

WET GRANULATION IN HIGH SHEAR MIXER: EFFECT OF PHYSICO-CHEMICAL PROPERTIES ON THE GROWTH KINETICS



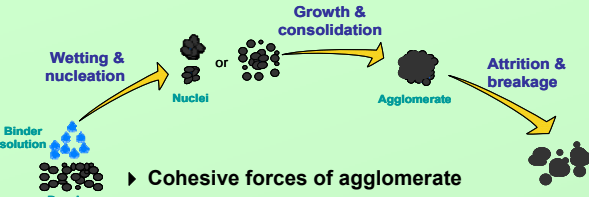
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Introduction

Wet granulation mechanisms (Lister et al., 2001)



Cohesive forces of agglomerate

Tensile strength of agglomerate

$$\sigma_t = C \frac{(1 - \epsilon) F_{bound}}{\epsilon d^2}$$

Static force (Rumpf, 1962)

$$F_{static} = \sigma d_p \gamma_L \cos \theta$$

Dynamic force (Ennis et al., 1991)

$$F_v = \frac{3}{8} \sigma d_p^2 \mu_L \frac{U}{L}$$

Capillary number Ca



$$Ca = \frac{F_{dynamic}}{F_{static}}$$

- $Ca < 10^{-3}$: Viscous term made negligible contribution to bridge strength (Ennis et al., 1990)
- $Ca > 1$: Viscous force predominate and the granule growth depends on viscous force

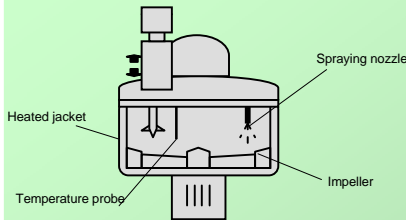
Objective

- Study of wet granulation of microcrystalline cellulose powder, MCC (Avicel PH101), by aqueous solutions of polymers using high-shear mixer granulators
- Understand the effect of physicochemical properties, such as the liquid viscosity μ_L , the liquid surface tension γ_L and the wettability of a binder solution on solid particles surfaces (contact angle, θ), on the agglomeration kinetics

Origin of the interparticles cohesion forces:
Static forces or Dynamic forces?

Granulation equipment

Zanchetta Roto high-shear mixer



Granulation parameters

- Capacity: 10L
- Impeller speed N: 400 rpm
- T° drying: 80°C
- Powder weight: 600 g
- Solution flow rate: 50 g/min

Granulation process stages

1. Dry mixing of powder
2. Liquid addition
3. Wet massing
4. Drying

Advantages

- Short process time (5min)
- Less liquid binder are needed
- Granulation of cohesive materials
- Production of dense granule with low porosity
- Porosity of the granule can be controlled

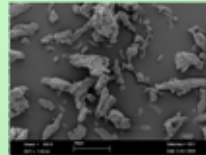
Materials

Feed powder

- Physical properties of MicroCrystalline Cellulose MCC (Avicel PH 101)

| | |
|---|------|
| d_{10} (μm) | 20 |
| d_{50} (μm) | 60 |
| d_{90} (μm) | 140 |
| True density (g/cm^3) | 1.54 |
| BET (m^2/g) | 1.36 |

SEM picture of MCC Particle



Binders solutions

- Characteristics of the binder solutions, liquid/solid adhesion work and capillary viscous number values

| Binder solution/particles | γ_L (mN/m) | μ_L (cP) | Adhesion work W_a (mN/m) | Ca' |
|---------------------------------------|-------------------|--------------|----------------------------|-------|
| Water/MCC | 72 | 1.0 | 98 | 0.06 |
| Water/MCC hydrophobic surfactant /MCC | 72 | 1.0 | 50 | 0.12 |
| 2% PVP/MCC | 26 | 1.0 | 52 | 0.11 |
| 3% PVP/MCC | 62 | 1.1 | 93 | 0.07 |
| 5% PVP/MCC | 61 | 1.5 | 114 | 0.08 |
| 0.1% Na-CMC/MCC | 72 | 3.6 | 94 | 0.22 |
| 0.3% Na-CMC/MCC | 72 | 7.2 | 92 | 0.46 |
| 1% Na-CMC/MCC | 73 | 25.4 | 91 | 1.64 |
| 1% HPMC/MCC | 53 | 10.0 | 73 | 0.80 |
| 2% HPMC/MCC | 54 | 50.0 | 75 | 3.90 |

