WIM OOSTRA

Granulation - a process with many faces

25| October | 16

CONTENT

- Introduction
- Mechanisms of granulation
  - Nucleation and wetting
  - Growth and coalescence
  - Breakage and attrition
- Outlook

WHY GRANULATION

Reason	*Typical Application*
To produce useful structural forms	powder metallurgy
To provide a defined quantity for dispensing and metering	agricultural chemical granules, pharmaceutical tablets
To eliminate dust handling hazards or losses	briquetting of waste fines
To improve product appearance	food products
To reduce caking and lump formation	fertilisers
To improve flow properties for further processing	pharmaceuticals, ceramics
To increase bulk density for storage	detergents
To control dispersion and solubility	instant food products
To control porosity and surface-to-volume ratio	catalyst supports
To improve permeability for further processing	ore smelting
To create non-segregating blends of powder ingredients	ore smelting, agricultural chemicals, pharmaceuticals

The Science and Engineering of Granulation Processes
By Jim Litster, Bryan Ennis

HOW

Dry

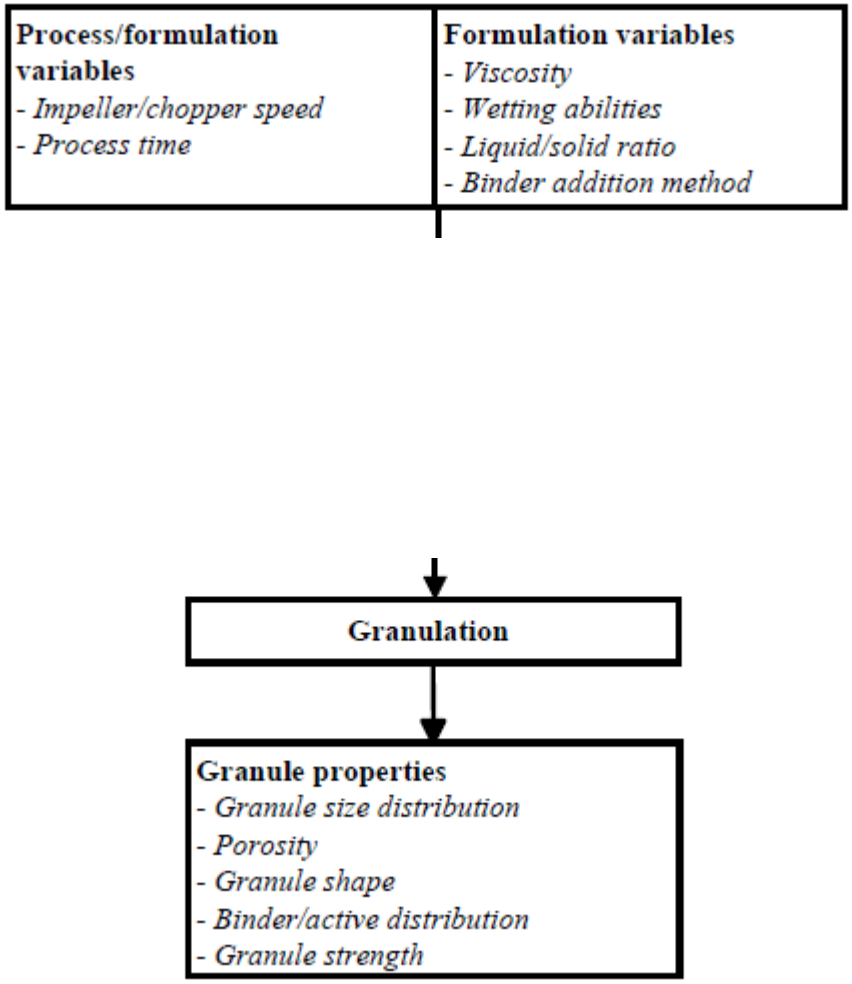
- Roller compaction
- Tablet compaction
- Pelletizing mills

Wet

- Drum granulators
- Disc granulators
- Planetary mixers
- High shear mixers
- Fluid bed granulators
- Extruders
- Spray drying
- Prilling

PHARMA - FUTURE?

MECHANISMS IN GRANULATION



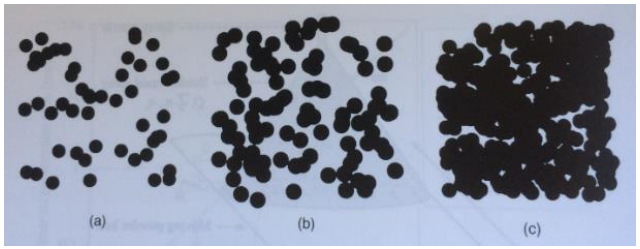
NUCLEATION AND WETTING

"Pour on"

- Relies on mechanical dispersion
- Short nucleation times
- Can be very reproducible for low viscous binders

