Achieving Ideal Coating & Laminate Properties Through Rheology

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-Rheology Specialist-

Overview

- What is rheology?
- What can rheology tell me about a coating?
- How can rheology help?
- Absolute v. Relative

Where Can Rheology Be Used?

Rheology:

Study of deformation and flow behavior of <u>all</u> materials

viscous ← ***Visco-elastic*** → ***elastic***

Ideally viscous liquids
like water / oils
Newton's Law

viscoelastic liquids
like glues, shampoos

viscoelastic solids
like pastes, gels, rubbers

Ideally elastic (rigid) ***solids***
like steel
Hooke's Law

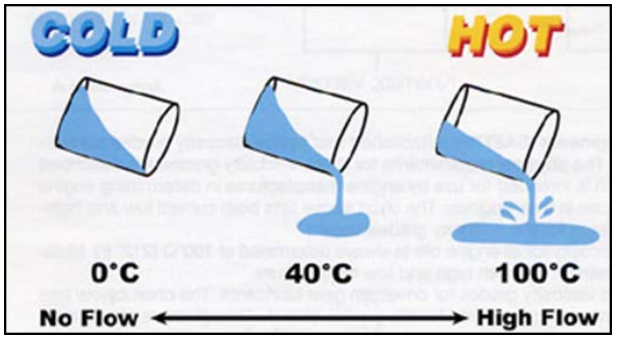
What is Rheology?

- The study of the flow and deformation of all materials.
- **Fluids** are characterized by their flow properties.
  - Apply a force to a fluid, and it will flow.
  - Remove the force and the material will not return to its original shape.
  - Fluids are viscos and lose energy
- **Solids** are characterized by their response to deformation.
  - Apply a force to a solid and it will deform.
  - Remove the force and the material will return to its original shape.
  - Solids are elastic and store energy
- Most materials are **Viscoelastic**, these materials have both fluid like and solid like properties.

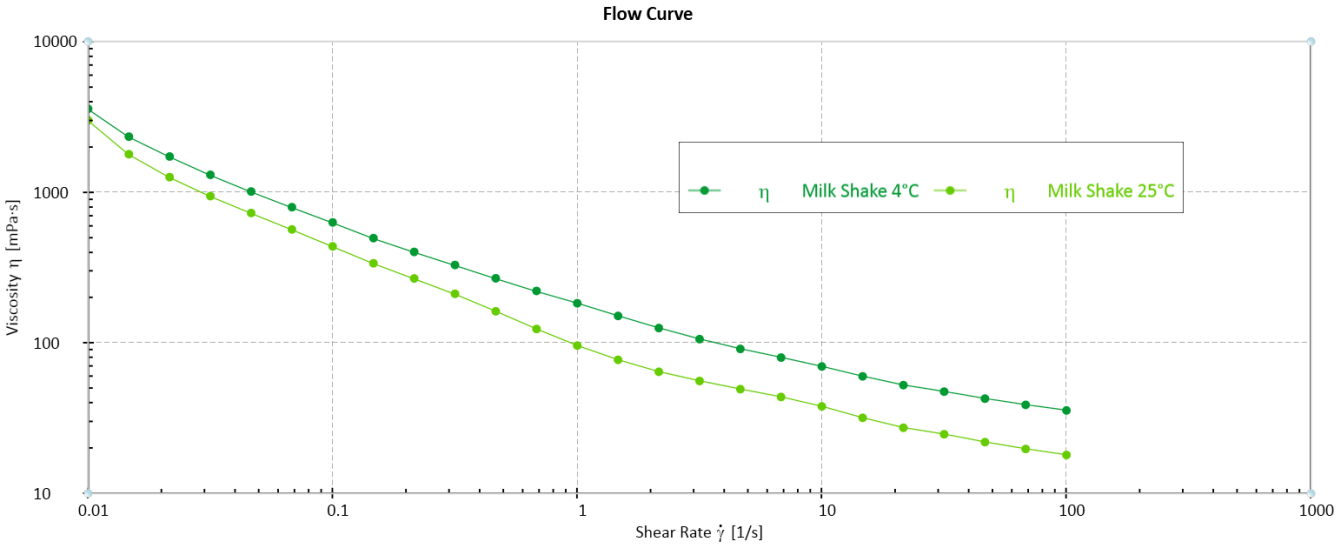
Rheology and Coatings

- Viscosity -> **Flowability**
- Structure Breakdown -> **Yield Point**
- Viscoelastic Balance -> **Separation**
- Thixotropy -> **Breakdown and Recovery**
- Change Over Time -> **Drying**
- Cohesion Strength and Fluidization -> **Powder Coatings**

