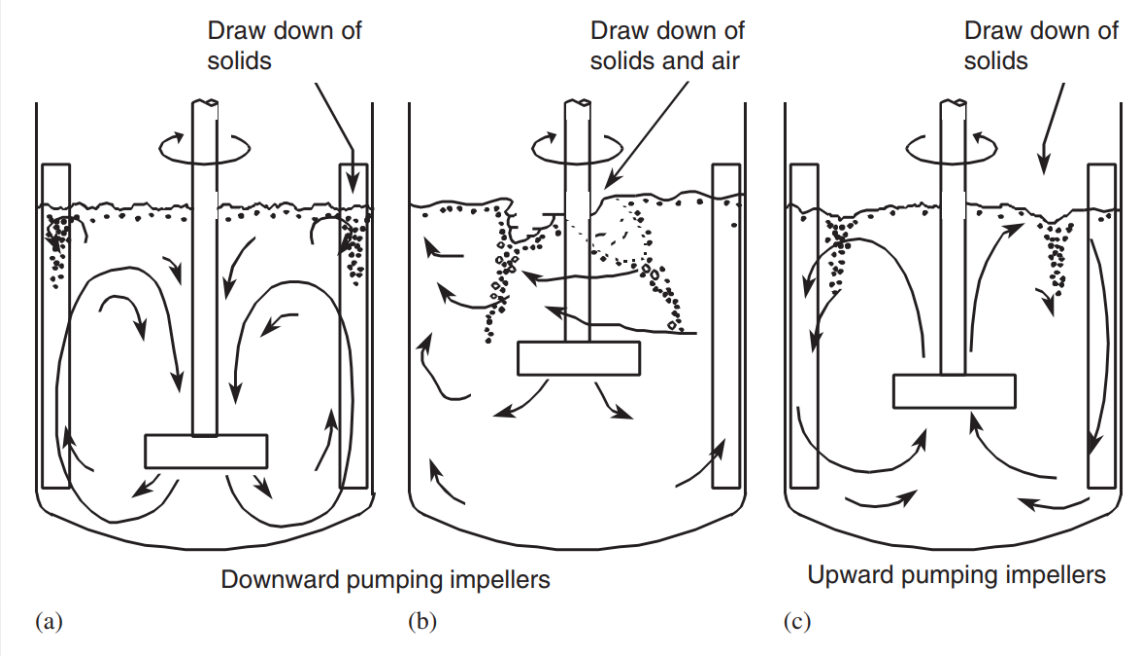
Work required for wetting:

$$\Sigma W = W_a + W_i + W_s = 6\Upsilon_{L/V}\, cos\theta$$

A combination of **material properties** and **hydrodynamic conditions** in the process equipment affect the incorporation process.

1.2 Powder Incorporation

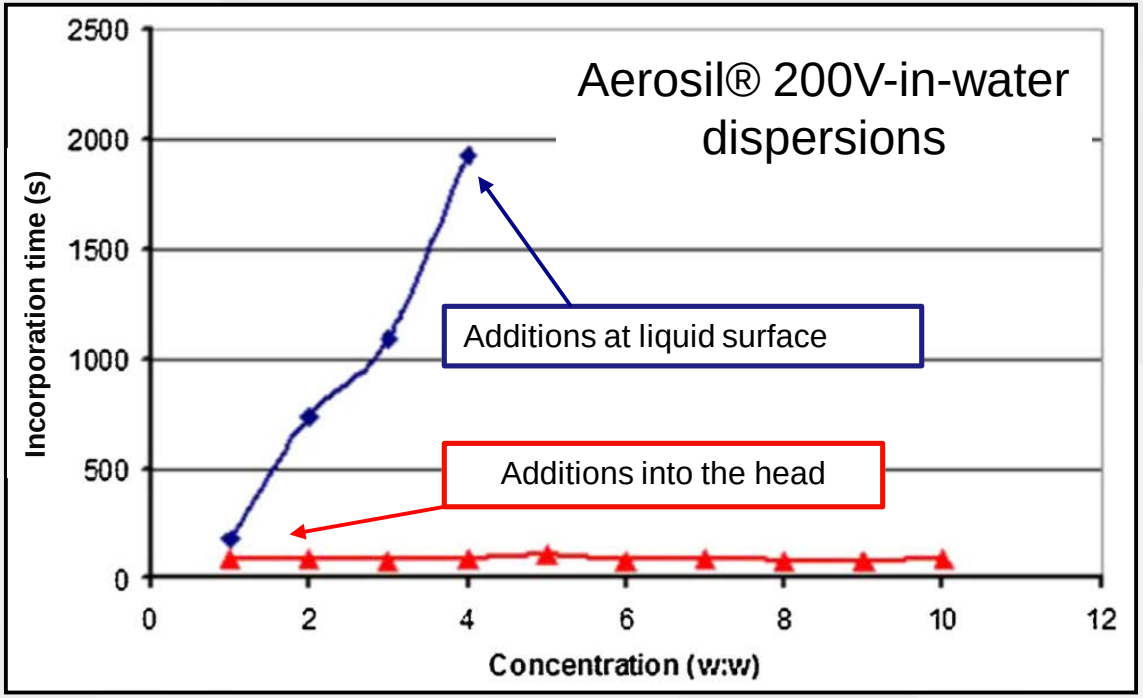
Özcan- Taşkin (2006)



