Analyzing Single-Drop Granule Formation and Strength

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How does impact velocity and liquid binder viscosity affect the penetration time of a liquid droplet into a powder bed for wet granulation?

Introduction

Wet granulation is used widely for many applications, most notably the pharmaceutical industry. It is done typically to improve transportation properties and production efficiency.

V_0 = Drop Volume
ε = Powder Bed Surface Porosity
r_{drop} = Drop Radius on Powder Surface
μ = Liquid Viscosity
P_c = Capillary Pressure
τ_{CDA} = Theoretical Penetration Time

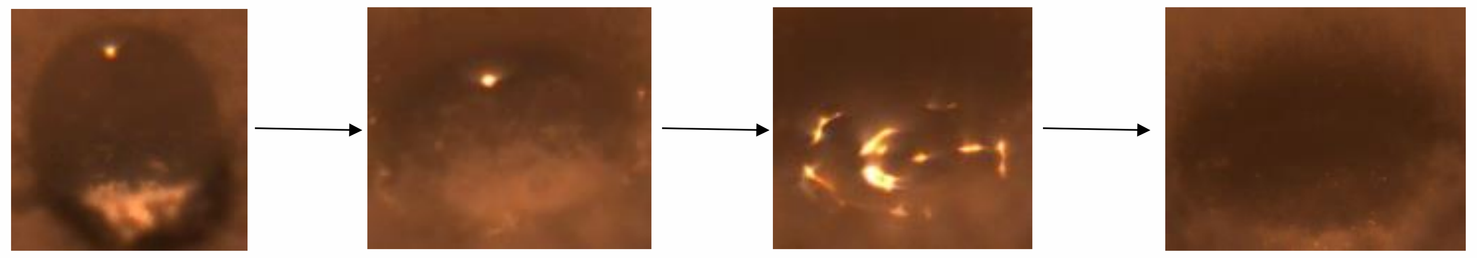


Figure 1. Drop Penetration into a Powder Bed

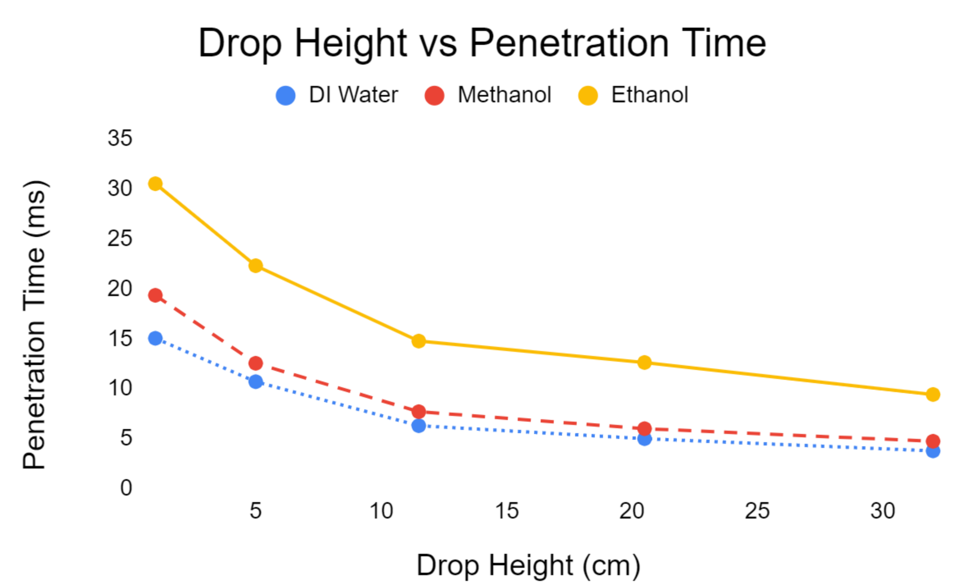
$$\tau_{CDA} = V_0^2 \pi^2 \varepsilon^2 r_{drop}^4 \mu P_c \quad [1]$$

