Predicting Stability of Emulsions and Dispersions by Conductivity

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Correlation between Rheology and Conductivity in Emulsions and Dispersions
Background Information

During storage emulsions and dispersions often change their structure and stability.

Consequently changes can be observed in Application Flow characteristics Stability
Instability described by Stokes Law

Instabilities of emulsions and dispersions are described best by Stokes law.

\[ V = \frac{2 \times r^2 \times g \times D\rho}{9\eta} \]

The velocity \( V \) of the particle to the top (creaming) or to the bottom (sedimentation) depends on the particle size radius \( r \) and the viscosity.

The higher the velocity \( V \) of the particles caused by gravity the more instable is the emulsions or dispersion.
According to Stokes’ law, the driving forces in emulsions and dispersions are the particle size and the viscosity. Any change in these parameters during storage leads to structural changes, which are very often followed by visible instabilities.

\[ V = \frac{2 \cdot r^2 \cdot g \cdot \Delta \rho}{9 \eta} \]

Instability described by Stokes Law
Impact of Structure Changes

Structural changes are caused by

Aggregation

Coalescence
Assessments of Structure Change by Rheology

Structural changes in emulsions and dispersions are analyzed today mainly by rheological assessment.

Most important information in rheological assessment can be obtained by oscillation performance.

Flow characteristics reveal only limited information on structural changes.

Structure changes in low viscous systems are extremely difficult to observe by rheological measurements.
Ion Mobility and Flow Ability in Emulsions

In emulsions and dispersions the reason of changes in conductivity and viscosity fall back on structural changes in the aqueous phase.

Decreasing ion mobility and flow ability due to structure built up

Structural changes in the aqueous phase lead to a change of the fluid mobility measured by rheology and a change of the ion mobility determined by conductivity.
Relation between viscosity and conductivity

Direct mathematical relationship between conductivity and viscosity

\[ \kappa = F \times C \left( v^+ \times z^+ \times \mu^+ + v^- \times z^- \times \mu^- \right) \]

\[ \nu_i = z_i \times e \times E / 6 \times \pi \times r_i \times \eta \]

\[ \mu_i = z_i \times e / 6 \times \pi \times r_i \times \eta \]

- \( F \) = accelerated force acting on an ion
- \( C \) = ion concentration
- \( E \) = electrical field
- \( z \) = charge number
- \( r \) = ion radius
- \( \gamma \) = ion velocity
- \( \mu \) = ion mobility
- \( \eta \) = viscosity
**Measurement Technique**

Two parallel electrode pairs - one pair on top, one pair at the bottom – detect droplet / particle migration

- **Electrode Pair**
  - **R** = Resistance
  - **I** = Current
  - **U** = Voltage

- **Ohm's Law**: \( R = \frac{U}{I} \)

- **κ**: 1/\( R \)

- \( \Delta K \)

- \( K_1 \)

- \( K_2 \)
Correlation between Viscosity and Phase Volume Fraction

\[ Y = A \cdot e^{(B \cdot X)} \]

- Measurement
- \[ Y = A \cdot e^{(B \cdot X)} \]
Correlation between Conductivity and Phase Volume Fraction

\[ Y = A \times e^{(B \times X)} \]
Correlation between conductivity and viscosity

Einstein equation

$$\eta = A \cdot e^{B \cdot \Phi}$$

Conductivity correlation

$$\kappa = A \cdot e^{-B \cdot \Phi}$$

The Einstein and conductivity equations differ only with respect to the sign in front of the exponent and can be correlated.

Conductivity –Viscosity correlation

$$k = A \cdot \eta^{-B}$$
Correlation between Viscosity and Conductivity

![Graph showing the relationship between Viscosity and Conductivity with the equation Y = A * X^B.]
Application of Conductivity in Stokes Law

We can conclude that the viscosity of the dispersion is indirectly proportional to the conductivity.

Consequently conductivity can be applied in Stokes law by exchanging the viscosity term

\[ dV = \frac{2 \cdot r^2 \cdot g \cdot D\rho}{9} \cdot \left( \frac{\Delta k}{A} \right)^{1/B} \]
Determination of Changes in Stability by Conductivity

No structural change

Coalescence

Aggregation
Determination of Sedimentation / Creaming by Conductivity

Sedimentation can be determined by conductivity top to bottom

\[ \kappa_1 \quad \Delta \kappa \quad \kappa_2 \]
Determination of Temperature depending Structure Changes by Oscillation Performance Measurement
Determination of Temperature depending Structure Changes by Conductivity Measurement
Determination of Temperature depending Structure Changes by Conductivity Measurement

Similar to temperature sweeps conducted by oscillation performance structural changes can be determined also by conductivity measurements.
Stability Prediction
and
Structural Analysis
of
Emulsions and Dispersions
By means of two parallel electrode pairs, one pair on top, one pair at the bottom – droplet / particle migration is detected:

**Measurement Technique**

- Electrode Pair

- Ohm's Law: \( R = \frac{U}{I} \)
- \( K = \frac{1}{R} \)

**Diagram:**
- \( R \): Resistance
- \( I \): Current
- \( U \): Voltage
- \( K_1 \), \( K_2 \): Distances
- \( \Delta K \): Change in distance

**Notes:**
- \( R = \) Resistance
- \( I = \) Current
- \( U = \) Voltage
- \( K = \) Conductivity
DualCon Measurement during Creaming Process
DualCon Measurement during Creaming Process

Area of "No Detection"
Creaming Phenomena

Bottom - Electrodes
Top - Electrodes
Creaming Phenomena

[Graph showing voltage over time for different conditions with labeled axes and timelines.]
Flocculation Phenomena

Bottom - Electrodes

Top - Electrodes

Flocculation
Flocculation Phenomena

During the flocculation, an "internal structure" is built up. Within that structure, water is entrapped.

As a result, viscosity increases and the ion-mobility decreases.

Logically, conductivity decreases parallel at top and bottom.
Flocculation Phenomena
Flocculation Phenomena
Coalescence Phenomena

As a result of droplets in the internal phase flowing together, more water becomes available from the external phase. Logically, the conductivity increases.
Coalescence Phenomena
Coalescence Phenomena
DualCon Features

Temperature Range: -20°C / +100°C

Independent
Heating and Cooling Rate

Variable
Measurement Time

Number of Cycles variable (1-15)

Automatic
Thermostat Control

Temperature dependent measurements, adaptable to standardized measurements in YOUR company.
DualCon Features

The DualCon is compatible with the following Thermostats:

- Thermo-Haake DC30/K10
- Julabo F12/MV and F25/MV
DualCon Features

Up to 8 Samples can be examined at the same time under equal conditions!
DualCon Features

Easy to understand Analysis Software
DualCon Features

Each sample has a detailed Sample report, containing all measurement data and describing data.
The comprehensive „EASY STAB“ database is available to assist you in the interpretation of obtained results, containing lots of hints and information.

The database is updated frequently and works with any internet browser. Updates can be downloaded free of charge!

DualCon Features

Choose your result.

Get detailed Information

Hyperlinks bring up a complete encyclopedia
Conductivity reacts just as sensitively as viscosity to changes in emulsion structure. Consequently conductivity can be applied in Stokes law by exchanging the viscosity term:

$$\frac{dV}{d\tau} = \frac{2 \cdot r^2 \cdot g \cdot \rho \cdot D \cdot \rho}{9} \cdot \left(\frac{d\kappa}{A^B}\right)^{1/B}$$

Consequently, conductivity measurement offers a fairly uncomplicated method of determining the stability of emulsions and dispersions over a short period of time.