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Measuring the induction time for particle–bubble attachment in flotation

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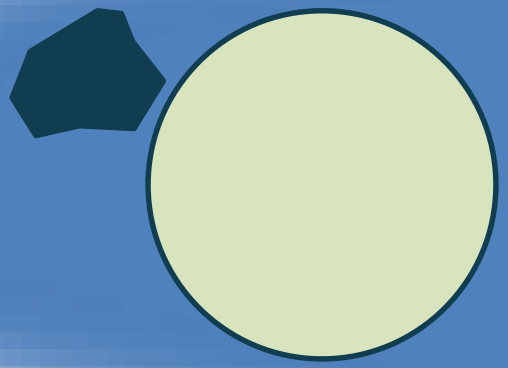
GECAMIN Conferences for Mining

Induction time

- No inherent theoretical definition
- *Practically* defined by the limiting step in bubble–particle attachment

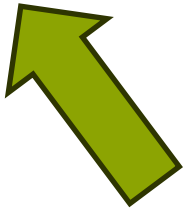


- Several experimental techniques

...that provide different estimates!

Induction time

Aim to investigate this



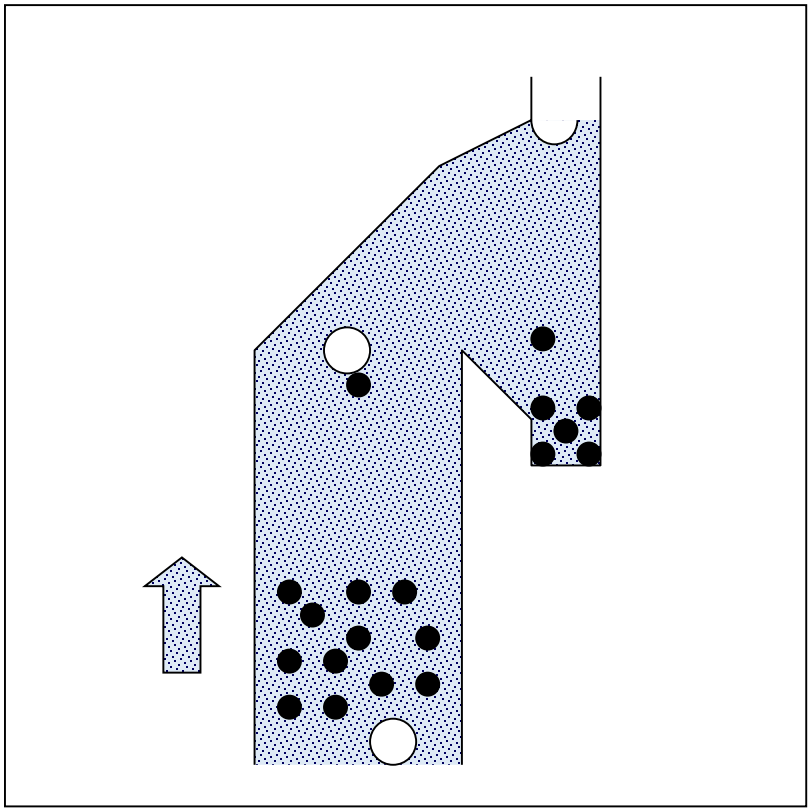
- Several experimental techniques

...that provide different estimates!