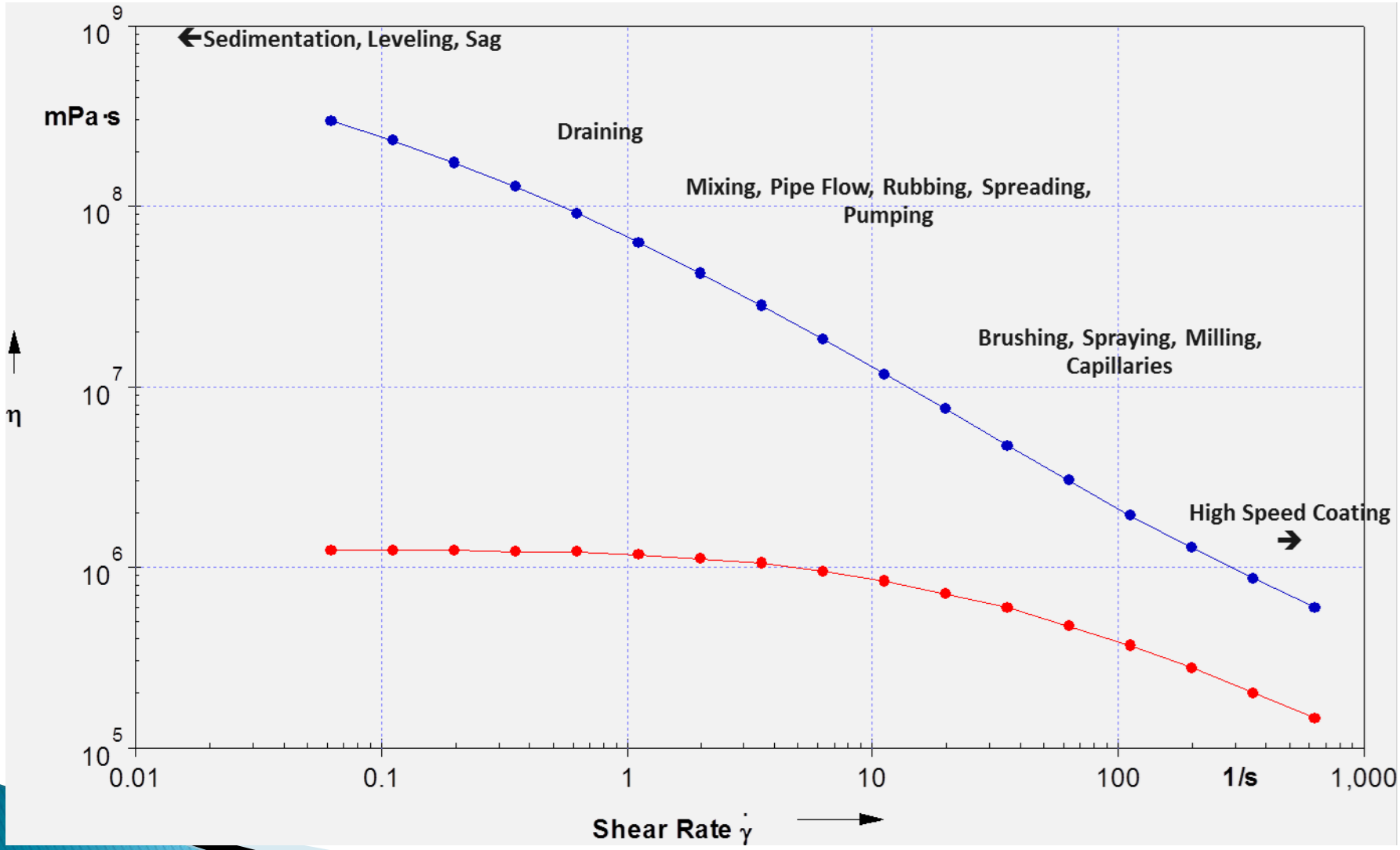
Viscosity



- Viscosity is not a single point.
- Viscosity is dependent on…
  - Shear rate
  - Temperature
  - Pressure
  - More!

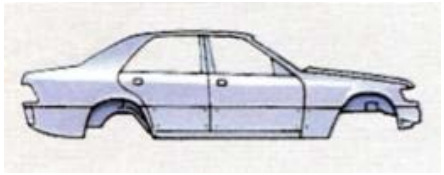


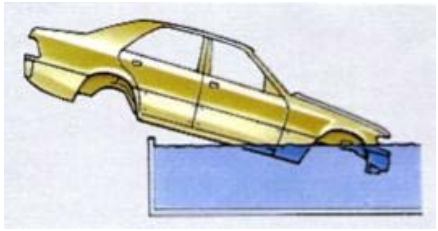
Shear Rates of a Typical Process



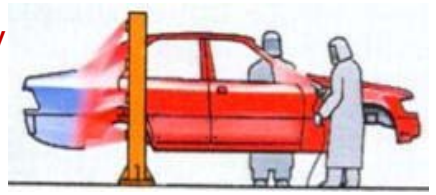
Shear Rates in Automobile Production

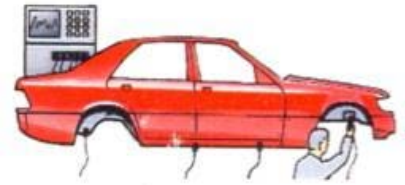
Practical Example:**Car Production, Automotive Coatings, etc.**





1) car body press: drawing greases, oils
2) body shell work: construction adhesives
3) pretreatment: cleaning, degreasing, phosphating, silane chemistry
4) anti-corrosion: dip coatings
5) acoustic damping: **sealants**, foams
6) seam sealing: **plastisols**
7) underbody coating: plastisols
8) + 9) + 10) paint shop: **filler** + **base coats** + **clear coats**
11) Cavity coating: waxes
12) assembly of components: glass adhesives, elastomers, tire rubbers, greases

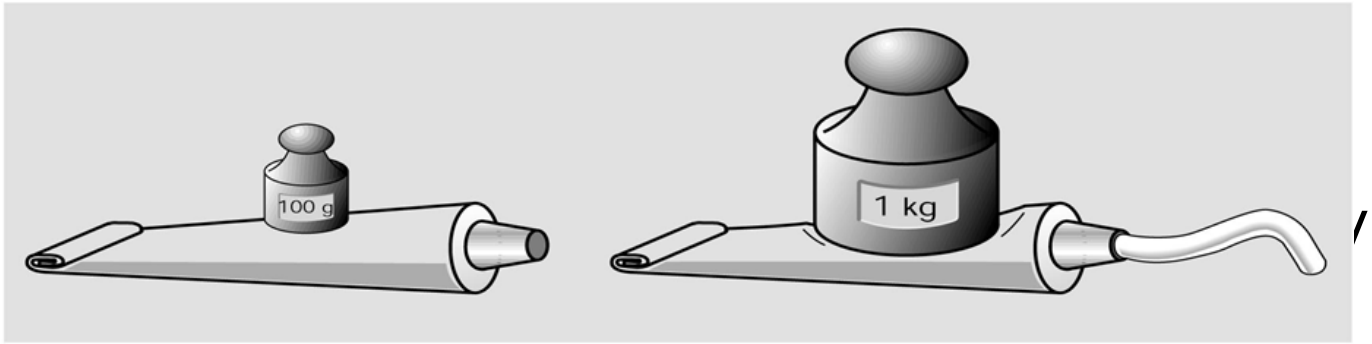




Spraying, Coating takes place at high shear rates of 1000 to 10,000 s^{-1}

Structure Breakdown

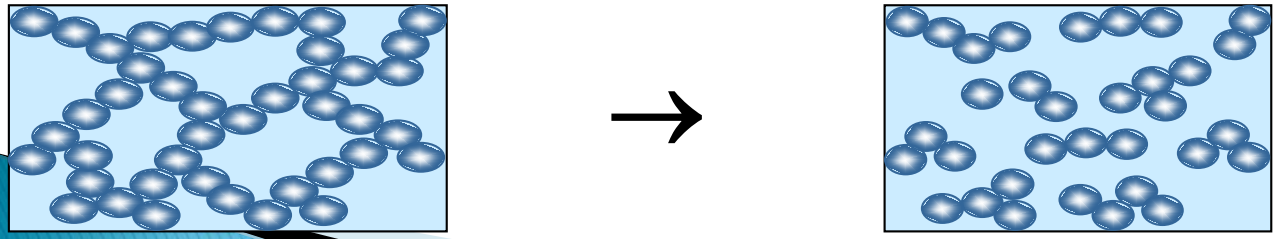
- Determining yield



shear

material

Break of the structure – at – rest.