Powder incorporation in a stirred tank can cause particles to become trapped in dead zones, or result in air entrainment

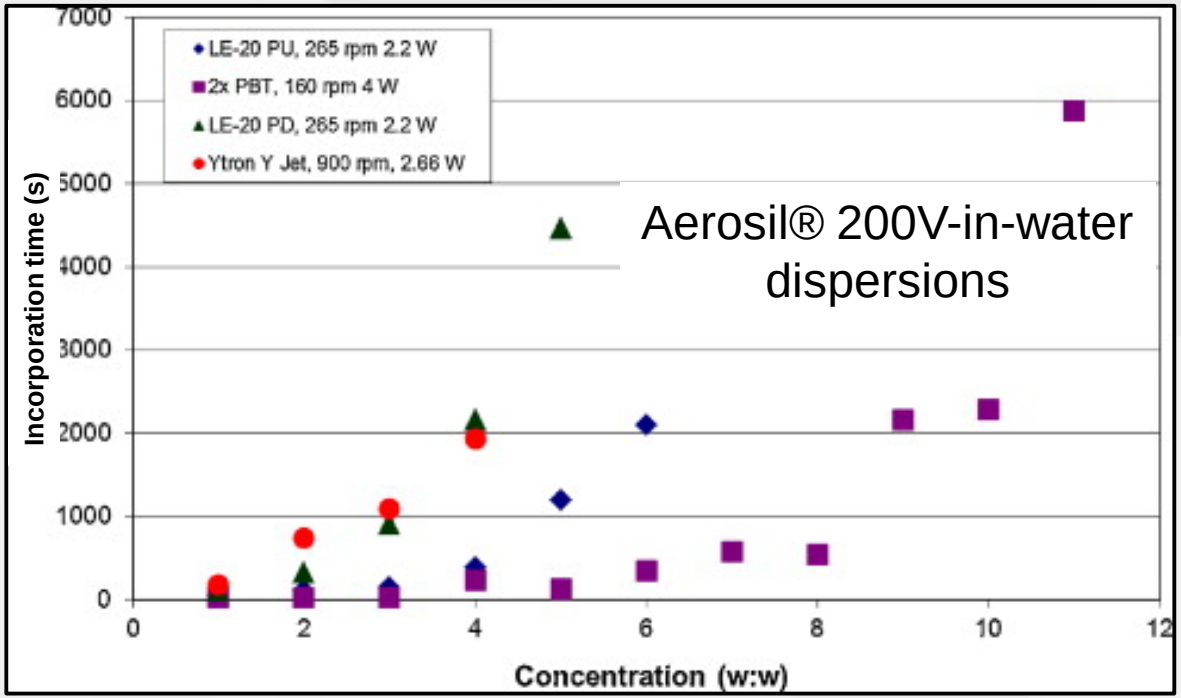
1.3 Previous Work with a Batch Rotor-Stator

Özcan- Taşkin, (2013)



Ytron Y Jet: Powder addition into head ➡ constant rate of incorporation with increasing concentration