Available techniques

Back-calculation from microflotation tests **(MF)**

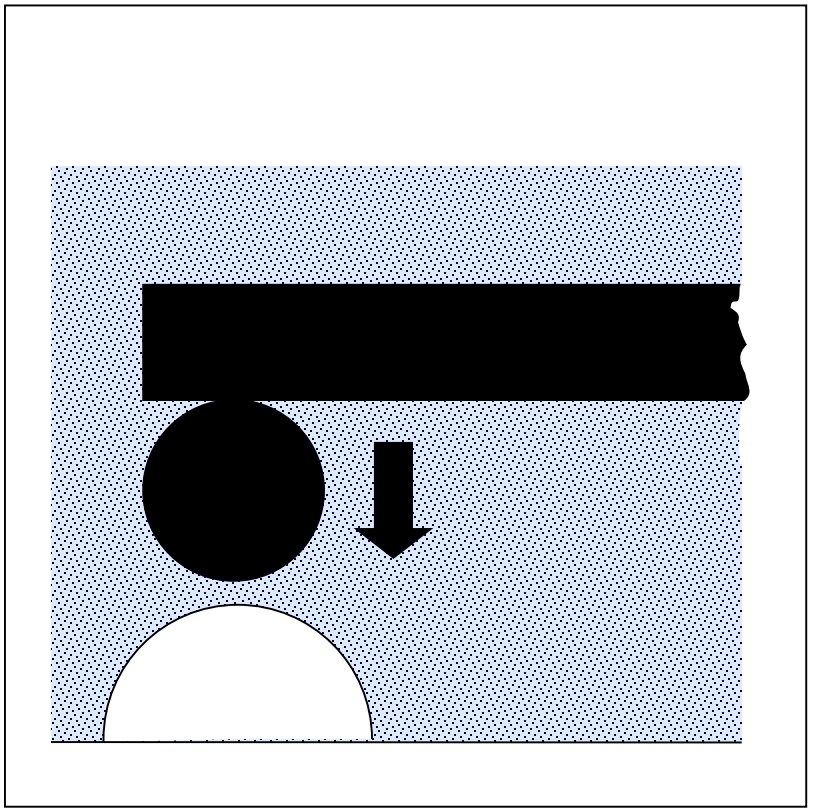
- Bubble rises naturally through particle bed
  - Liquid flow may be imposed
- Adjust parameter in a (theoretical) model to fit recovery data



Available techniques

Atomic force microscopy **(AFM)**

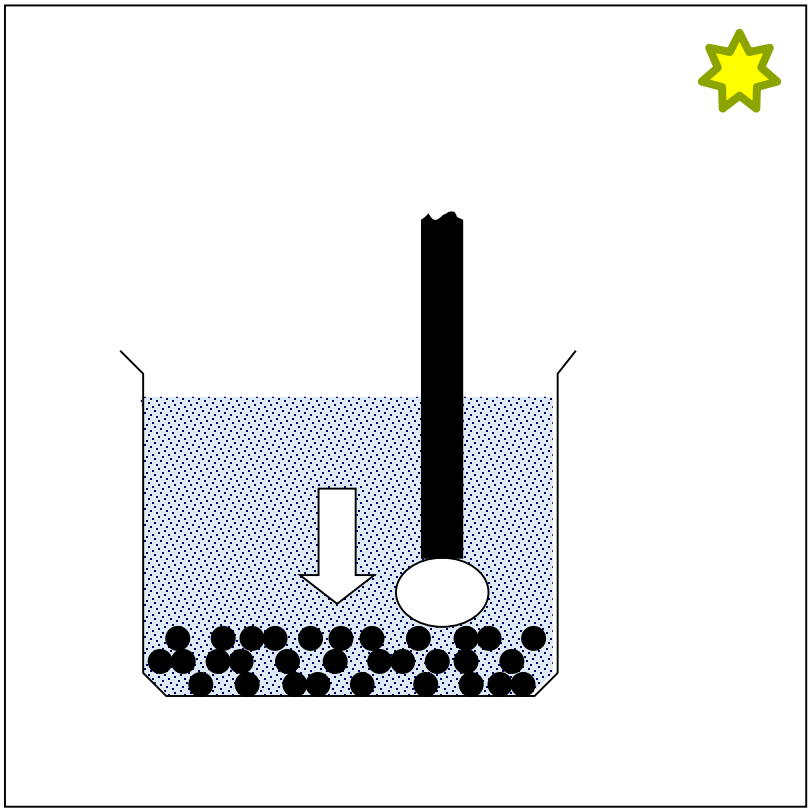
- Drive particle into bubble
- Measure force and position as functions of time