Spray-on

- Use spray flux density

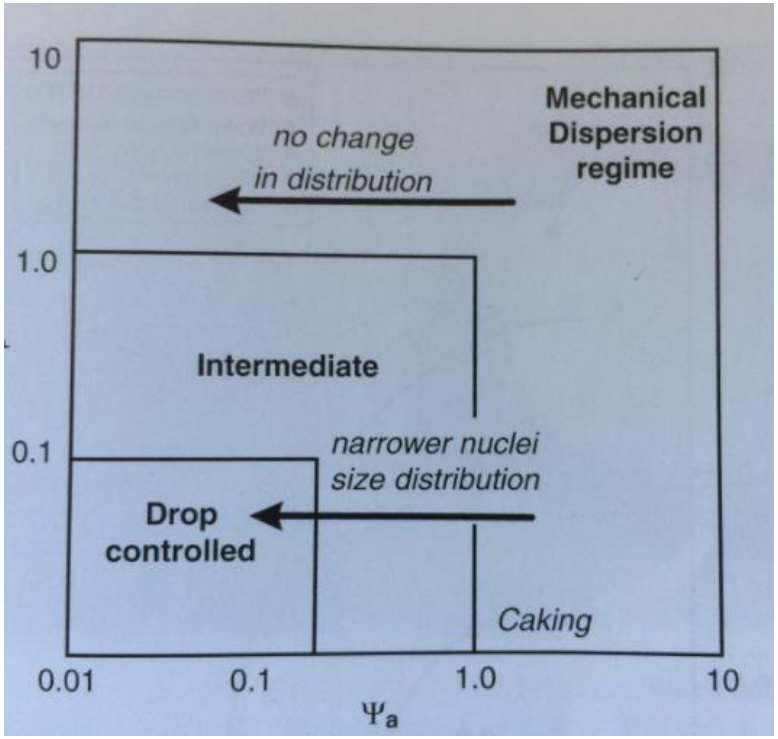


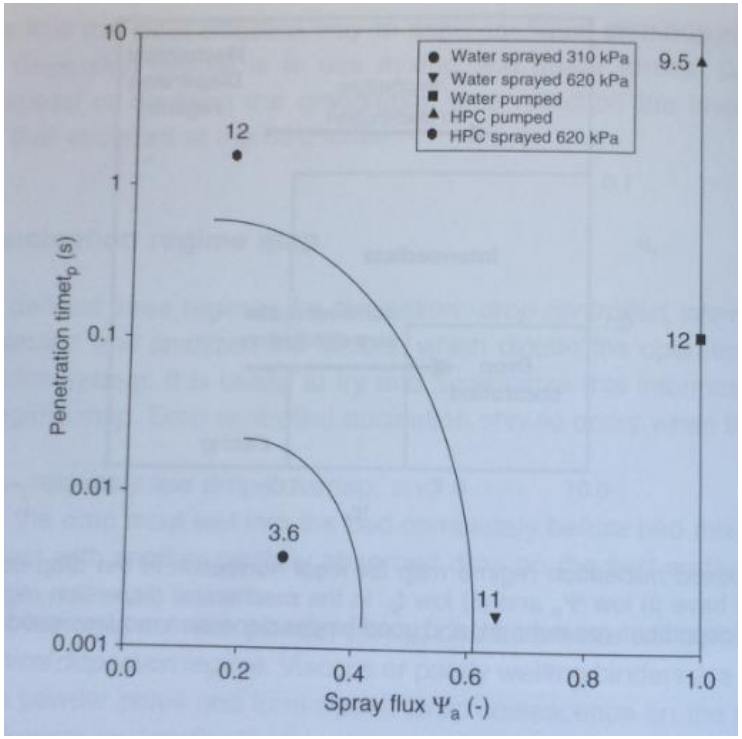
$$\psi_a = \frac{3\dot{V}}{2\dot{A}d_d}$$

- Well controlled nucleation
- Lead to long nucleation times in scale up and wider distributions