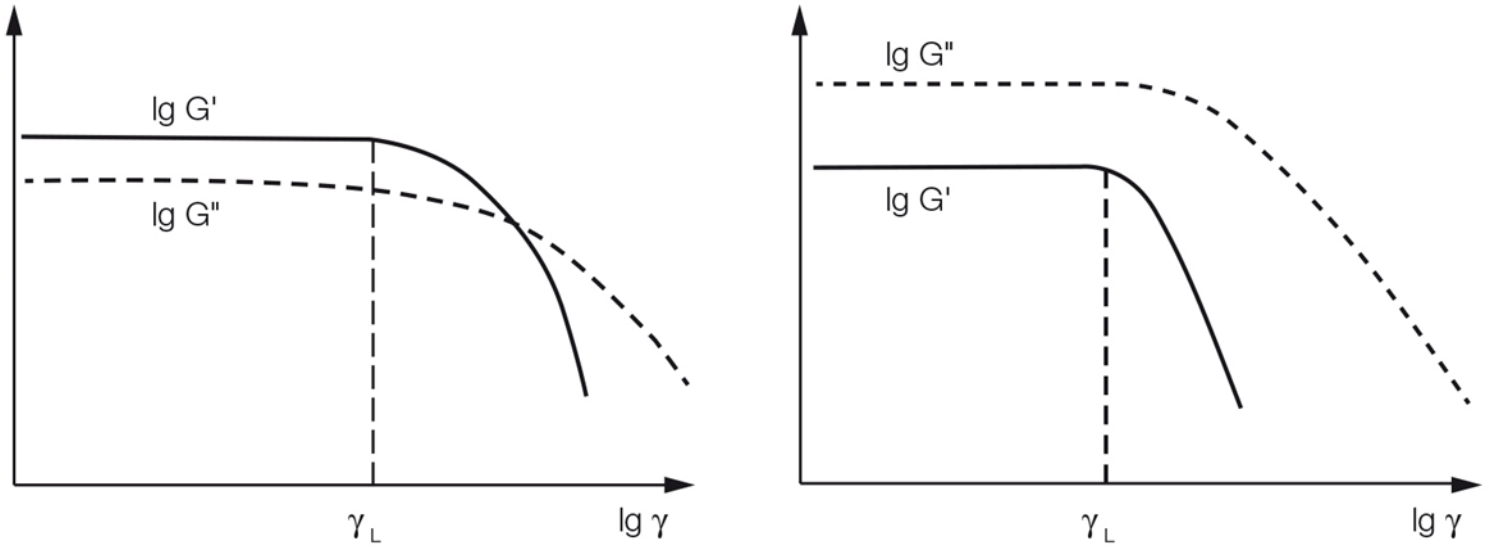


Viscoelastic Balance

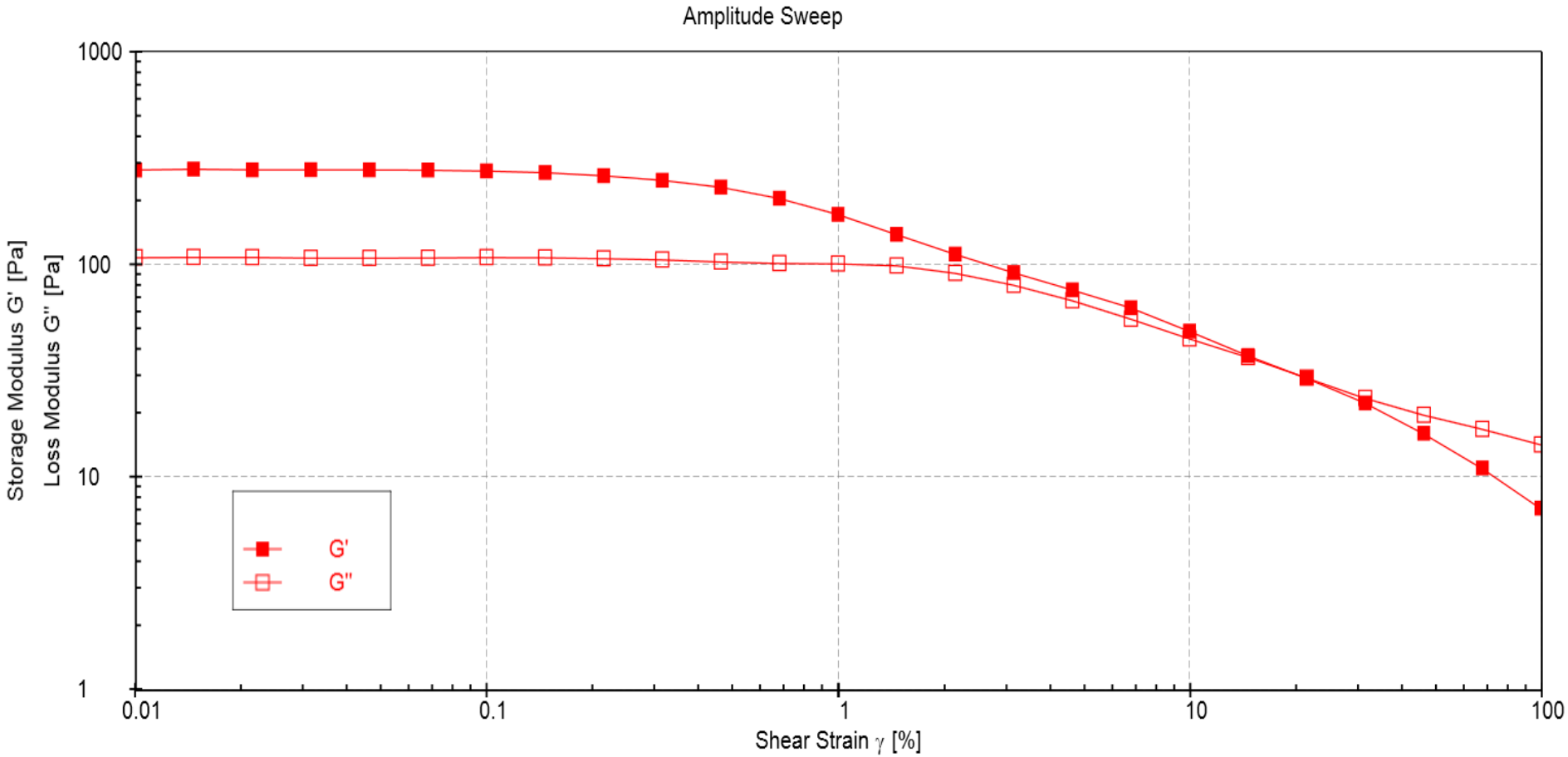
- Will my sample settle out or separate?