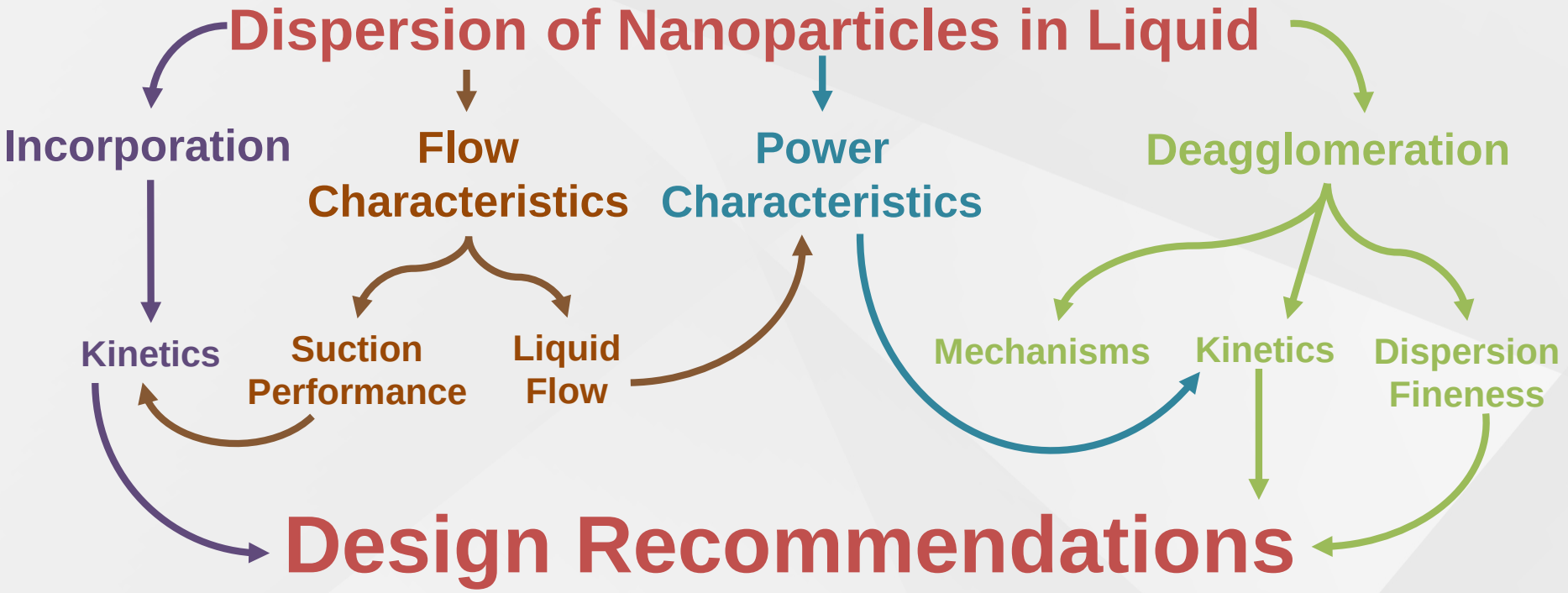
1.3 Previous Work with a Batch Rotor-Stator



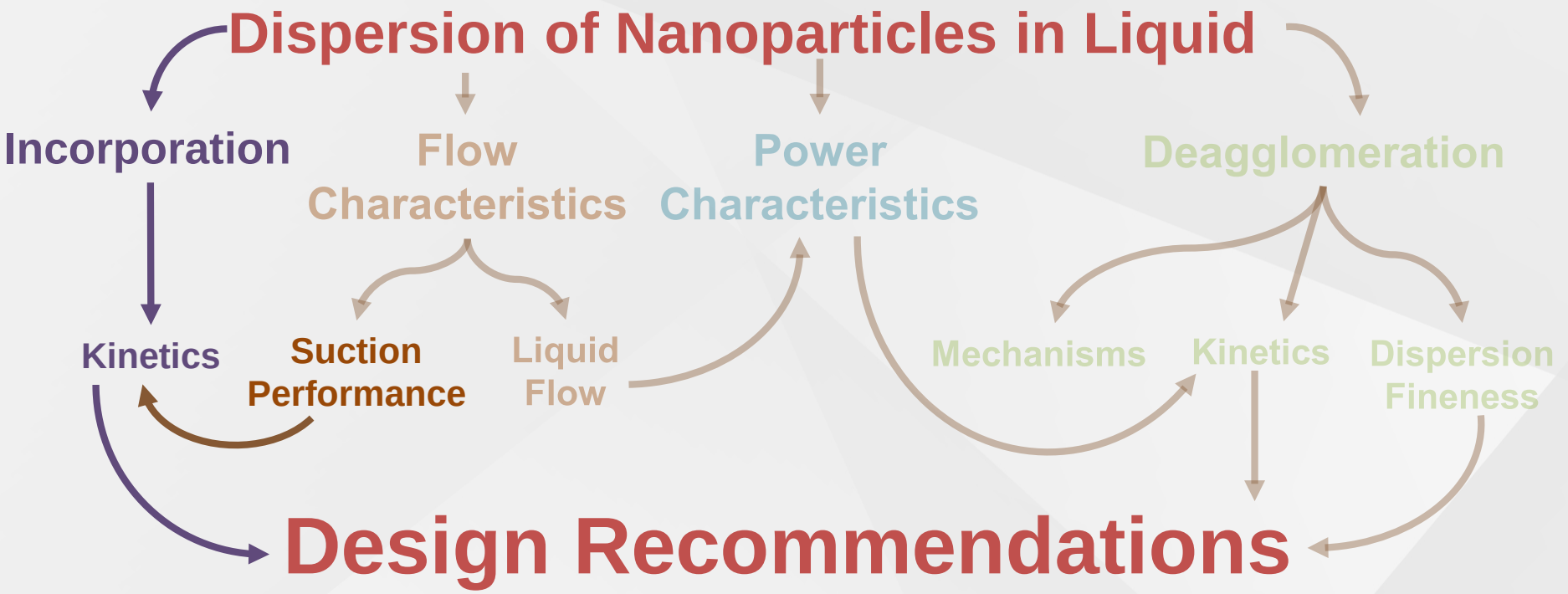
Özcan- Taşkin, (2013)