NUCLEATION AND WETTING

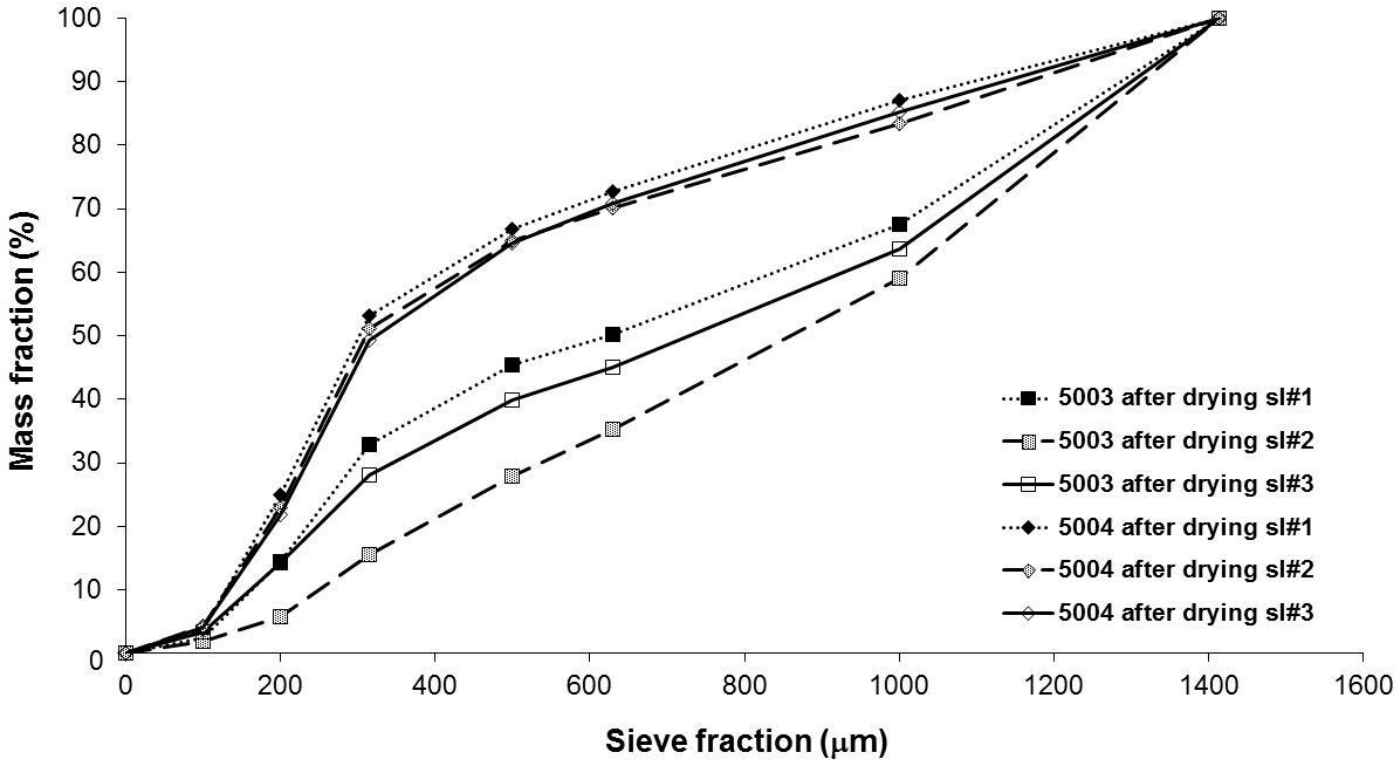
Nucleation regime maps





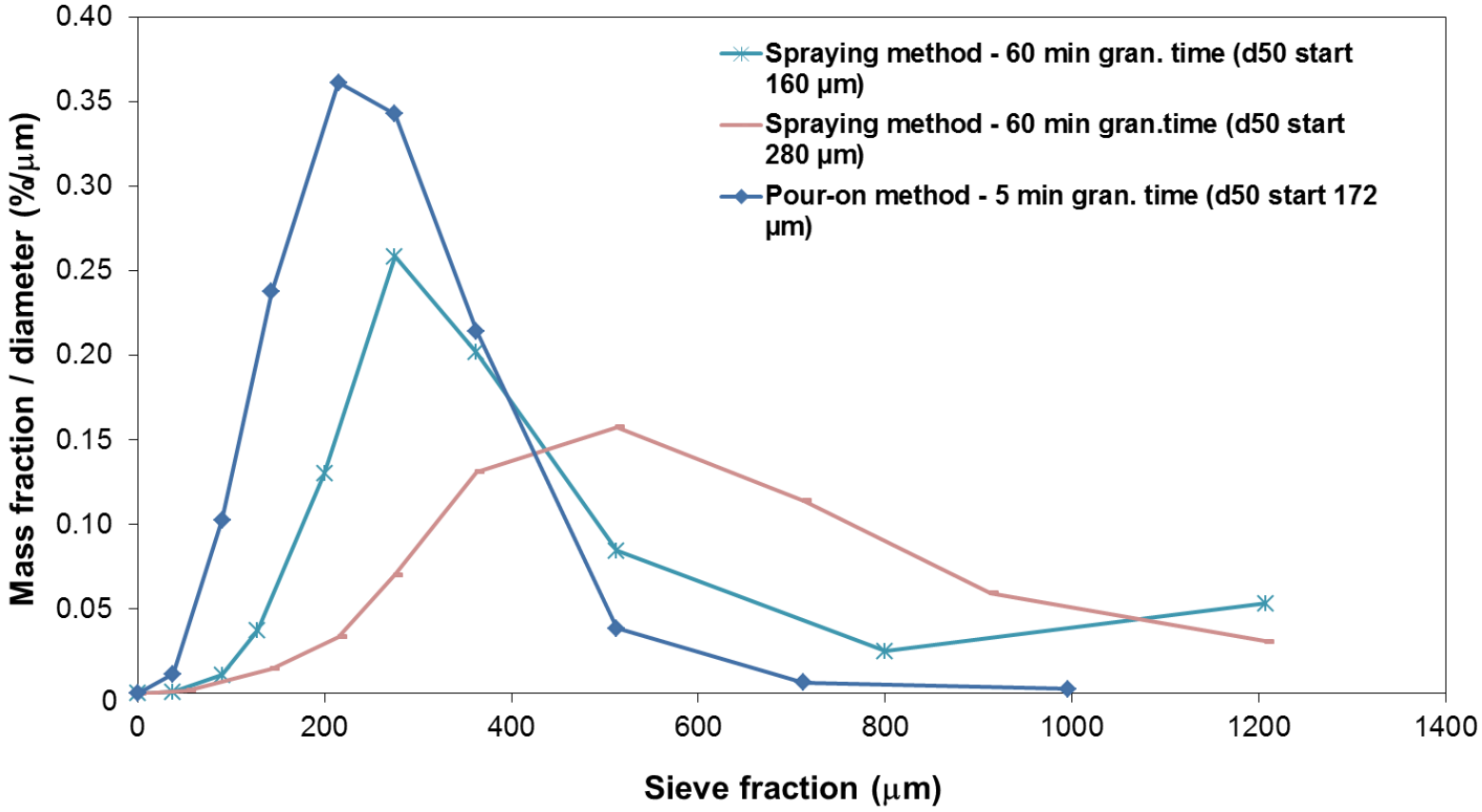
K.P. Hapgood, J.D. Litster, R. Smith, AIChE L, 49 (2), 350-361, 2003