Amplitude Sweep

- Oscillatory – “If it does not flow viscosity is not the way to go”
- The oscillations are so small that the inherent structures in a sample are measured without being damaged.



Amplitude Sweep



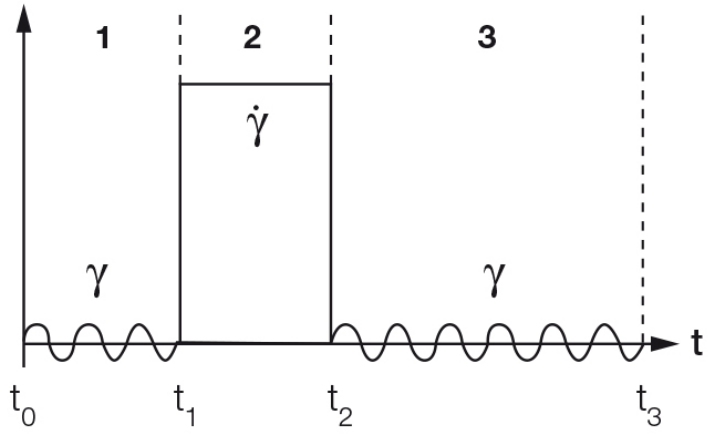
Thixotropy

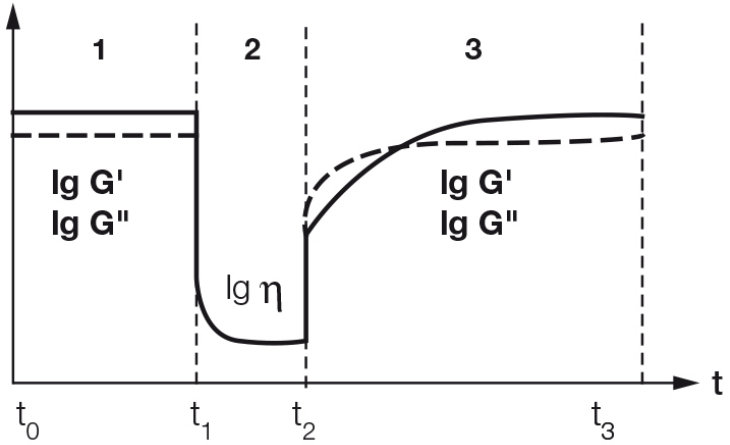
- Breakdown and Recovery
- What type of coating properties do we want?

1 fast structure recovery
high wet – layer thickness, good stability

2 slow structure recovery
small wet – layer thickness, good leveling

Three Interval Thixotropy Test – Oscillation-Rotation-Oscillation





Structure Recovery, Step Test (3ITT),
to determine thixotropic behavior

Preset

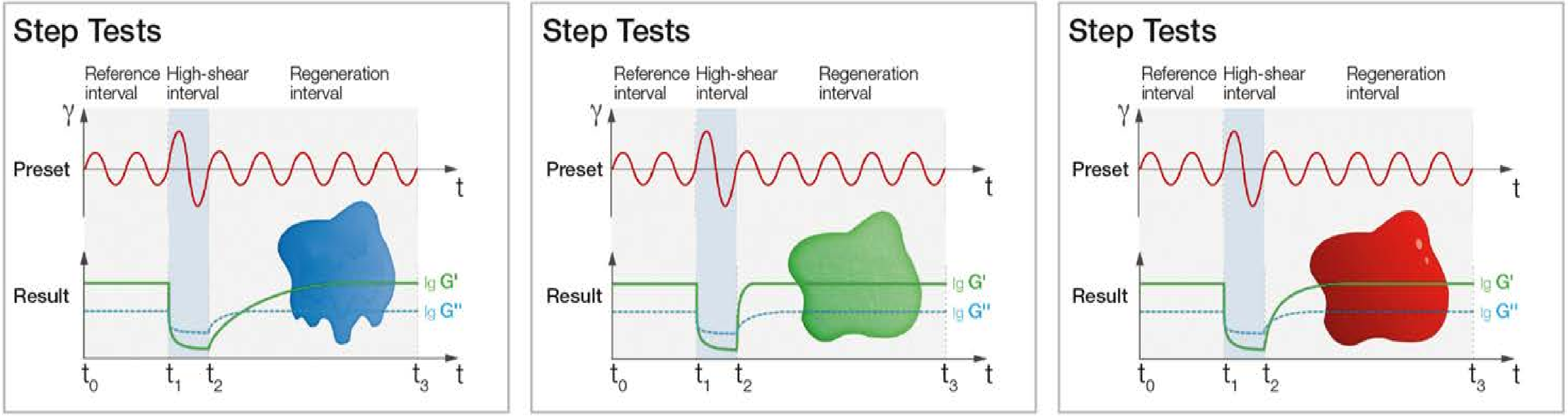
1 Low - shear conditions (strain in the LVE range, oscillation)
2 High - shear conditions (rotation)
3 Low - shear conditions (strain in the LVE-range, oscillation)

Test Result

1 State of rest
2 Structure decomposition
3 Structure regeneration

- in the 2nd interval: liquid
- in the 1st & 3rd interval:
  when G' > G" solid structure (at rest)