Additions at liquid surface (away from region of turbulence and fluid velocity) with a number of different impellers shows effect of solids concentration

1.4 Research Strategy – Whole PhD Project



1.4 Research Strategy – This Presentation



1.4 Objectives of the Study

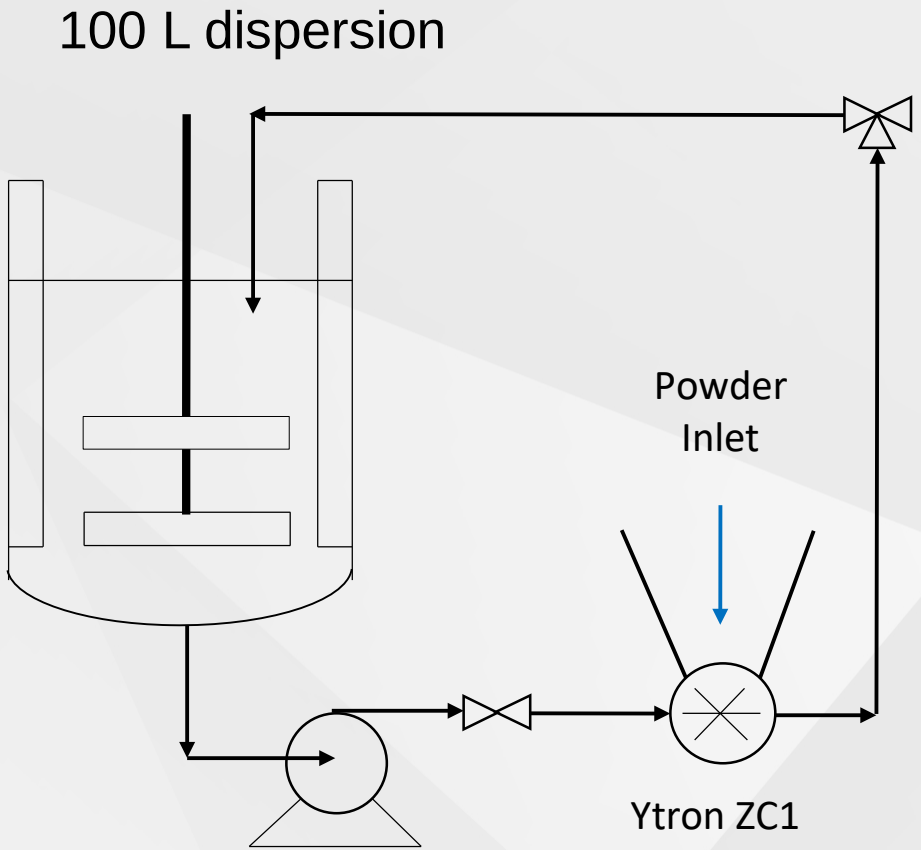
Establish the **performance** of an inline rotor stator, **Ytron ZC1**, for **powder incorporation** processes

and

provide **recommendations** for the **design** of such processes.