NUCLEATION AND WETTING - EXAMPLE

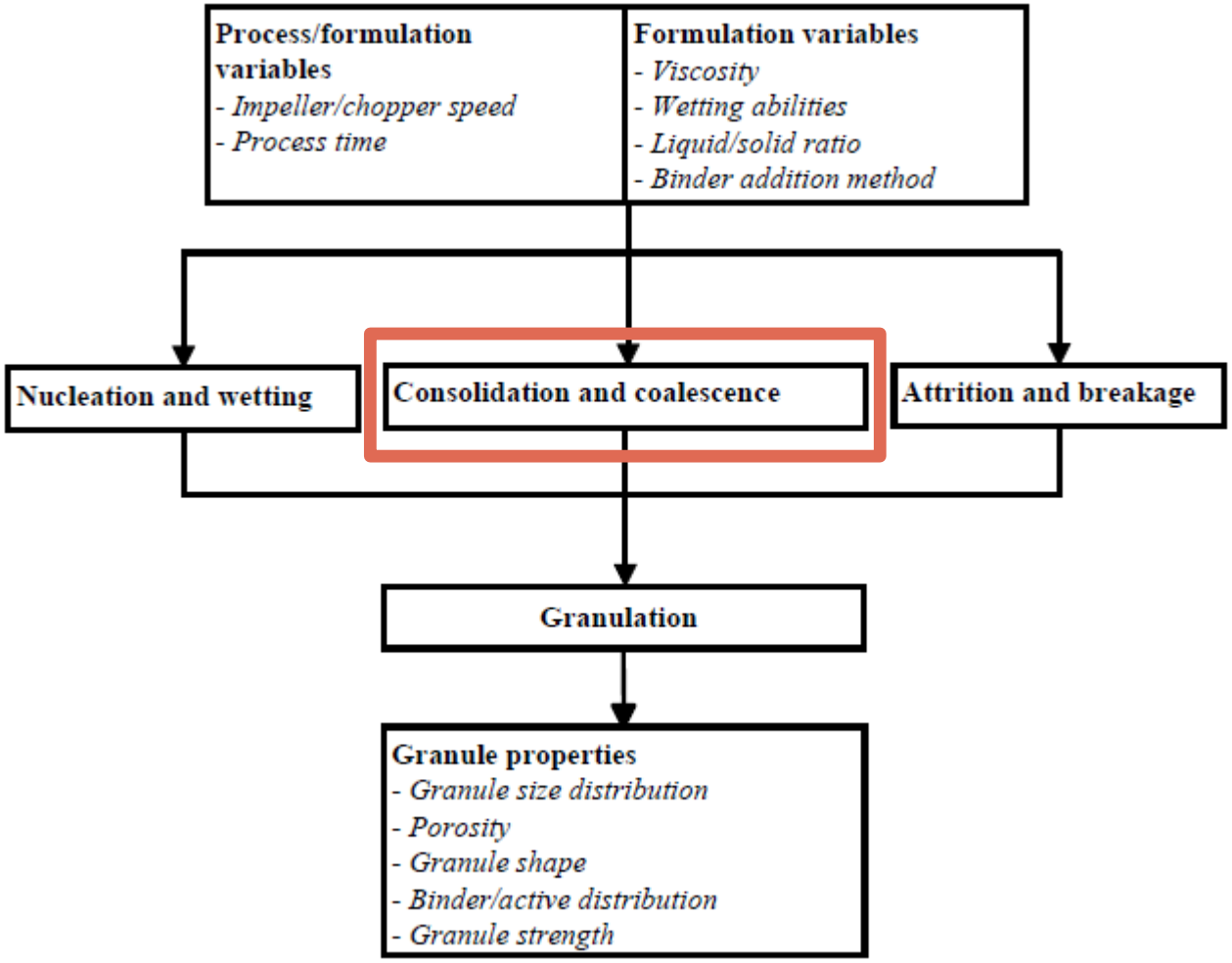


5003: Penetration time of binder > 60 s
5004: Penetration time of binder < 1 s

NUCLEATION AND WETTING – EXAMPLE 2



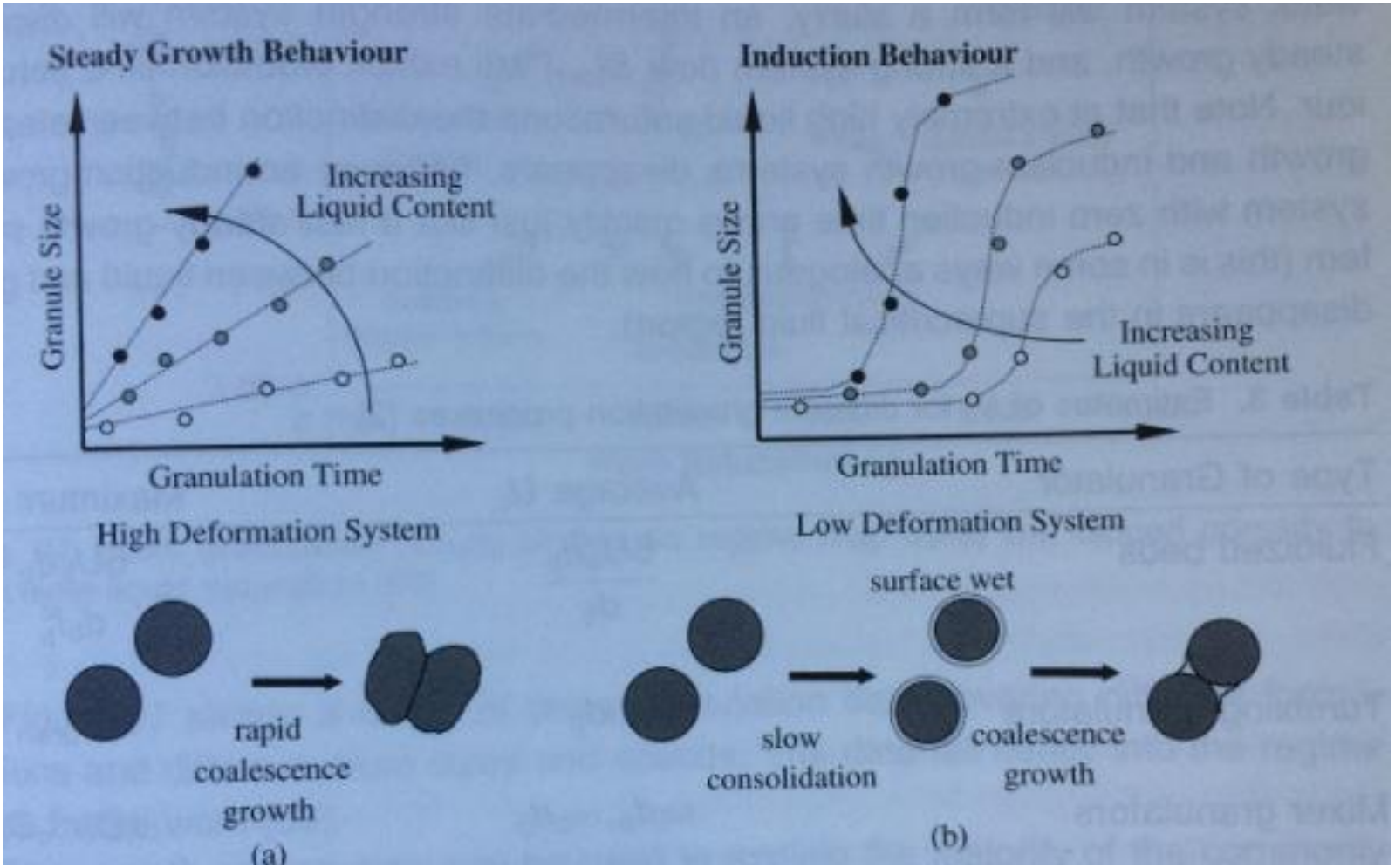
MECHANISMS IN GRANULATION



CONSOLIDATION AND COALESCENCE

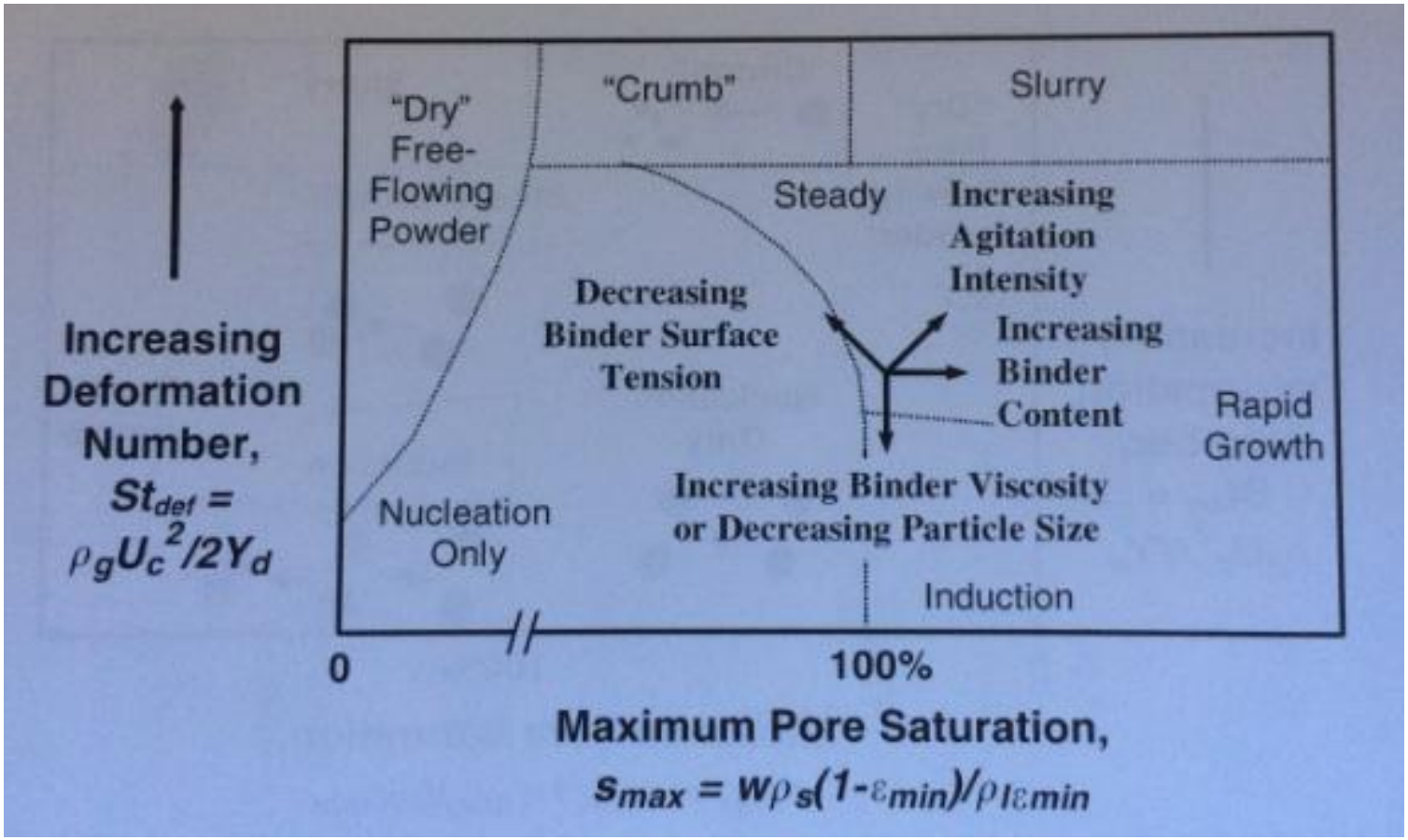
- Growth (pattern) observed depends on
  - Strength/deformability of granules (particle size, viscosity, porosity)
  - Pore saturation
  - Force applied (Fluid bed vs. high shear, impeller/chopper speeds)