Thixotropy


Step Tests
Reference interval
High-shear interval
Regeneration interval
γ
Preset
t
Result
lg G'
lg G''
t_0 t_1 t_2 t_3 t
Step Tests
Reference interval
High-shear interval
Regeneration interval
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Step Tests
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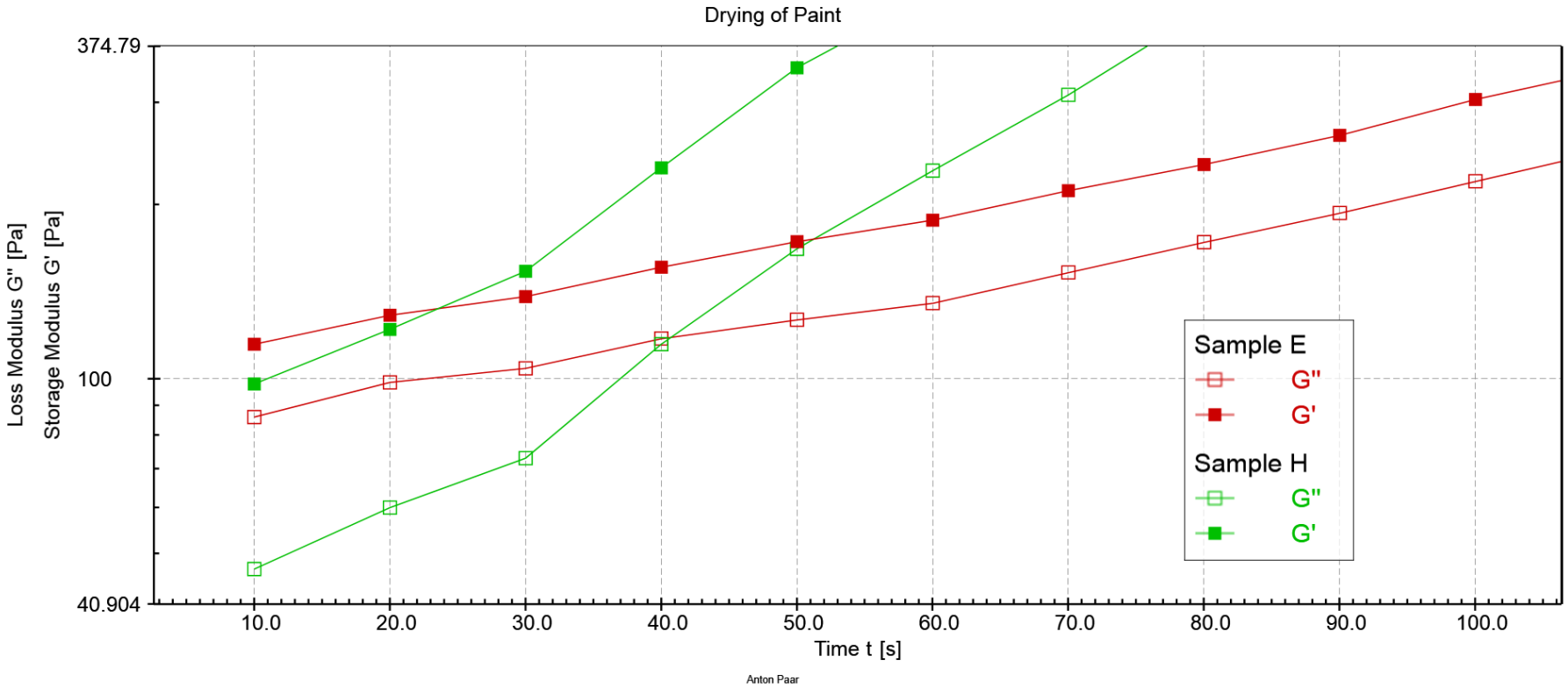
Regeneration interval
γ
Preset
t
Result
lg G'
lg G''
t_0 t_1 t_2 t_3 t

Change Over Time

- Materials that change under conditions other than shear or strain
  - Drying
  - Curing
  - Humidity
  - Temperature