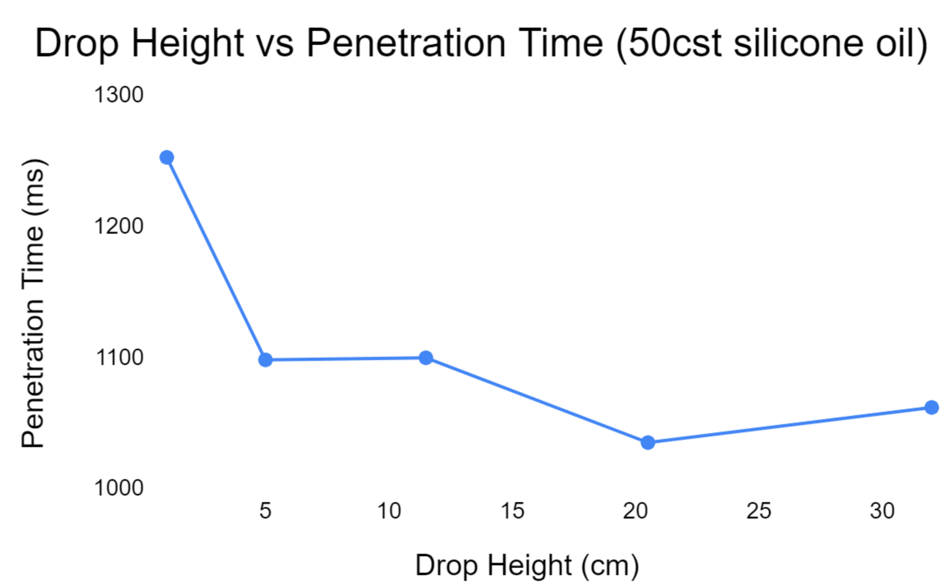
Experimental Setup

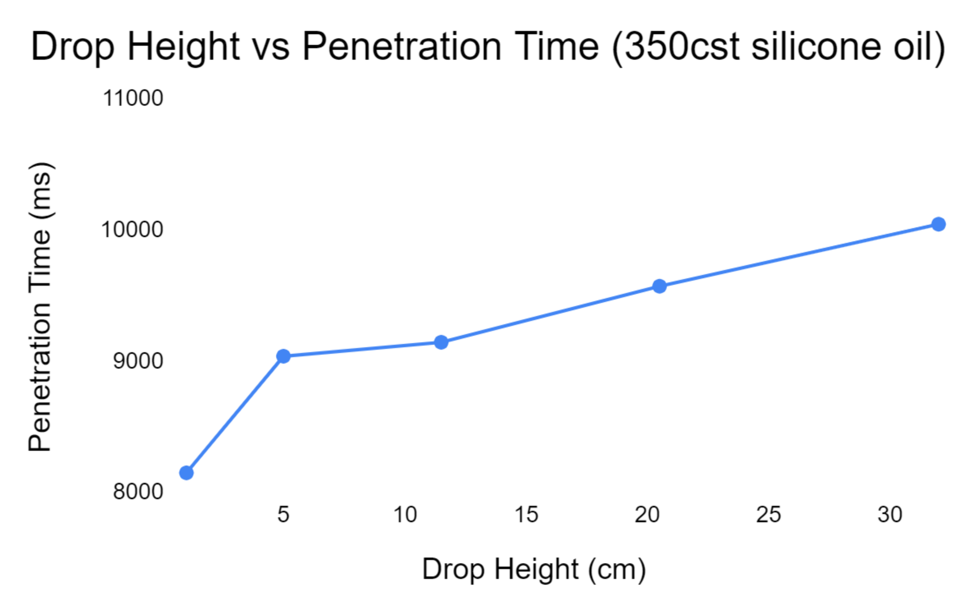
- Liquid binder dropped at set heights
- Penetration time captured with high-speed camera
- Number of frames from first impact to full absorption

Figure 2. Picture of Photron Fastcam Mini AX200

Conclusions







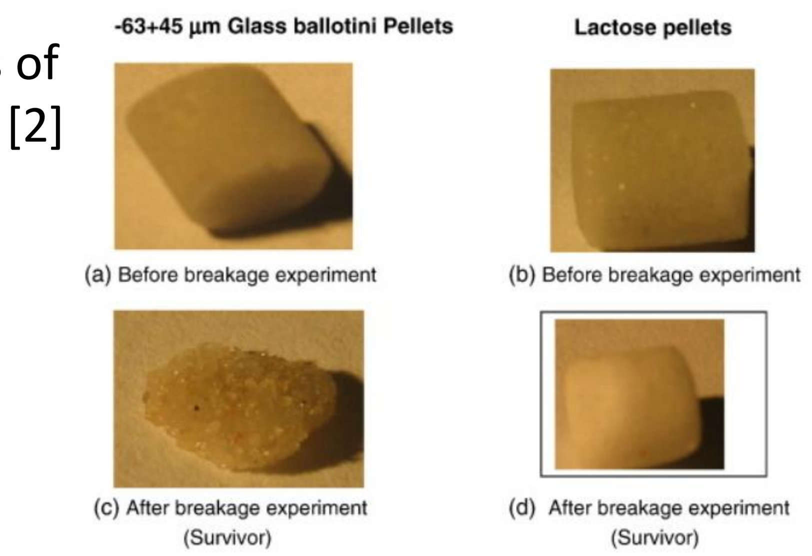
- Lower viscosity binder resulted in tunneling mechanism; Penetration time decreases with higher impact velocity.
- Higher viscosity binder led to spreading over powder surface and crater formation; Opposite correlation observed.
  - Liquid drops would initially bounce off the surface at higher viscosity/impact velocity.