CONSOLIDATION AND COALESCENCE



CONSOLIDATION AND COALESCENCE

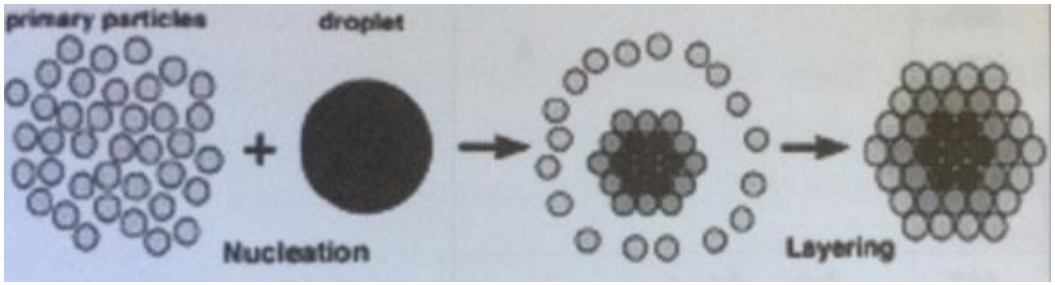
Granule growth regime map

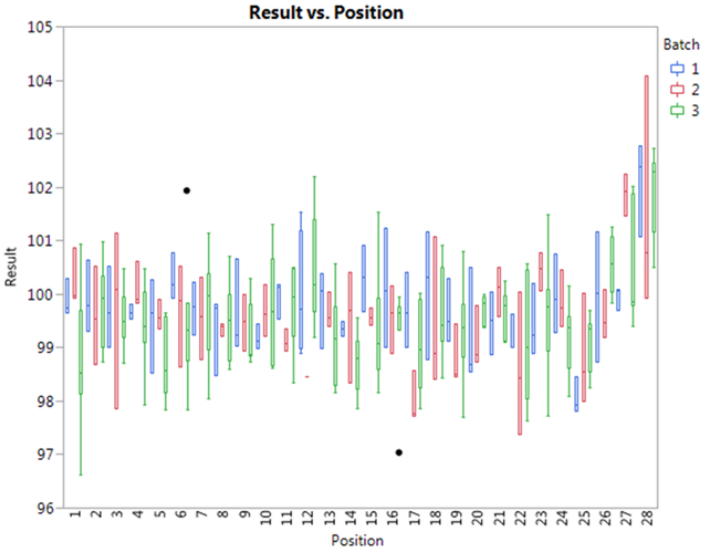


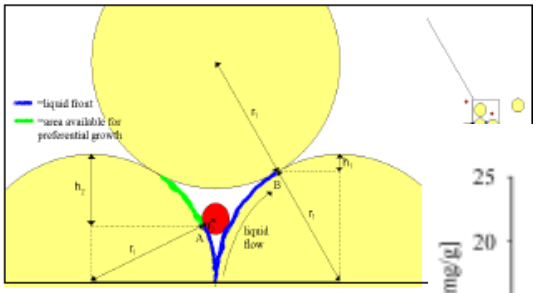
S.M. Iveson and J.D. Litster, AIChE J 44, 1510-1518 (1998)