Drying

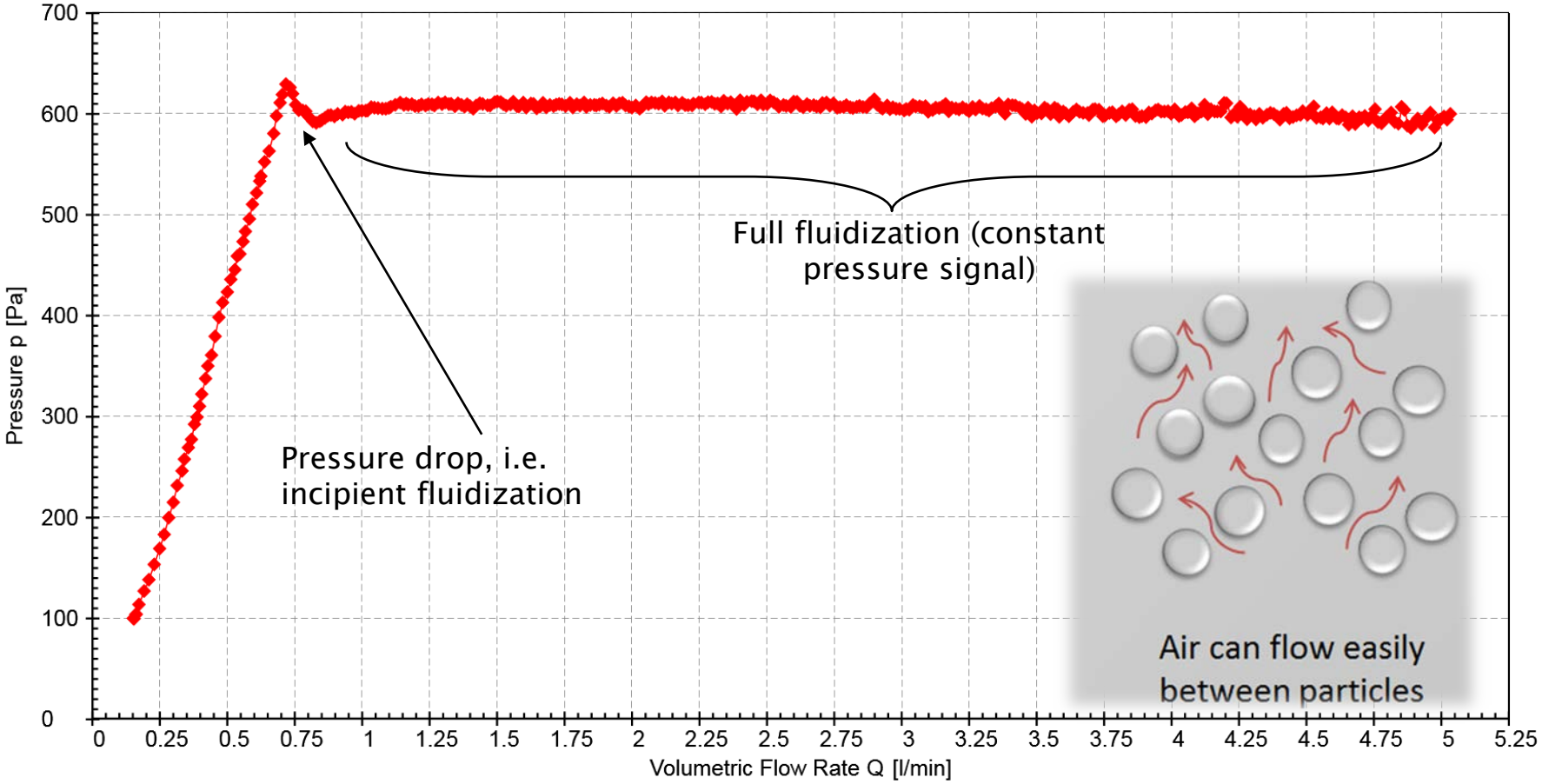


Comparing the drying rates of two paints

Powder Rheology

- Powder flow
- Fluidized powders
- Cohesion strength

Pressure Drop Method



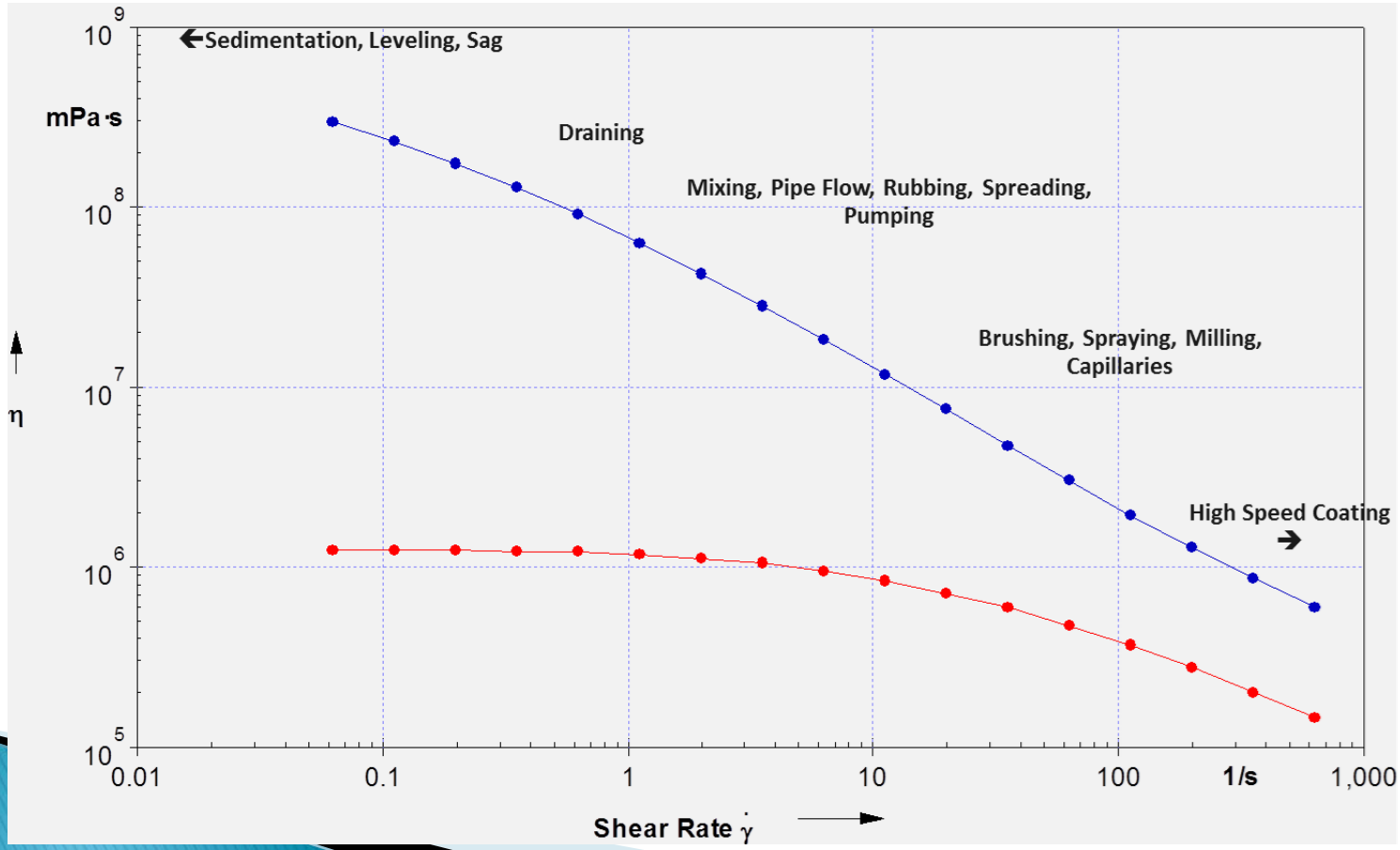
Pressure Drop Method

Pressure Drop Method

- Determination of the volumetric flow that **fully fluidizes** the sample
- Sample preparation: in order to erase the **powder memory**

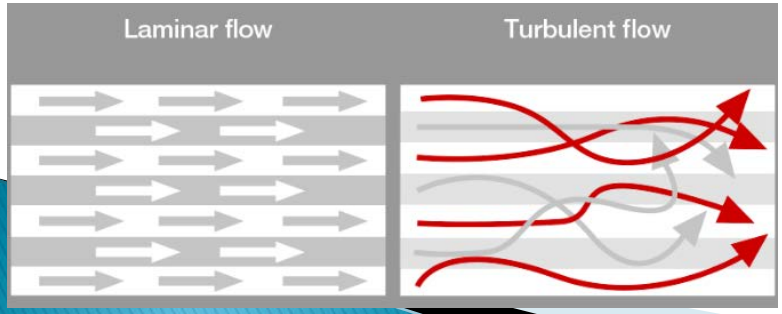
Powder Sprays

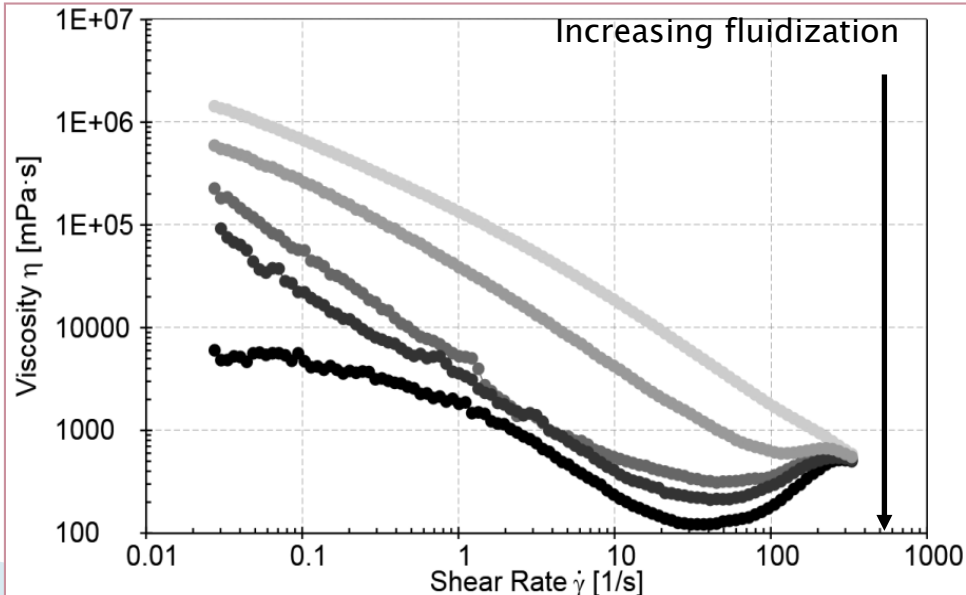
- Flow Curves
  - Typically done on liquids
  - Can be done on fluidized powders (sub or full)



