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Numerical analysis of non-Newtonian fluid in inclined cuvette for easy-to-implement viscosity measurement

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Background

It is difficult to quantitatively assess the viscosity and fluidity in hand creams and so on. Then, experimental studies are in progress.

The relationship between the flow and viscous properties of non-Newtonian fluids needs to be investigated in detail.

Measurement of non-Newtonian fluids requires special equipment, a lot of time and efforts.

Object This study suggests an easy-to-implement method for viscosity measurement by aiding the numerical analysis.

Test fluid

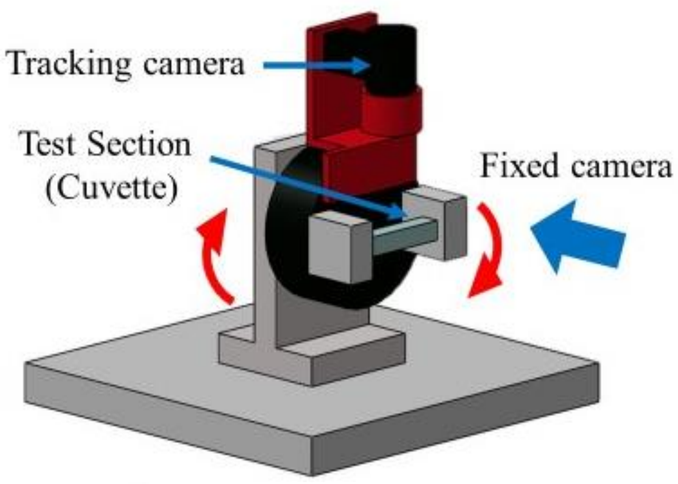
The test fluids were **O/W emulsions** of two different viscosities.

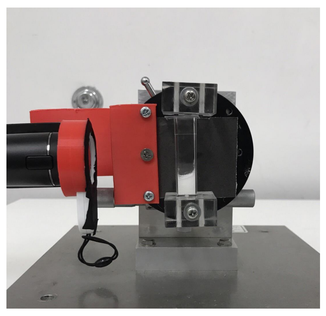
		High viscosity 829Pa・s	Low viscosity 86Pa・s
Oil phase	Amani-oil [mL]	9.83	7.60
	Oleic acid [mL]	4.92	3.80
	Stearic acid [g]	0.492	0.38
	Palmitic acid [g]	0.246	0.2
Water phase	Water [mL]	24.6	28.5
	Ethanol [mL]	9.83	9.5
	Sodium benzoate [%]	0.15	0.15

Inorganic chloride concentrations were determined by checking stability.

Method

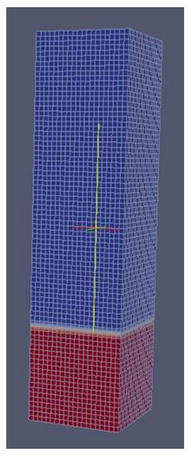
①Experimental device





- Rotated the cuvette **90 degrees in 3 seconds**.
- After that, kept the **horizontal position in 2seconds**.
- Observed flow by 2 cameras.

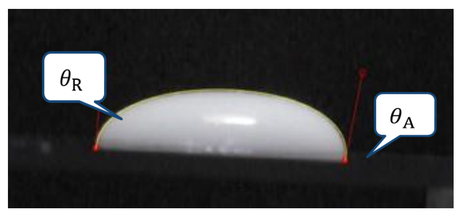
②Analytical system

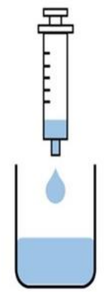


Analysis with OpenFOAM
- Scope of analysis : 10×40×10mm
- Mesh : 20×80×20mm
- Solver : Two-phase flow interDyMFoam
- Free surface : VOF method

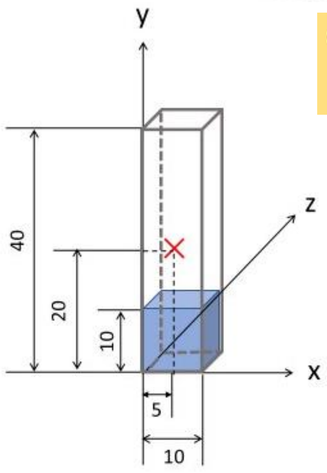
③Measurement of surface tension and contact angle

Contact angle and surface tension were measured by the sliding method and drop method.