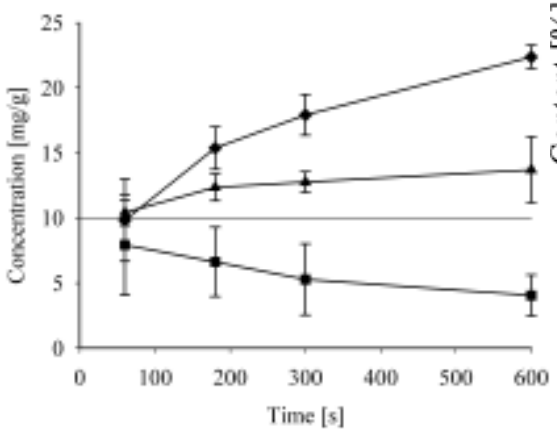
CONSOLIDATION AND COALESCENCE

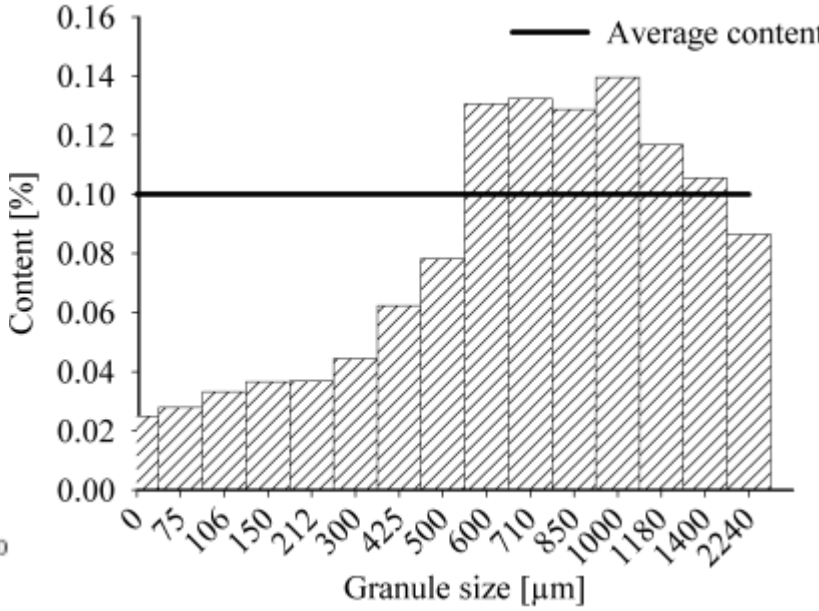
Layered growth





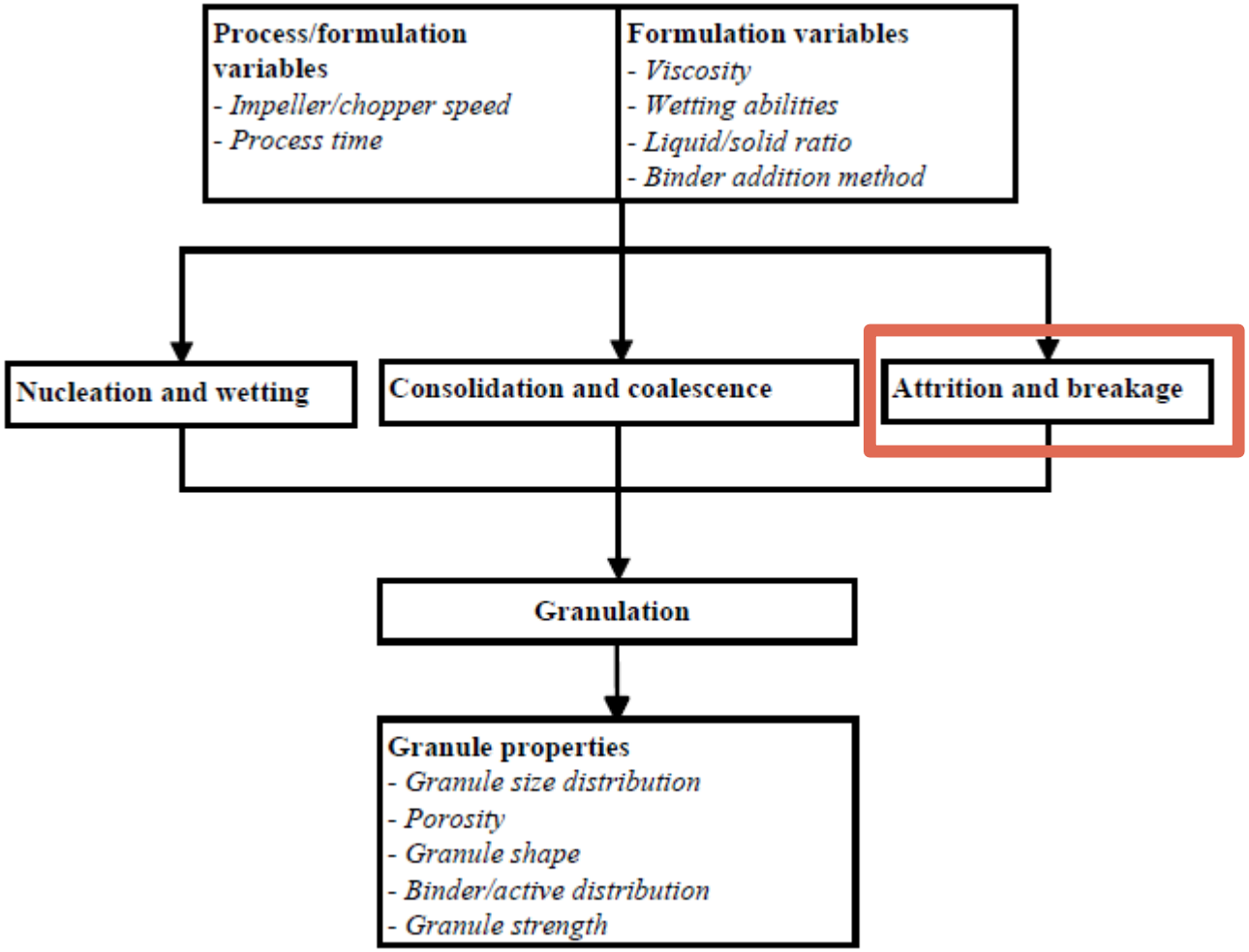






K. Van den Dries, Paradox of high shear granulation, PhD thesis, Utrecht, 2004

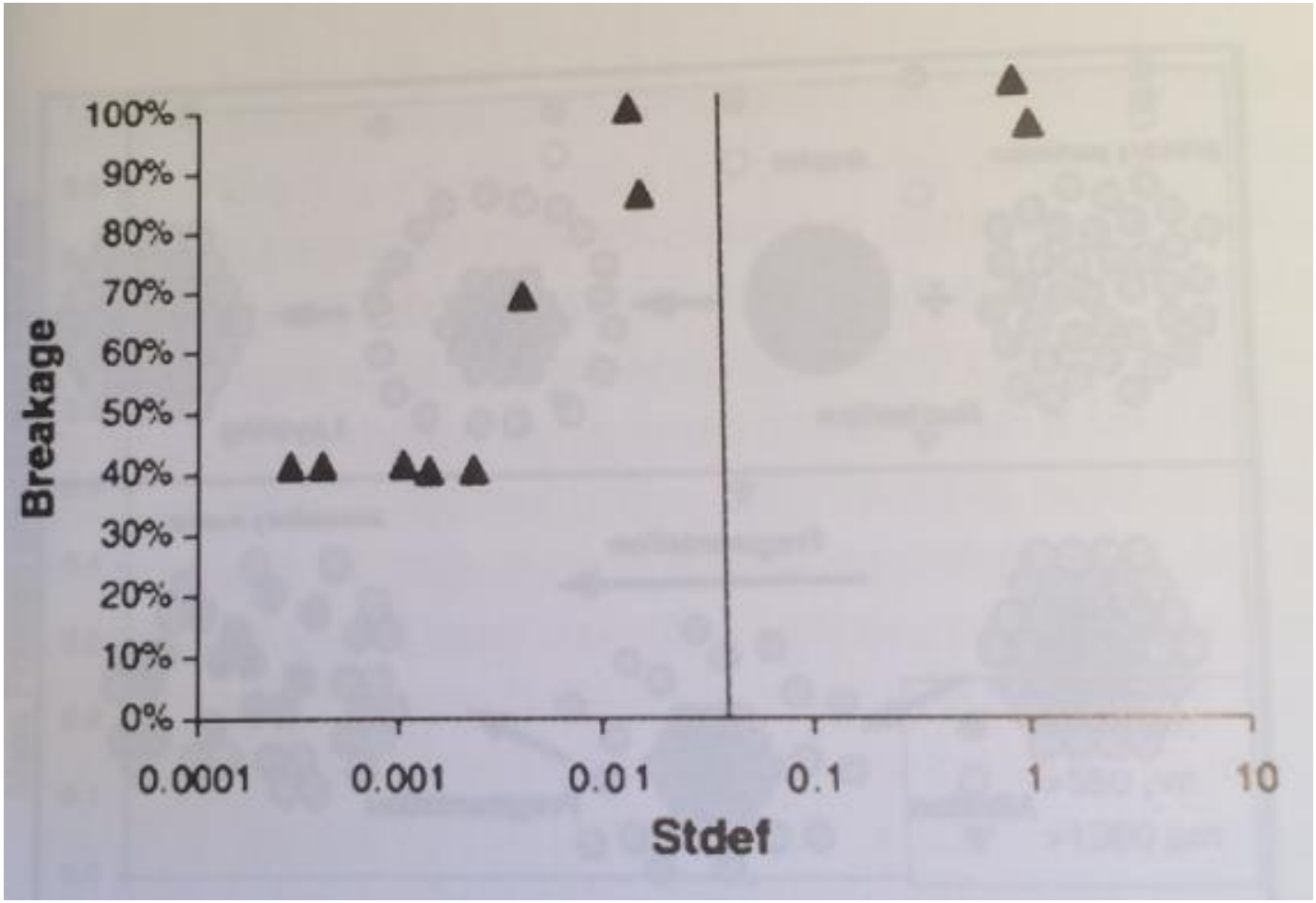