Powder Sprays

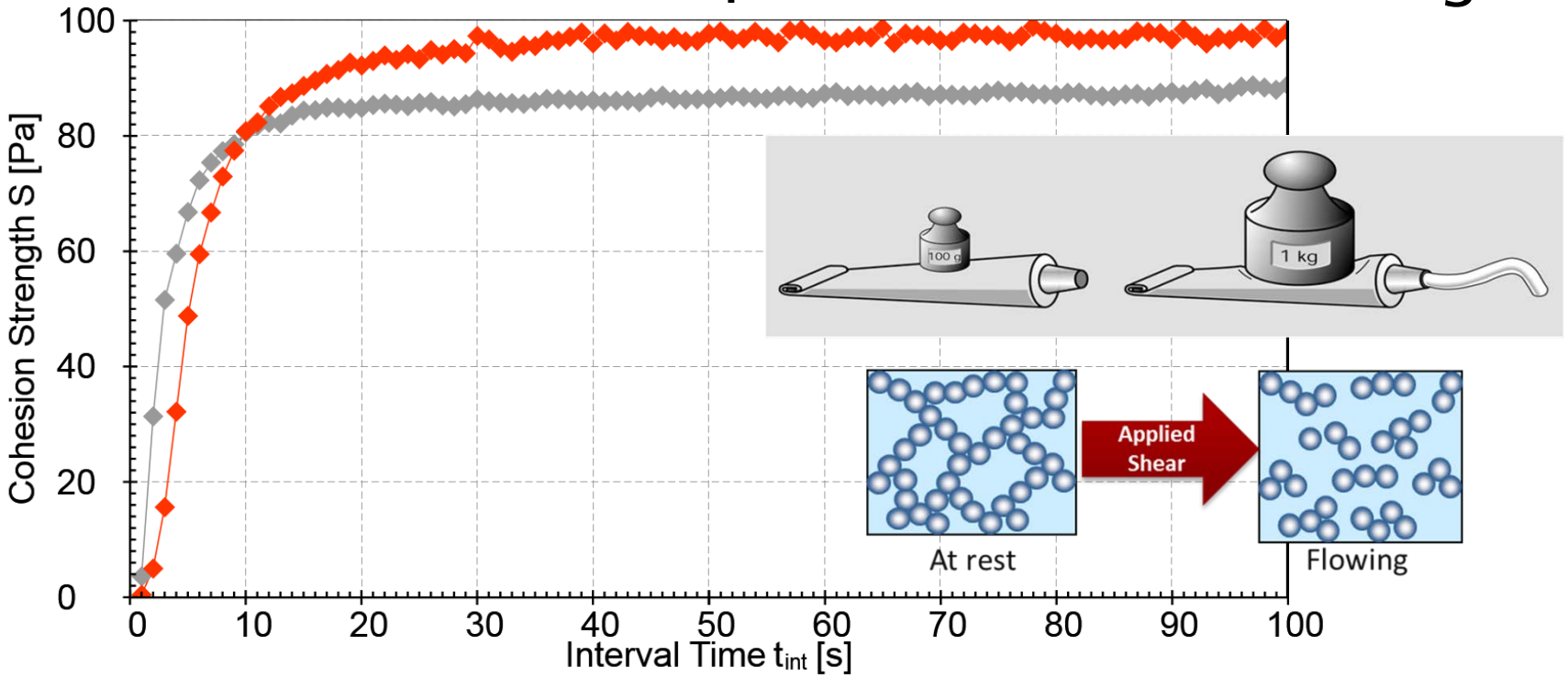
- Viscosity is a function of shear rate and fluidization
  - Non-fluidized, sub-fluidized and fully fluidized
- Useful for…
  - Showing powder flow properties in many states
  - Indicating jamming
  - Laminar v. Turbulent flow
  - Perfecting processes





Cohesion Strength

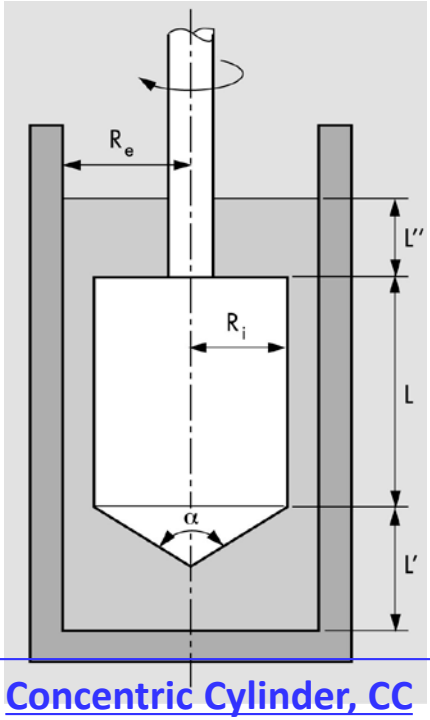
- Cohesion Strength is the internal resistance of the powder to flow
- Predicts whether the powder will flow through



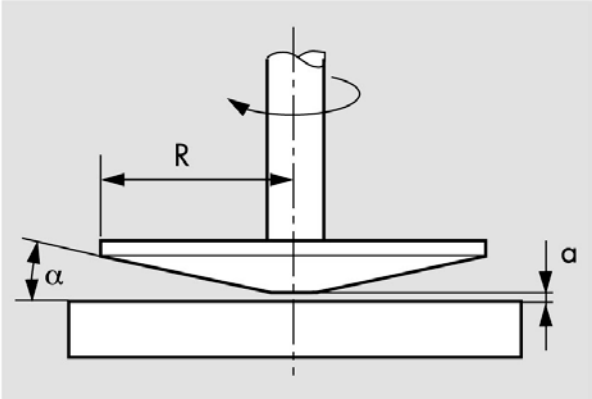
Absolute V. Relative

- Relative measurements can be used as a ranking system made on the same instrument.
- Absolute measurements can be compared to ANY other absolute measurements made any time anywhere.
  - To get an absolute measurement we need a define geometry.

