RHEOLOGY AND SOLVING EMULSION PROCESSING PROBLEMS

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IMPORTANCE OF EMULSIONS

• Allow incorporation of many water and oil soluble ingredients
• Many applications for cosmetic products
• Inexpensive to make
MOST IMPORTANT REASON:

Our customers love our emulsions!
Why?
They are not only safe and effective, they look nice and feel great! (Thanks to their rheological properties!)
Dr. Albert Kligman
(Cosmeceutical)
POTENTIAL PROBLEMS

• Emulsions are unstable by nature
• The Second Law of Thermodynamics
• Difficult to predict and assure stability
• Must be careful in formulating the product
• Must be careful in processing the product
HOW TO ASSURE QUALITY?

• Good Formulation:
  Right amount of right surfactants, stabilizers …

• Correct Manufacturing Procedure:
  Correct equipment, method …
TWO IMPORTANT VARIABLES

- Composition Variable: cV
- Process Variable: pV
- Both affect Rheology and Stability
THE NATURE OF pV

• Difficult to Anticipate
• Tricky to Control (Surprise!)
• Can Be Your Enemy or Friend
MY STORY

Beauty Counselors, Detroit, 1959
My Boss: Maison G. deNavarre
( SCC Founding Father)
MY RHEOLOGY LESSONS

• Brookfield Viscometer
• Rheology and Process Problems
• Art of Emulsion Manufacturing
• Betting on Newtonian Shampoo
• What You Put in the Product (cV)
• How You Put Them Together (pV)
FINDING THE RIGHT BALANCE

• “More” is not always better
• Sometimes, “Less Is More”
Less is More

- Y (OUTPUT)
- X (INPUT)

Points:
- A
- B
- C
- D
- E

Note: "Zp" and "(DREAM) (REALITY)" labels indicate different regions on the graph.
IMPORTANCE OF Zp

- Zp is the optimum point
- Finding Zp is not always easy
- But it will help solve many problems
- And reducing cost
HOW TO FIND Zp?

- Understand the basic principles
- Experiments
- Patience
Since rheological properties can affect the product’s stability, efficacy, skin feel and appearance, control of composition variables (cV) is very important in formulation work.
EXAMPLE OF LESS IS MORE

• Sometimes, we can actually improve the stability of an emulsion by reducing the amount of certain surfactant in the formula.
Controlling process variables, pVs, is also very important since process equipment can affect rheological properties and degrade the quality of emulsion products.
THE POWER OF pV

• pVs can affect rheology and drive us crazy
• But pVs can be a powerful tool
• We need more research on pVs.
EXAMPLE: LOW-ENERGY EMULSIFICATION (LEE)

• A simple way to reduce energy use in making emulsions
• No need to change formula
• No need to buy new equipment (PPE)
• Reduce processing time
• Save money while reducing carbon footprint
LOW-ENERGY EMULSIFICATION (LEE)

CONVENTIONAL HOT PROCESS

A

h \Rightarrow INT. PHASE

H \Rightarrow EXT. PHASE

h \Rightarrow EMULSION

h + H \Rightarrow EMULSION

B

LEE

h \Rightarrow INT. PHASE

H \Rightarrow \alpha PHASE

\beta PHASE

h + \beta H \Rightarrow CONCENTRATE

h + H \Rightarrow EMULSION
SOLVING A RHEOLOGICAL PROBLEM WITH LEE

Case Study:

• My first crisis at Max Factor
• A shear-sensitive, thixotropic moisturizer
• No problem making 200-gal batch
• Low viscosity when making 500-gal batch
• Reason: shear-thinning effect of the mixer
• Fixed speed mixer, could not reduce speed
SOLUTION: MODIFIED LEE

- Even if we could reduce mixer speed, cooling time would increase and mixing time would be longer
- Tried a modified LEE procedure to promote faster cooling. It reduced cooling time and shear-thinning effect. The product passed QC.
ANOTHER EXAMPLE USING LEE TO SOLVE RHEOLOGICAL PROBLEM

Case Study:

• Product: Spray-type Sunscreen
• Problem: Scale-up
• Lab Batch, Pilot Batch: No Problem
• 2000-Gallon Production Batch: High Viscosity
• Difficult to Spray, Large Droplets, Unstable!
INVESTIGATION OF THE CAUSE

• Why does batch size matter?
• Slow cooling for large batch
• PIT (phase inversion temperature) effect?
• Very low surface tension at PIT, producing very fine, low-viscosity emulsion
• Slow cooling promoted coalescence of droplets to produce high-viscosity emulsion?
QUESTION?

How fast should it cool

ANSWER:

Find out by experiments!
EFFECT OF REDUCED COOLING RATES ON EMULSION QUALITY

Temperature (°C) vs. Time (Minutes)

- R-1 = 2.5 °C/min
- R-2 = 1.9 °C/min
- R-3 = 1.0 °C/min
DISCOVERING THE Z-POINT

Critical Cooling Rate: $\sim 1.6 \, ^\circ\text{C/min}$

Safe Cooling Rate: Above $2^\circ\text{C/min}$
SOLUTIONS

• LEE
• Heat Exchanger
AIR BUBBLES CONTROL

Many cosmetics emulsions are shear-thinning type and can trap air bubbles during mixing or transferring. If the product has yield value, the trapped air may not escape, causing an uneven surface appearance.
\[(W_e)_p = 10(R_e)_p^{0.74}\]

Weber Number

\[(W_e)_p = \frac{D_p V_e \rho}{\gamma}\]

Reynolds Number

\[(R_e)_p = \frac{D_p V_e \rho}{\mu}\]
Z-POINT FOR PREVENTING AIR BUBBLE ENTRAINMENT

We = 10 (Re)\(^{0.74}\)

We = Weber Number = \(DV^2\rho / \gamma\)
Re = Reynolds Number = \(DV\rho / \eta\)

CONCLUSIONS

• Emulsion products are very important.
• They can be difficult to formulate and manufacture.
• Understanding of rheology and process variables (pV) can be very useful in solving formulation and manufacturing problems.
• It will help us finding Z-Points and reducing carbon footprint in manufacturing!
REFERENCES