MECHANISMS IN GRANULATION



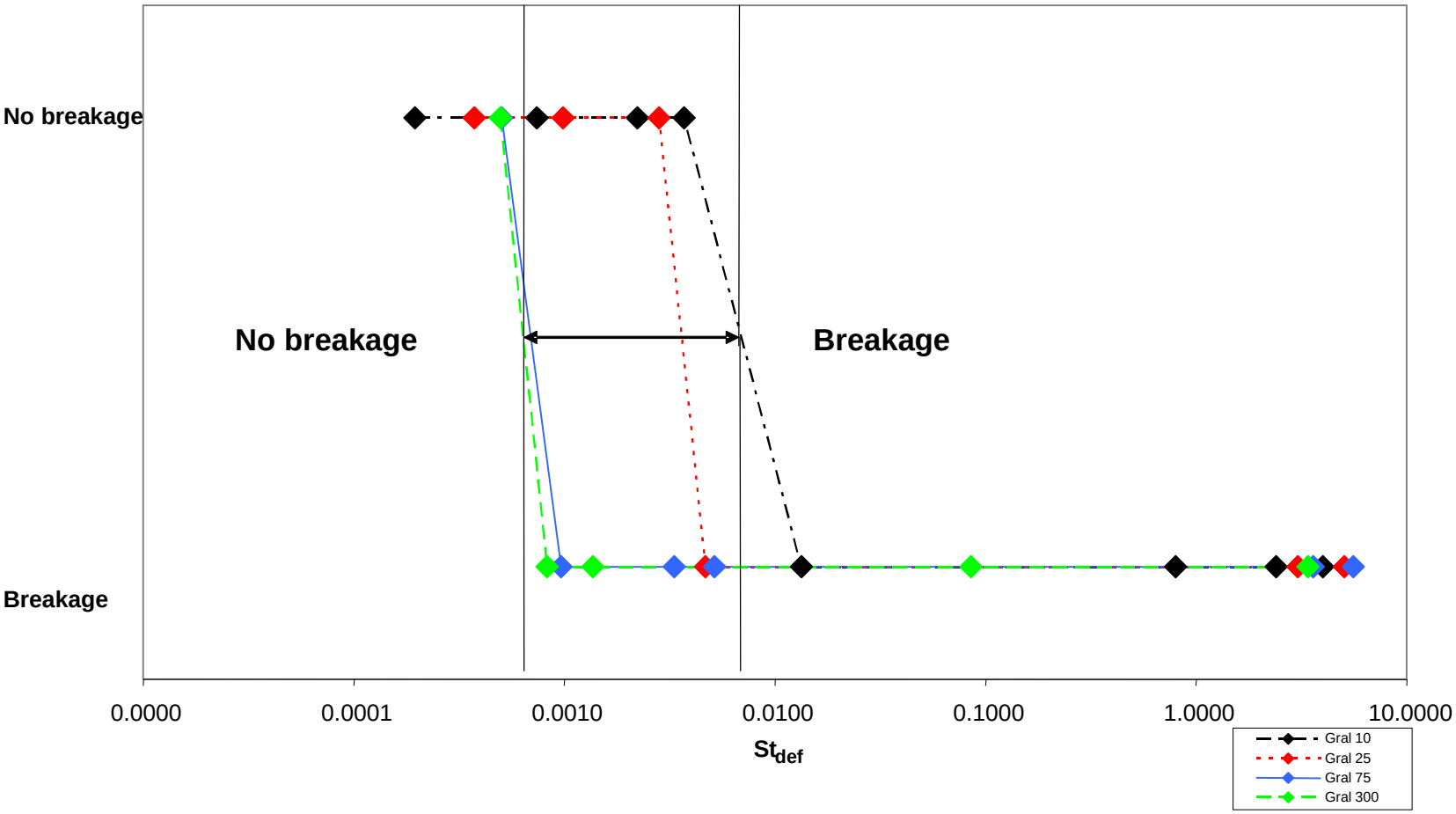
ATTRITION AND BREAKAGE

- Important process which affects, even, may control the PSD….
  - Less understood than other phenomena
  - Difficult to study/separate from other phenomena
  - Various semi-quantitative theories available