Available techniques

Induction Timer device **(IT)**

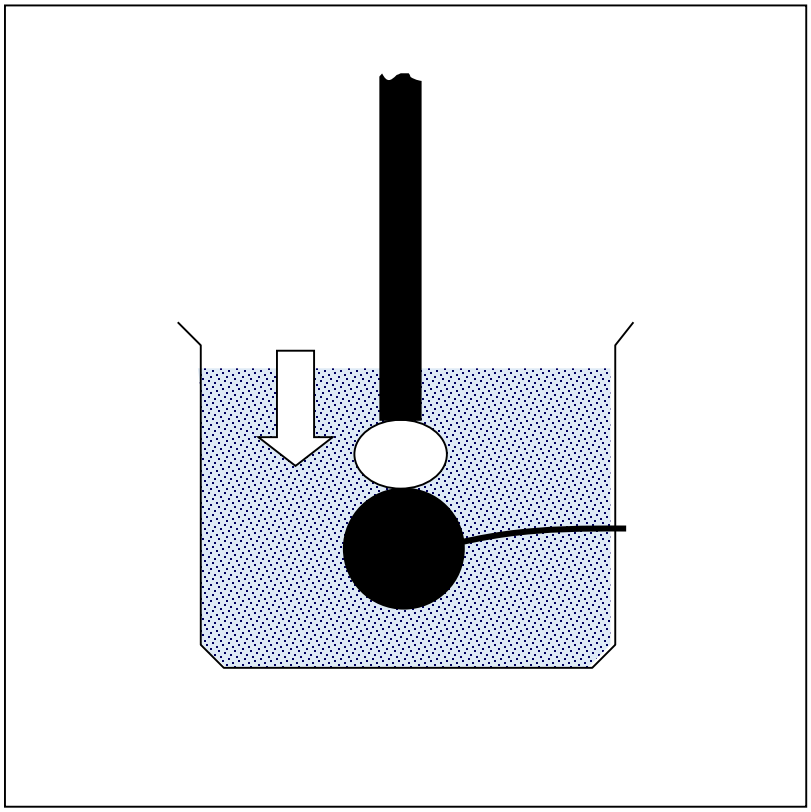
- Drive bubble into particle bed
- Observe presence of attached particles



Available techniques

Integrated thin film drainage apparatus **(ITFDA)**

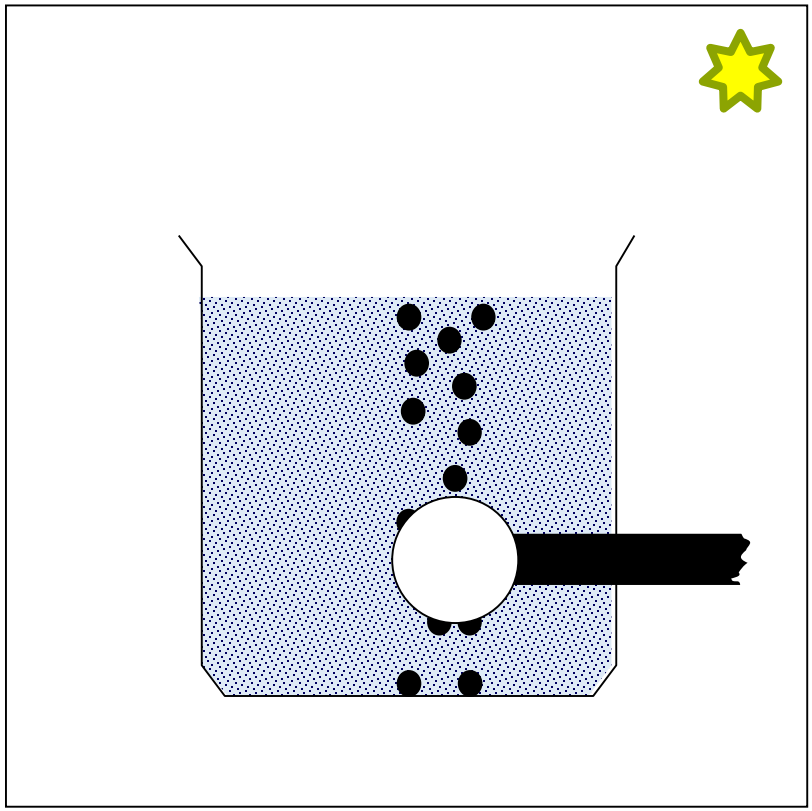
- Drive bubble onto (large) solid ‘particle’
- Measure force as a function of time