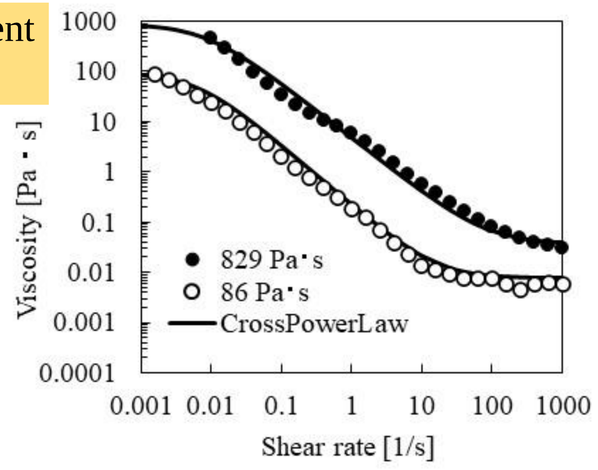




④Viscosity measurement with a rheometer

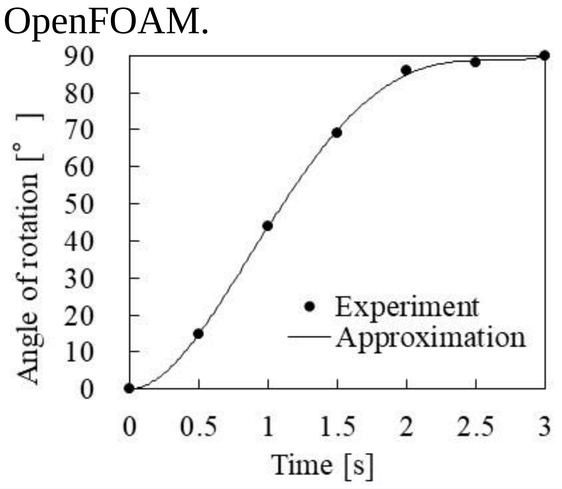


cuvette



⑤Angle of rotation

Approximate the measured rotation angle and assign it to OpenFOAM.



Result

⑥Emulsion stability tests

Condition after 2weeks

0wt%

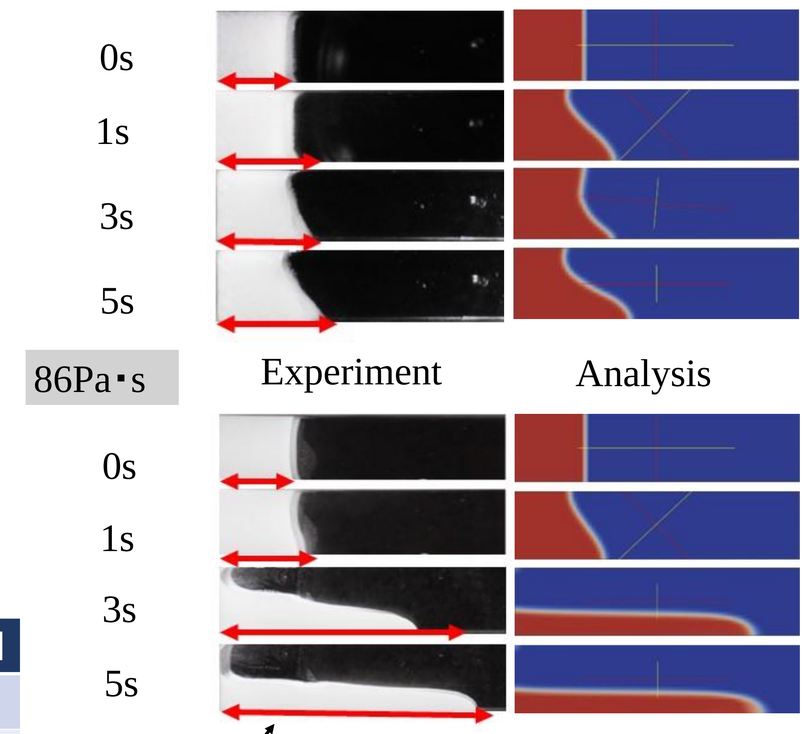
0.15wt%

Addition of 0.15wt% sodium benzoate improved stability.