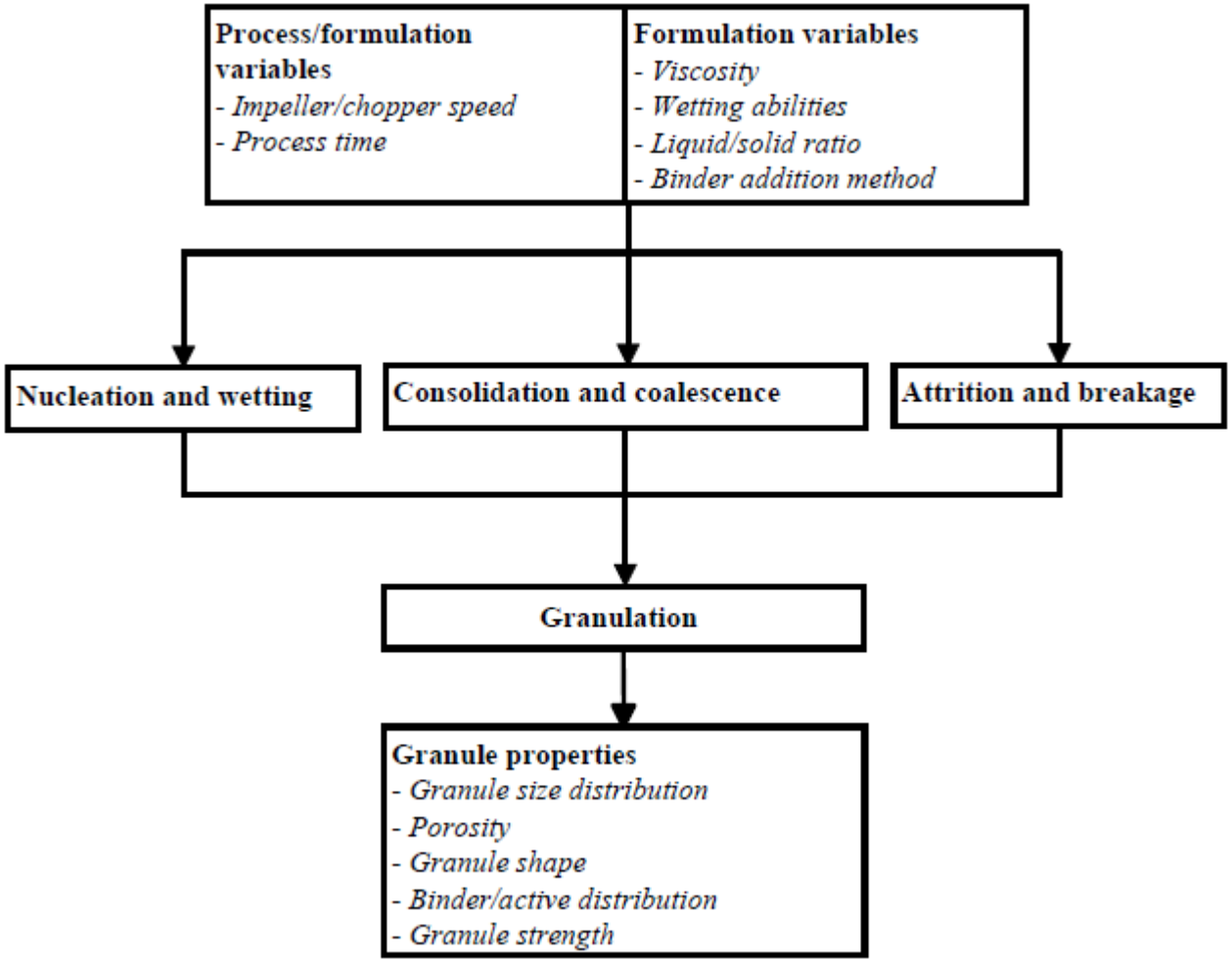
BREAKAGE


Breakage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0001
0.001
0.01
0.1
1
10
Stdef

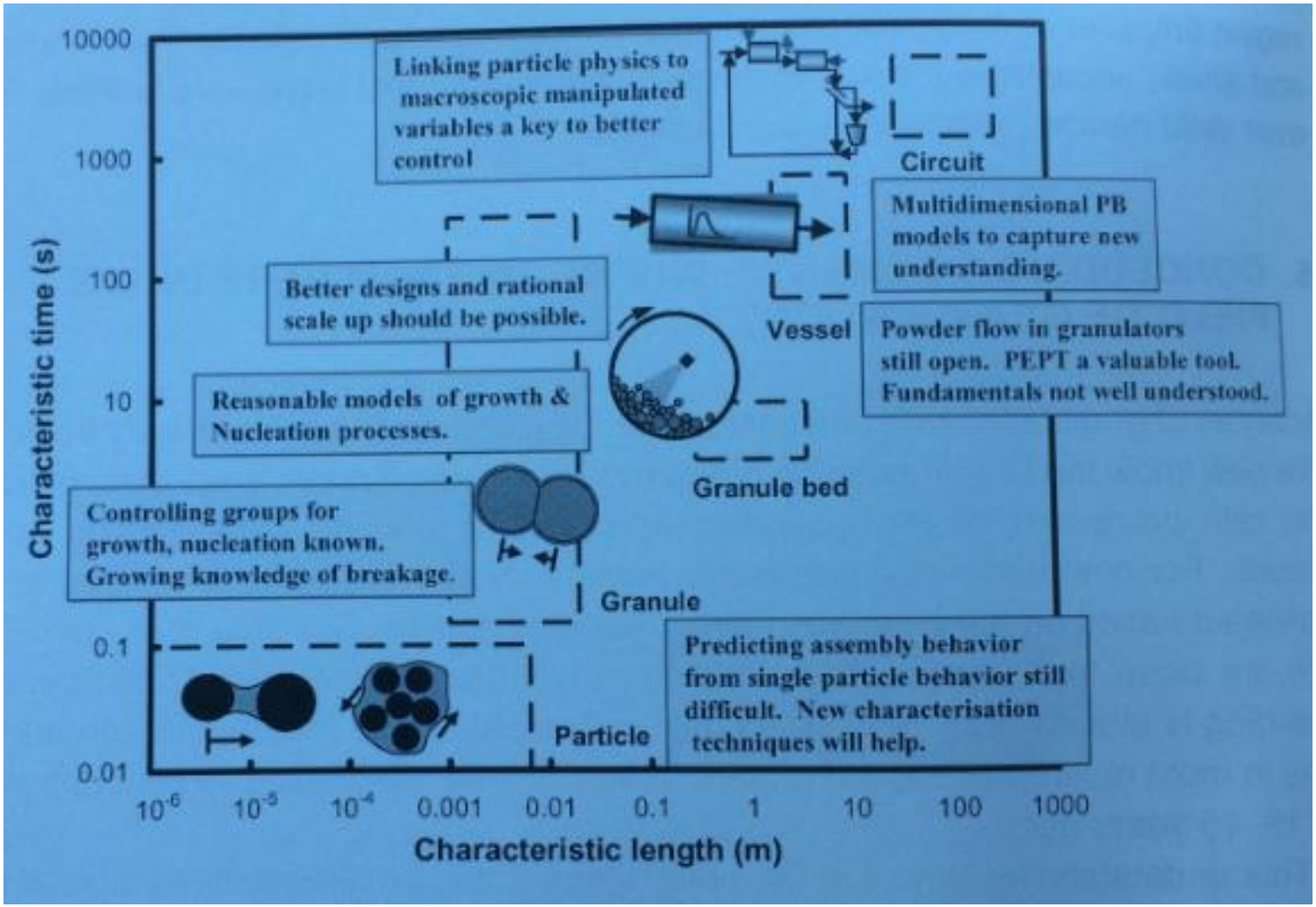
ATTRITION AND BREAKAGE



MECHANISMS IN GRANULATION



SUMMARY, OUTLOOK



Abbott