Available techniques

Milli-Timer apparatus **(MT)**

- Particles fall naturally onto captive bubble
- *Directly observe* induction period from particle motion on video



Available techniques

See full paper for more details

Experimental approach

Compare measurements of induction time on two devices (**IT** and **MT**) using same materials

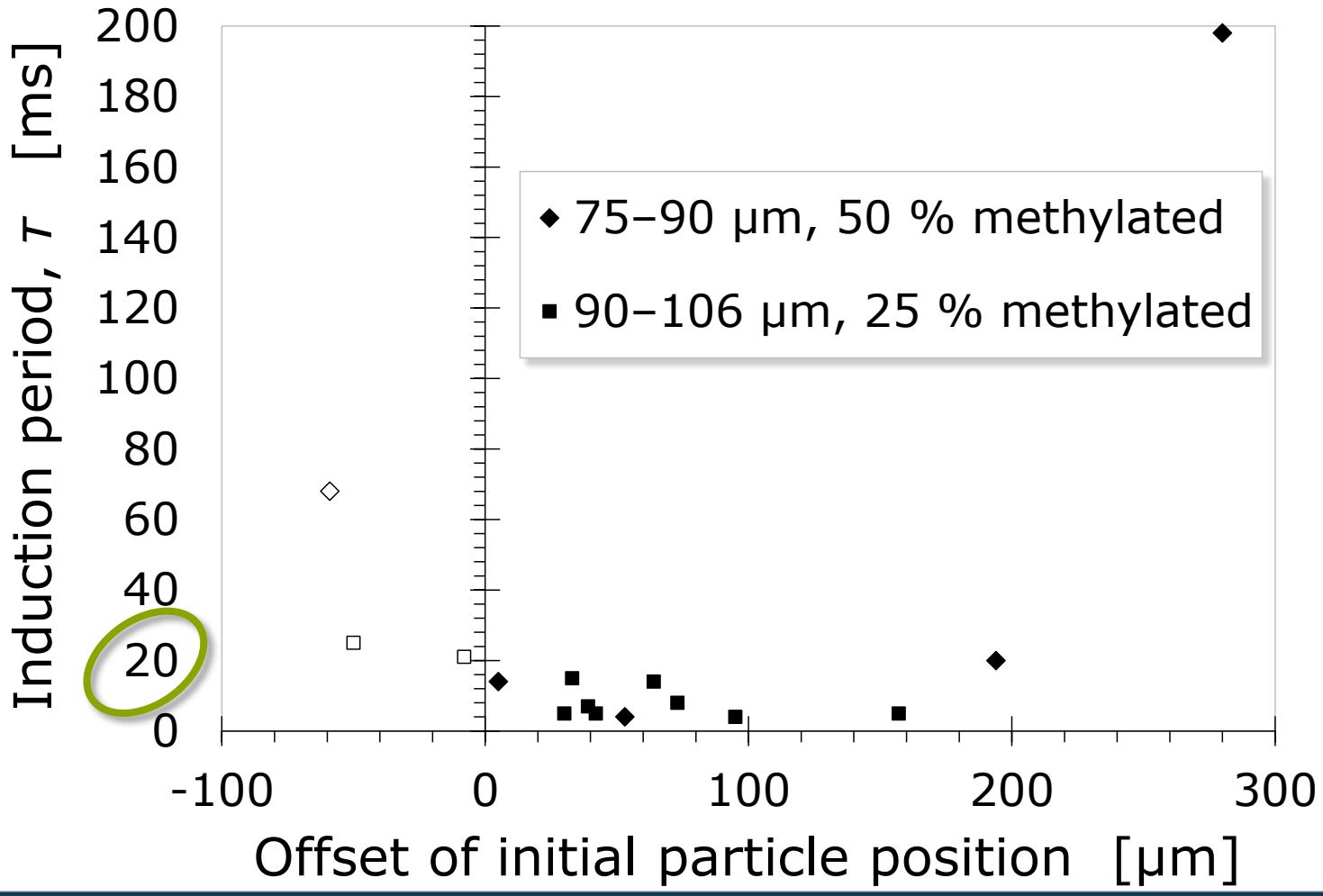
- Particles — hydrophobised borosilicate glass spheres