Absolute Measuring Systems

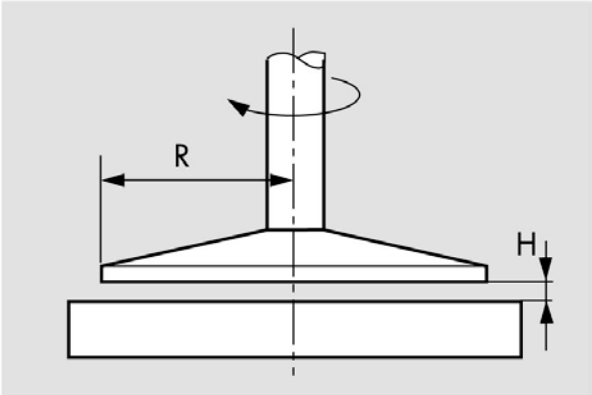


Concentric Cylinder, CC
for low-viscosity liquids, not for pastes (air bubbles)



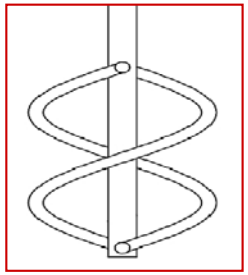
Cone & Plate, CP
for liquids; for dispersions only with a limited particle size

Example: For CP 25-1, with 2R = 25 mm and $\alpha = 1^\circ$, typically a=50 µm; and thus, for max. particle size $d \leq (a/10) = 5$ µm

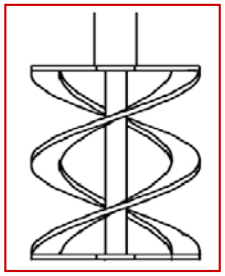


Parallel Plate, PP
useful for gels, pastes, soft solids, polymer melts

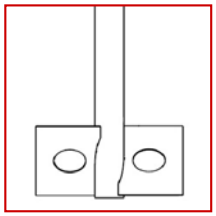
Relative Measuring Systems



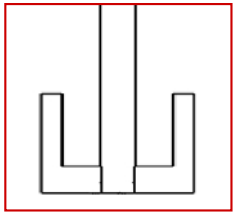
Helix 1



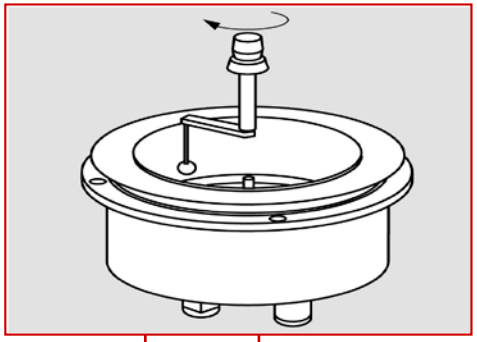
Helix 2



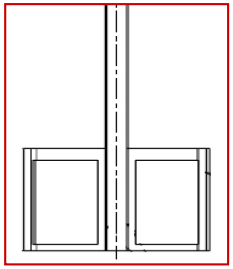
Blade



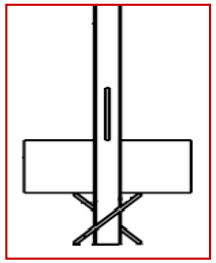
Anchor



Ball



Building

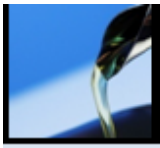
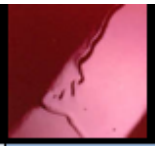


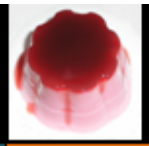
Starch

All these measuring systems are *Relative* measuring systems

- Helix
- Building (according to Schleibinger)
- Starch
- Blade (with eyes)
- Anchor
- Ball – Measuring System
- And many more!

Choosing a Measuring System

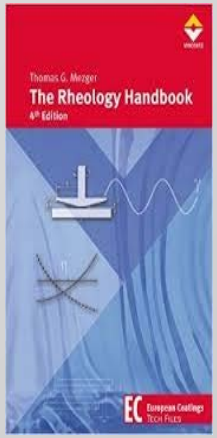



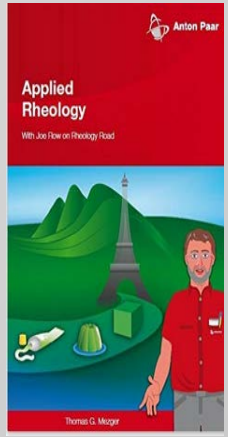

laquers, inks, beverages, fuels, oil, surfactants	coatings, paints, paper coatings, resins, adhesives, polymer solutions, bio-polymers, emulsions, suspensions, dispersions	asphalt, lubricants, sealants, polymer granules, polymer powders, polymer discs, poylmer tablets, glass powders, glas tablets, glass metals	printing inks, slurries, pastes, building materials, food, emulsions, plastisols, ceramics, ERF, MRF, sealants, suspensions, dispersions	hydrogels, bio-polymers	asphalt, sealants, elastomers, rubbers	powder coatings, resins, multi component adhesives, resins, uv curing materials, thermosets, food	polymer films, polymer fibers, polymer bars, solid food, coated films, thermo-sets, thermo-melts, cross-linked resins, asphalt, elastomers, rubber
LOW-VISCOSITY LIQUIDS	VISCOELASTIC LIQUIDS	MELTS	PASTE-LIKE MATERIALS	GEL-LIKE MATERIALS	SOFT SOLIDS	REACTIVE SYSTEMS	SOLIDS
almost 100% liquid	←	←	←	←	←	←	almost 100% solid
Rotation	**Rotation**	Rotation	**Rotation**				**Tension**
Oscillation	**Oscillation**	**Oscillation**	**Oscillation**	**Oscillation**	**Oscillation**	**Oscillation**	**Torsion**
DG, CC	CP & PP (50-25)	CP25-3 & PP25	CP & PP (25-50)	CP & PP (25-50)	PP25	PP15	SRF, UXF
CP & PP (60) Ti	DG or CC	CP35-3 & PP35	Special	DG, CC	PP15		SER

Additional Education

Recommended Reading

- The Rheology Handbook by Thomas Mezger
- Applied Rheology by Thomas Mezger





Anton Paar Rheology Workshops, Seminars, and Webinars

- User Workshops offered several times at year at Anton Paar USA in Ashland, VA and Houston, TX.
- Introduction to Rheology Seminars offered throughout the year at various locations throughout the U.S.
- http://www.anton-paar.com/us-en/events/seminars/

Educational webinars offered throughout the year

- http://www.anton-paar.com/us-en/events/webinars/

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