⑦Surface tension and contact angle measurement results

η [Pa・s]	θ_A [°]	θ_R [°]	σ [mN/m]
829	63	55	30
86	100	87	39

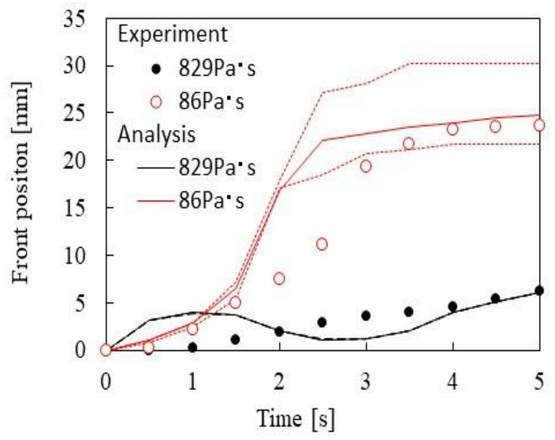
⑧Comparison of free surface geometries



Front position of analysis

Deformation of the free surface was in good agreement.

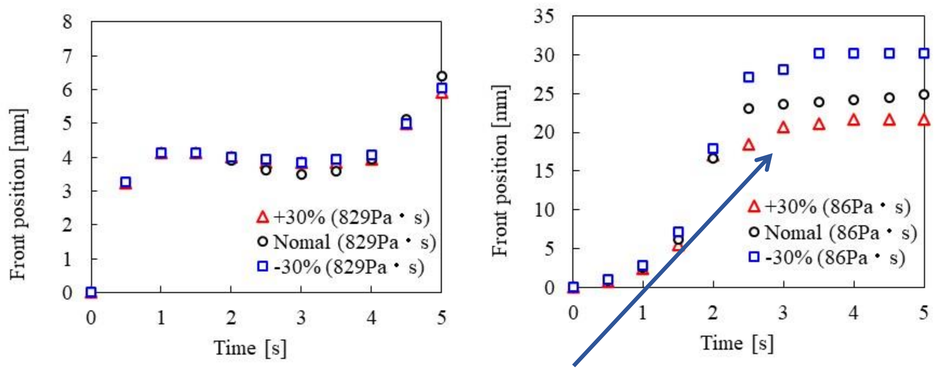
⑨Comparison of front position



The flow after rotating (> 3s) cuvette can be simulated by substituting viscosity, surface tension and contact angle.

⑩Sensitivity analysis of surface tension

Analysis with surface tension values of ±30%

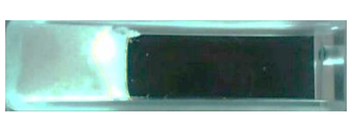


Sensitivity for surface tension was found on the front position after rotating on 86 Pa・s.

⑪ Sensitivity of contact angle

Sensitivity for contact angle was found on the top view of free surface on the bottom.

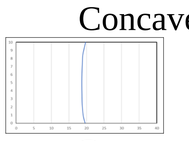
1.8 s, 829 Pa・s
$\theta_A = 63^o$



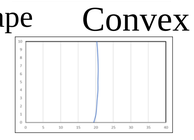
1.8 s, 86 Pa・s
$\theta_A = 100^o$

Detect the shape

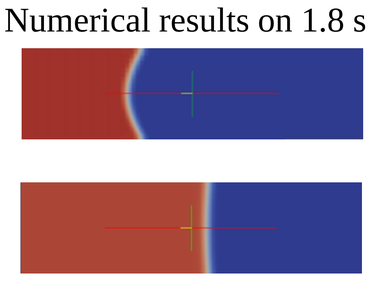
Concave



Convex



Numerical results on 1.8 s



Conclusion

We suggested the flow in rotating cuvette for easy-to-implement viscosity measurement.
The sensitivity of surface tension and contact angle was detected.