  Sample 1 = 90–106 µm, 25 % methylated

  Sample 2 = 75–90 µm, 50 % methylated

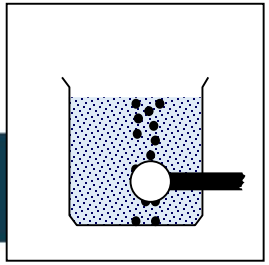
- Liquid — purified water
- Gas — ambient air (freshly introduced)

Milli-Timer results (both samples)

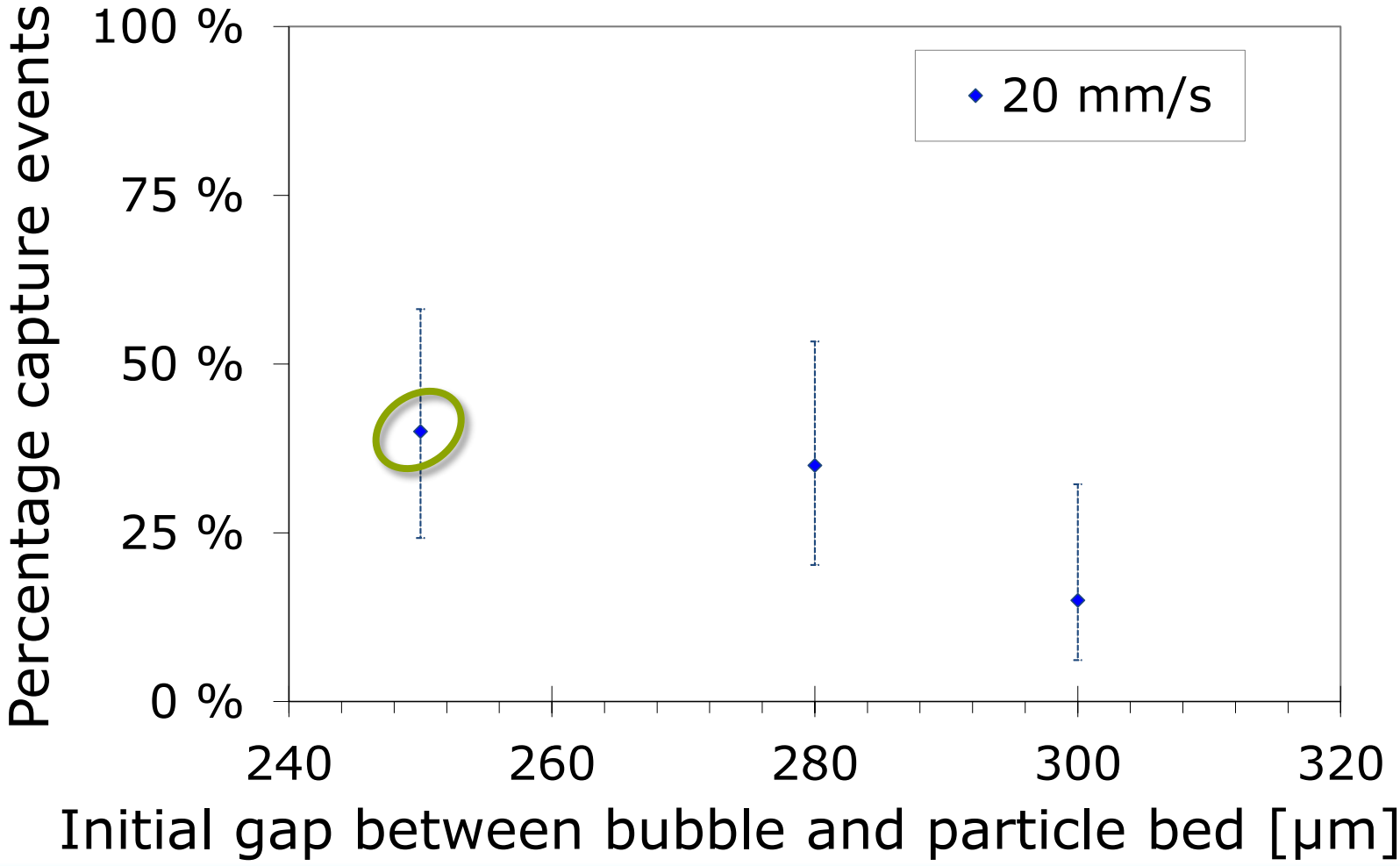


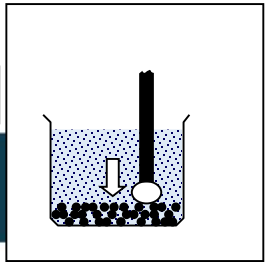
Refer to:

Verrelli, Koh, Bruckard & Schwarz, *Minerals Engineering*, 2012. **36–38**: 219–230.