How do liquid binder properties affect the breakage rate of granules in high shear mixer granulation?

Introduction

Breakage of particles allows for better dispersion of a liquid binder and limits maximum particle size. Controlling the rate of breakage allows for a more efficient process design.

Figure 3. Examples of Surviving Granules [2]



$$St_{def} = \frac{\rho_g v_c^2}{2\sigma_p} \quad [3]$$

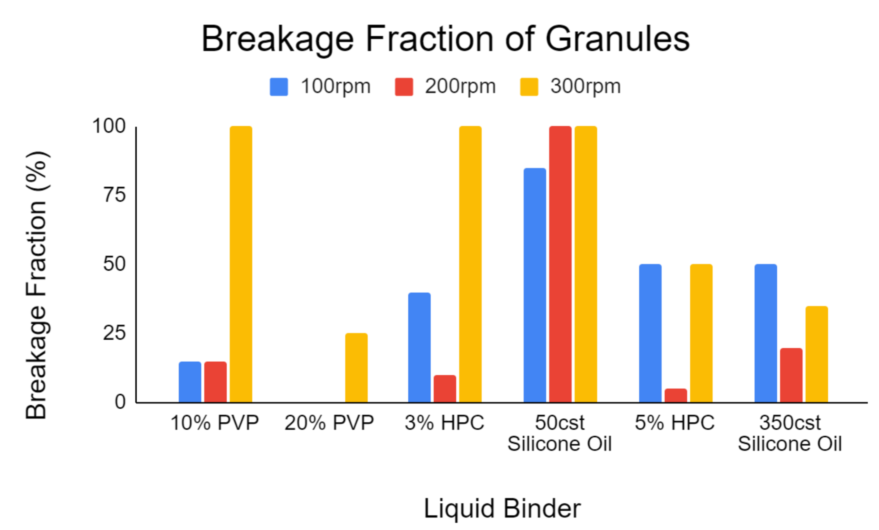
ρ_g = Granule Density
v_c = Impact Velocity
σ_p = Granule Yield Strength
St_{def} = Stokes Deformation Number

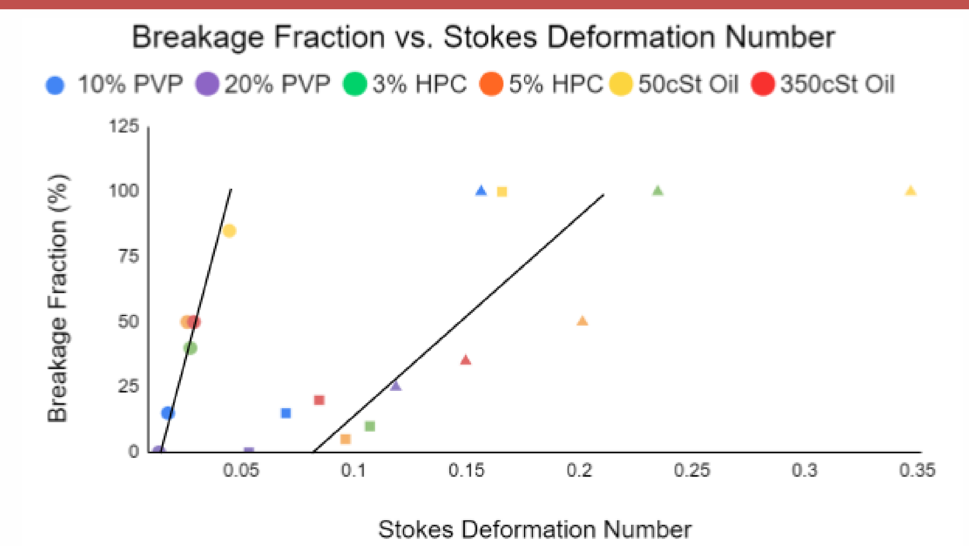
Experimental Setup

Figure 4. Picture of Key International KG5 High Shear Mixer/Granulator

- 20 granules placed into mixer bowl with carrier sand
- Number of surviving granules checked in 15 second increments for a total time of 1 minute

Conclusions





- Breakage rate depends on liquid, powder, and equipment properties, not just viscosity.
- Breakage rates follow trend lines at $St_{def} = 0.02$ and $St_{def} = 0.2$ with some outliers.

References

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2. Liu LX, Smith R, Litster JD. Wet granule breakage in a breakage only high-hear mixer: Effect of formulation properties on breakage behaviour. *Powder Technology*. 2009;189(2):158-164. doi:https://doi.org/10.1016/j.powtec.2008.04.029
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