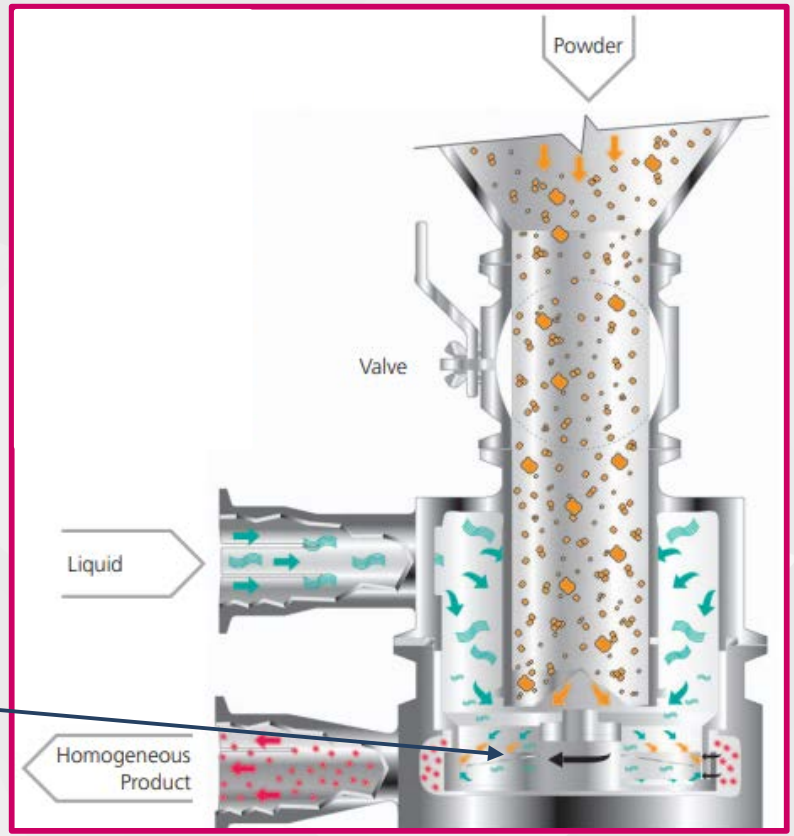
2. Experimental

- **Ytron ZC1**
  - recirculation loop of fully baffled stirred tank
  - Pilot scale device
    - Liquid – 180 L/min
    - Powder - 33 kg/min



2. Experimental

- Low pressure developed in rotor-stator head, drawing powder into head
- Two heads used in study, 1.5 and 3.0 mm gaps between teeth



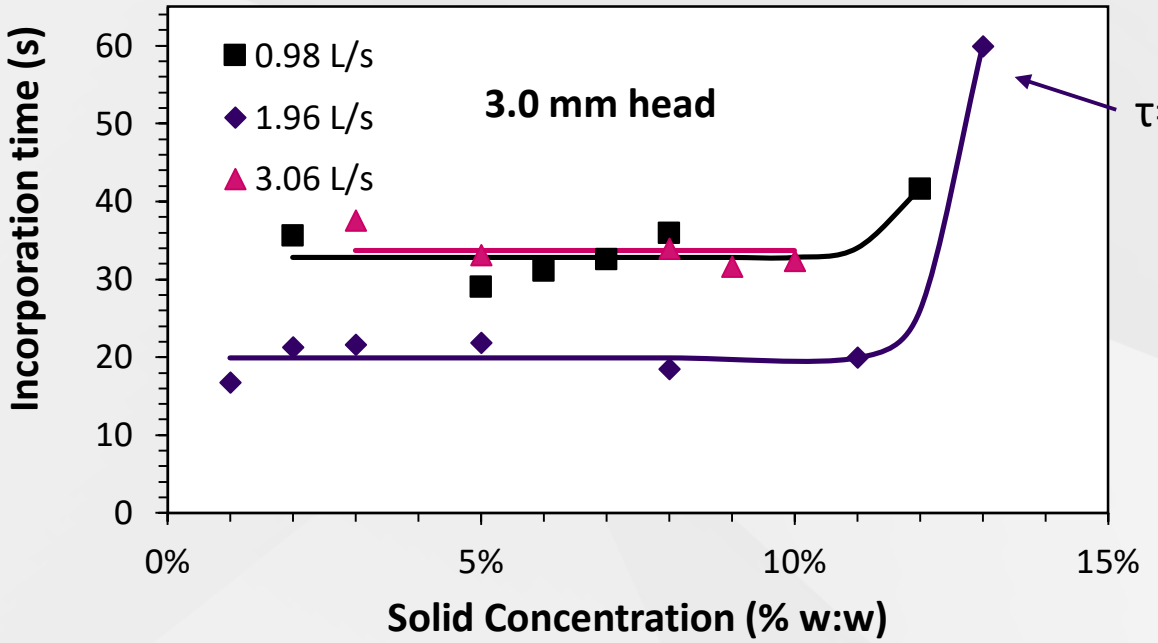
2. Experimental

- Silica nanoparticles-in-water: **Aerosil® 200V**: densified, fumed, hydrophilic silica (Evonik Ind); [**1-10**] % w:w
- N: **6380** RPM; Q: [**1-3**] L/s
- **Air velocity** measurements were made at the **powder inlet**

3. Results and Discussions

- Effect of **powder concentration** on powder incorporation rate
- **Suction velocity** at the powder inlet
- Comparison of 3.0 and 1.5 mm heads