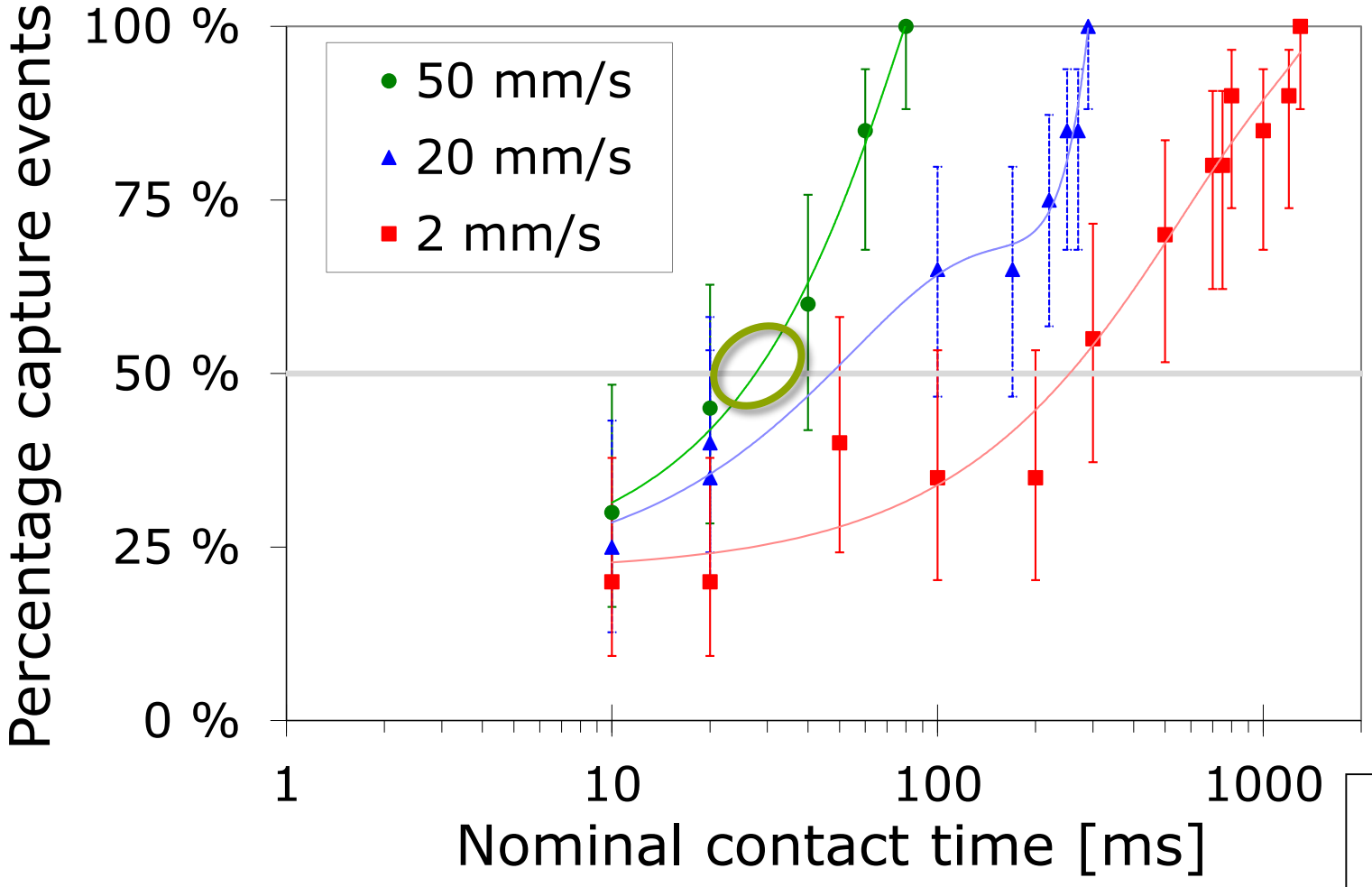


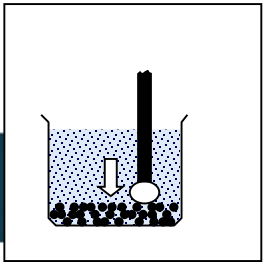
Induction Timer results (sample 1)





Induction Timer results (sample 1)





Induction Timer results (sample 1)