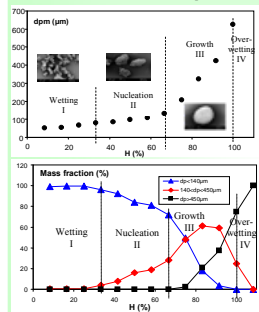
non-Newtonian solutions. The apparent viscosity is calculated for a velocity gradient of 1500/s⁻¹

- Capillary number: $Ca' = \frac{\mu_L U}{W_a}$ with $W_a = \gamma_L (1 + \cos \theta)$, $U = \pi N D$ and $N = 400 \text{rpm}$

- Non ionic surfactant $\Rightarrow \gamma_L \searrow W_a \searrow \mu_L$ is not affected
- 1% (w/w) PVP $\Rightarrow \gamma_L \searrow W_a \nearrow \mu_L$ is not affected
- 1% (w/w) Na-CMC $\Rightarrow \gamma_L \nearrow W_a \nearrow \mu_L$ are weakly affected
- 1% (w/w) HPMC $\Rightarrow \mu_L \nearrow \gamma_L \searrow W_a$ are weakly affected

Typical example of granulation

Granulation profile



Studied criteria

- Mean diameter: $d_m = \frac{\sum f_i d_i}{\sum f_i}$
- Growth rate: $X = \frac{d_m - d_{m0}}{d_{m0}}$
- Three characteristic particle classes fraction:
 - Fine class: diameter less or equal to 140 μm
 - Intermediate class: $140 < dp < 450 \mu\text{m}$
 - Coarse class: $dp > 450 \mu\text{m}$
- Liquid content: $H = \frac{\text{Liquid mass}}{\text{Dry solid mass}} \times 100$

Growth kinetic constant K

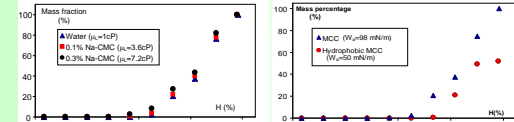
$$K = \frac{d}{dH} \ln \left(\frac{x_{fine}^0}{x_{fine}} \right)$$

The evolutions of the three characteristic size classes versus H in the regime II and III are similar with those of first order consecutive chemical reactions: A \rightarrow B \rightarrow C.

Influence of the physicochemical properties

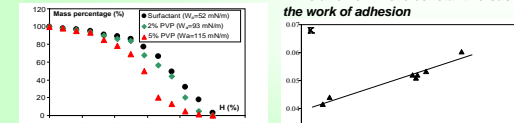
Effect of the work of adhesion: $Ca' < 1$

Evolution of coarse agglomerates percentage



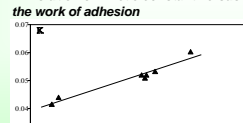
$W_a \Rightarrow$ a smaller amount of liquid binder required to enhance the growth

Evolution of fines particles percentage



$W_a \Rightarrow$ a faster disappearance of the fines particles

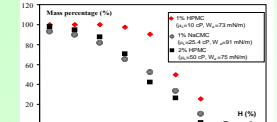
Evolution of kinetic constant versus the work of adhesion



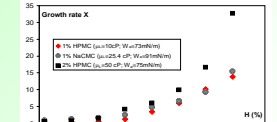
The kinetic constant K is directly related to the work of adhesion

Influence of the viscosity: $Ca' \geq 1$

Evolution of fines particles percentage



Evolution of granule growth rate



$\mu_L \Rightarrow$ decrease of the amount of liquid to achieve agglomerate growth

$\mu_L \Rightarrow$ increase of the growth rate, X, by a factor of 2

Conclusion

The results of our study on wet granulation of the microcrystalline cellulose show that :

- The viscosity of the solution has no significantly effect on the granulation process for a capillary number lower than 1.64. In these conditions, the increasing the work of adhesion enhances the growth kinetics
- For a capillary viscous number higher than 1.64, the granule growth is controlled by the viscous dissipation forces

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