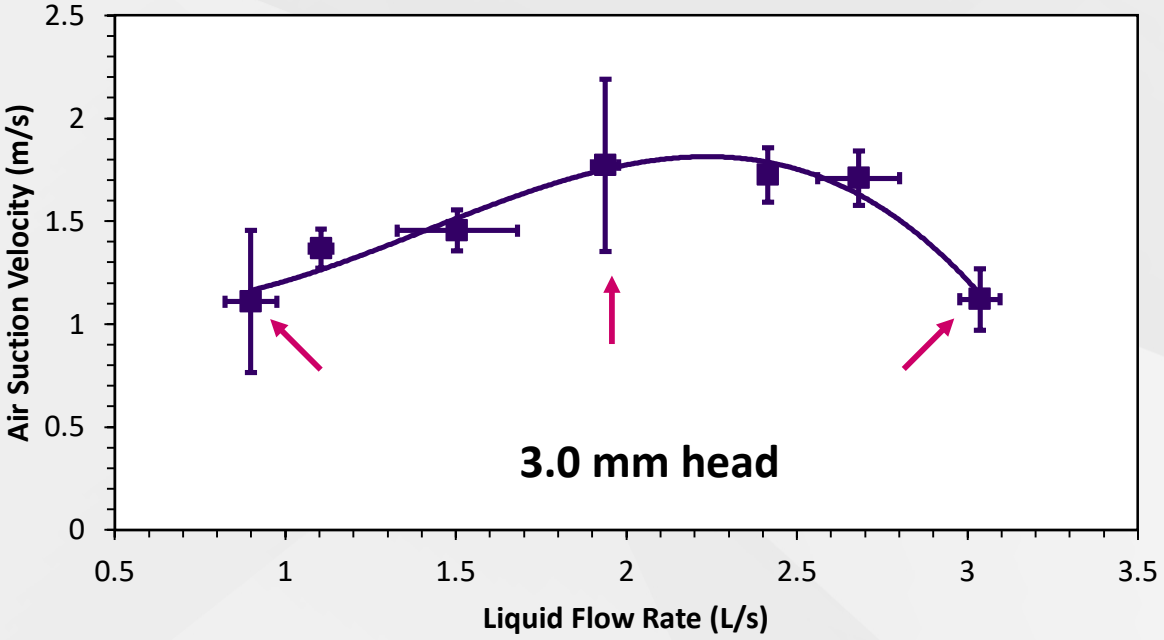
3.1 Effect of Concentration on Incorporation Rate



$$\tau = 23 + 0.16\,\dot{\gamma}^{0.6}$$

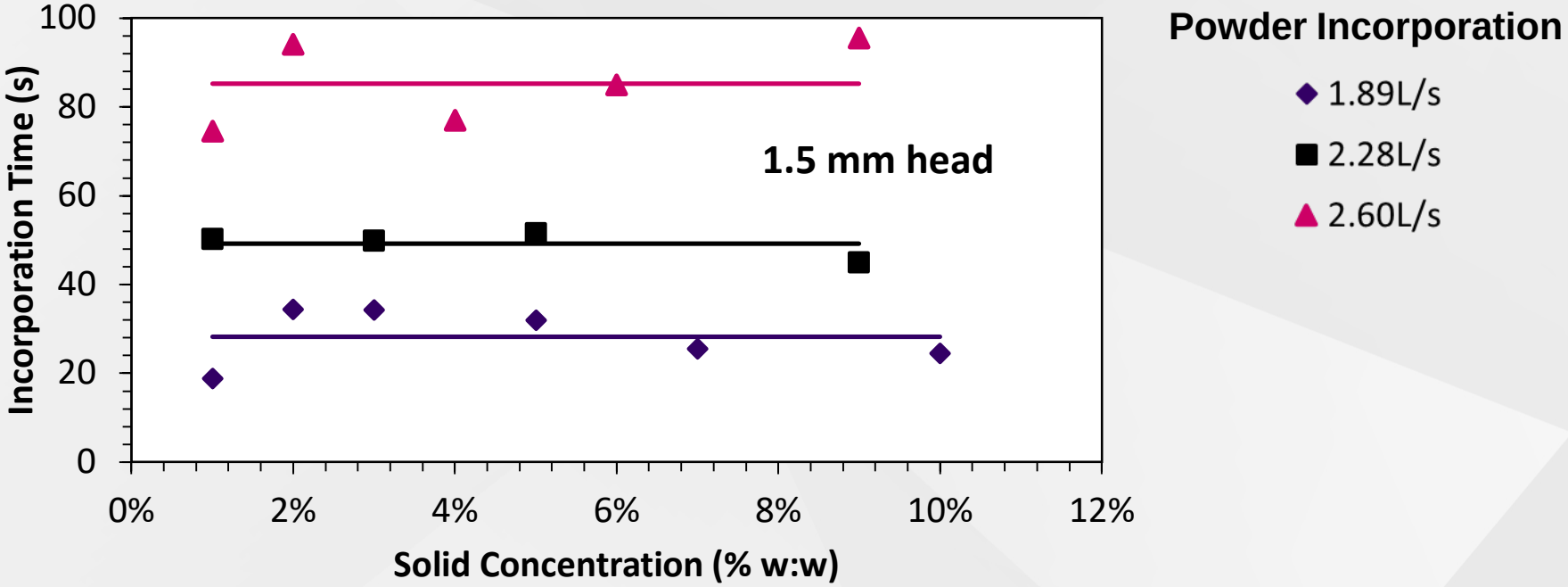
Constant incorporation rate over a wide range of concentrations (<12% w:w)- until **non-Newtonian** rheology develops. Incremental additions of 1% powder incorporated within less than 1 min.