Induction period from IT comparable to MT for

- initial gap ≈ 250 µm
- approach speed ≈ 50 mm/s

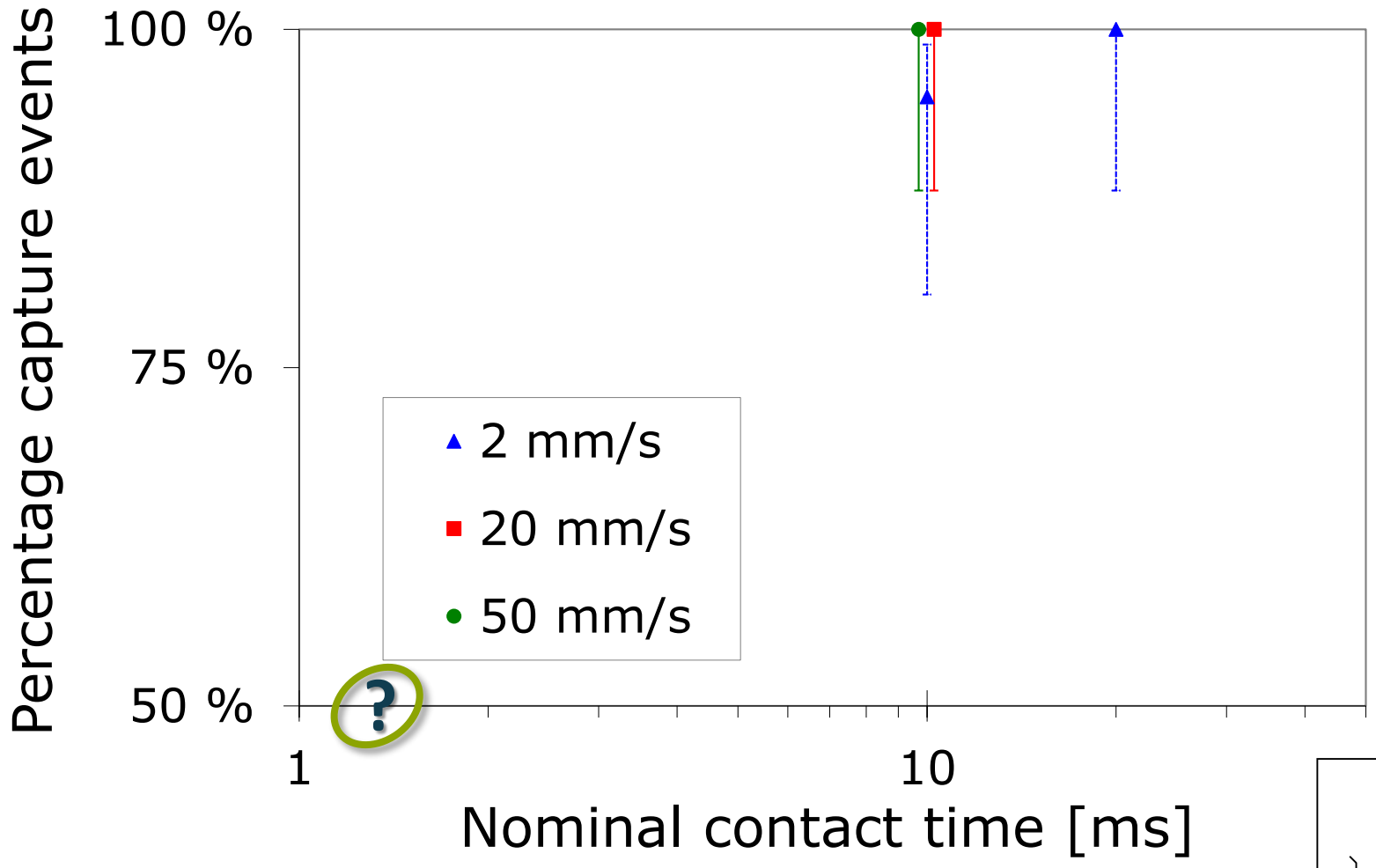
Perpendicular speeds in MT are smaller:

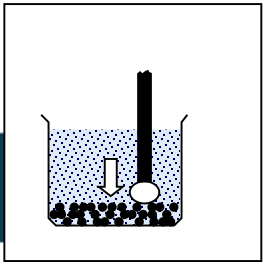
- ~10 mm/s far away,
- < 10 mm/s at 100 µm gap,
- ~1 mm/s at 10 µm gap

Refer to: Verrelli, Koh & Nguyen, *Chemical Engineering Science*, 2011. **66**(23): 5910–5921.

D.I. Verrelli. *Ninth International Conference on Computational Fluid Dynamics in the Minerals and Process Industries*. 2012. Melbourne. http://www.cfd.com.au/cfd_conf12/PDFs/160VER.pdf

Induction Timer results (sample 2)





Conclusions

Each technique to estimate τ has its own pros and cons.

Some are dependent upon experimental parameters (*e.g*. speed of approach).

The presented method may allow a device to be **calibrated**.

- Not needed for *qualitative* comparison ($\tau_1 > \tau_2$).
- Useful for
  - *quantitative* comparison ($\tau_1/\tau_2 = 7.5$)
  - *numerical simulation* ($\tau_1 = 90$ ms, $\tau_2 = 12$ ms).

Acknowledgements

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Statistical uncertainty for IT

Typical handling of statistical uncertainty in *Induction Timer* (IT) results is not rigorous.

The best (most correct) statistical approach to generate the confidence interval is to use **Wilson's 'score interval'**.

Typical experiments use $N = 10$ for each setting.

We have used $N = 20$

- 95% confidence intervals still broad even for $N = 20$