3.2 Air Velocity at the Powder Inlet



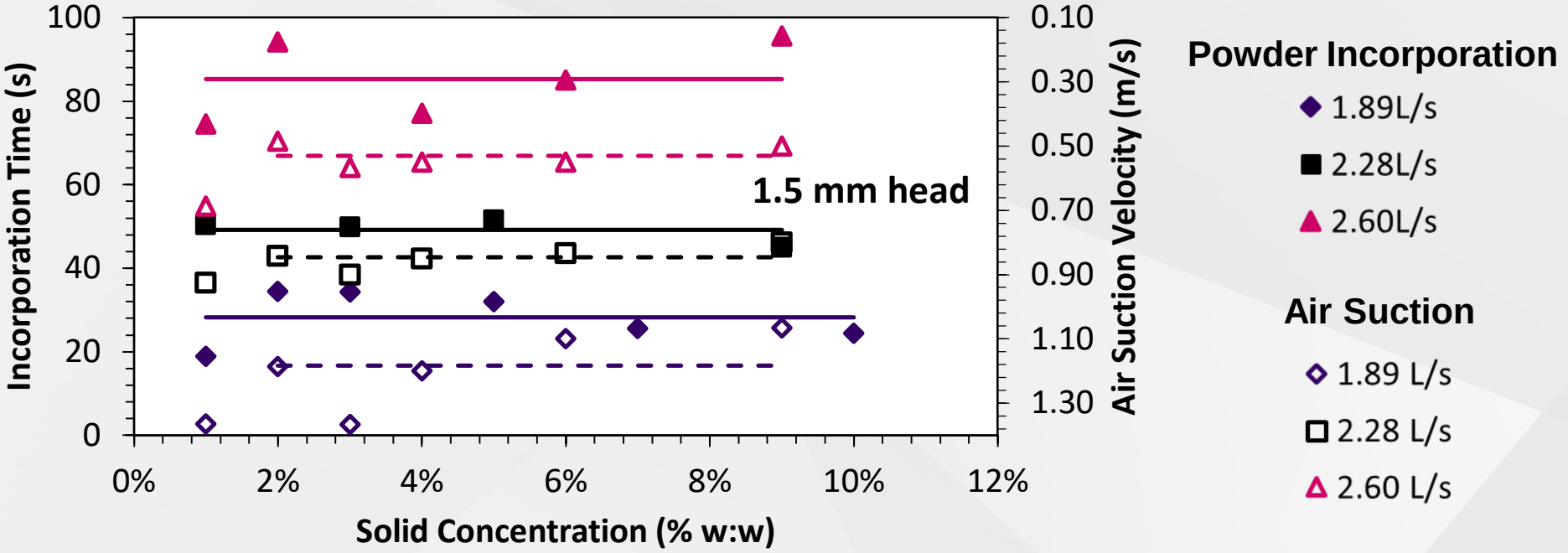
Incorporation time results could be explained with **air velocity data** at the powder inlet

3.3 Incorporation Rate & Suction Velocity



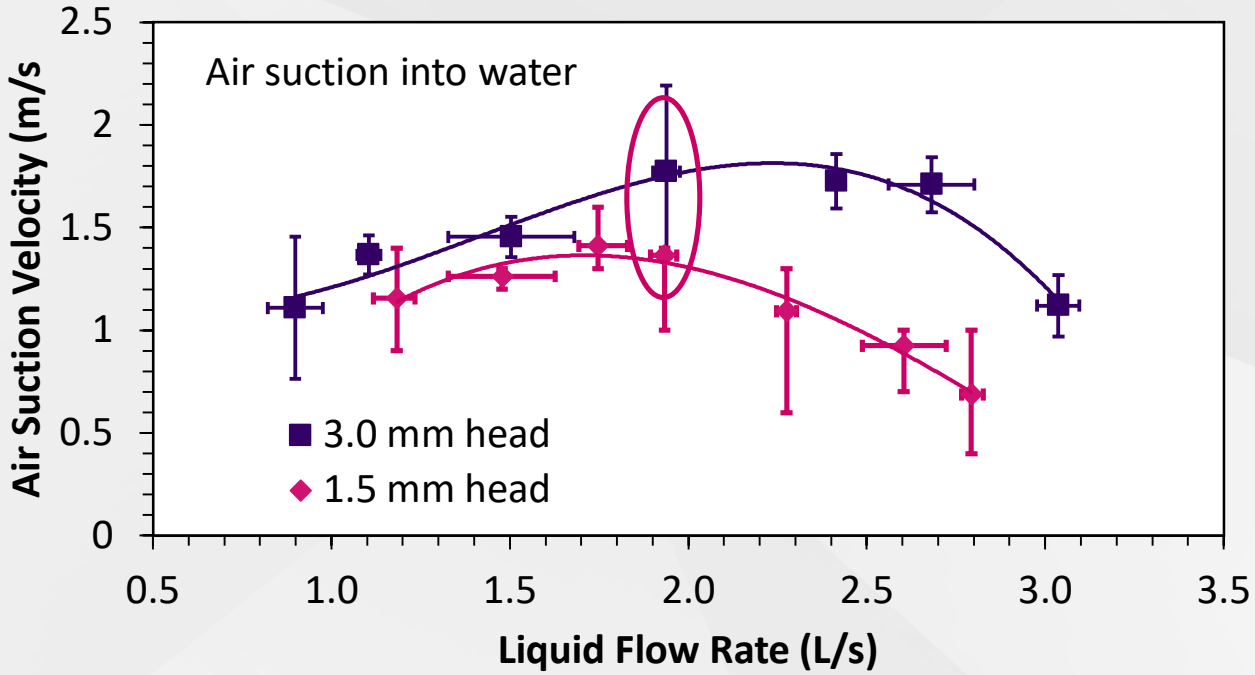
Similar trends with 1.5 mm head

3.3 Incorporation Rate & Suction Velocity



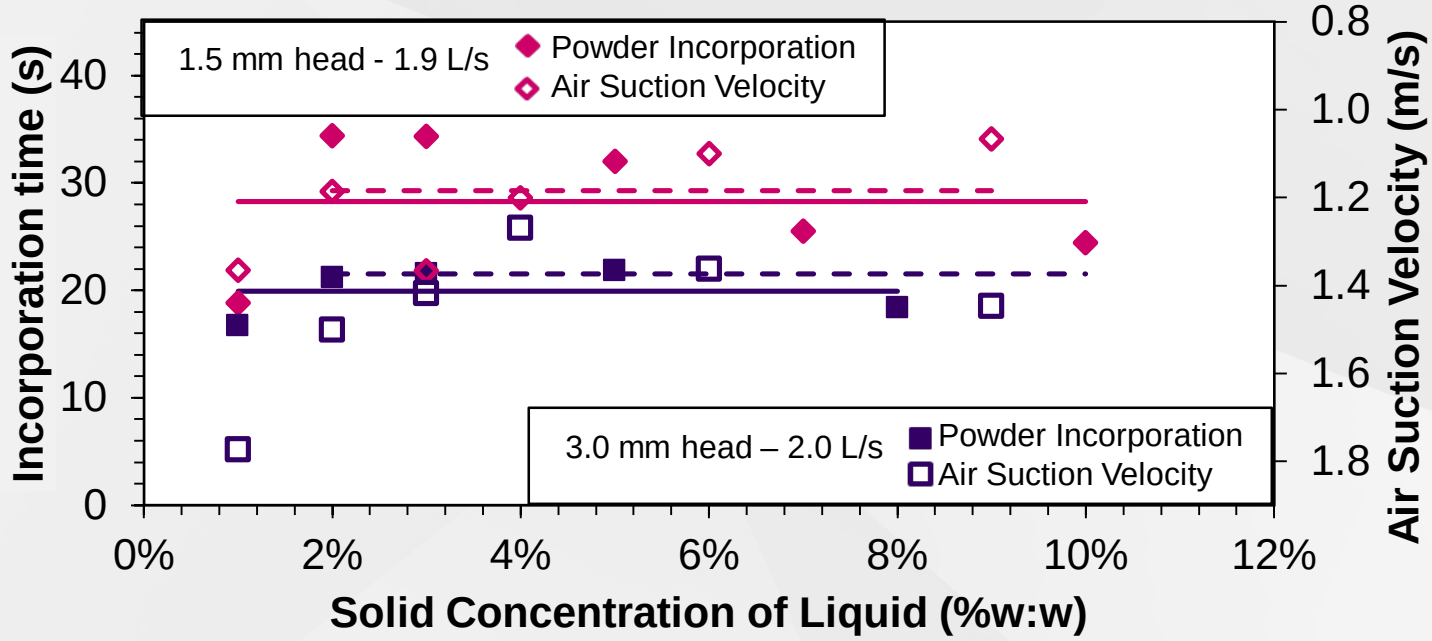
Air suction velocity at the powder inlet is indicative of **powder incorporation rate**

3.4 Effect of Gap Width – Air Suction



Higher air suction velocities with the **3.0 mm** gap head.

3.4 Effect of Gap Width – Powder Incorporation



Incorporation rate with **3.0 mm** gap head was **faster** in line with the higher air velocities measured at a given liquid flow rate.

4. Conclusions

- ✓ Establish the **performance** of an inline rotor stator, **Ytron ZC1**, for **powder incorporation** processes
  - Constant incorporation rate until challenging dispersion rheology
  - Air suction velocity measurements made at the powder inlet indicative of incorporation performance
    - Optimum flow rate for incorporation identified
    - Lower incorporation rate with smaller gap width head

and based on these

- ✓ provide **recommendations** for the **design** of such processes.

Thank You

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