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Viscosity evaluation of ZrO_2 dispersed molten stainless

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Introduction

The flow behavior of high-temperature suspensions is industrially crucial, such as in the steelmaking process[1)]

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However, due to the experimental challenges, there is limited understanding of high-temperature suspensions.

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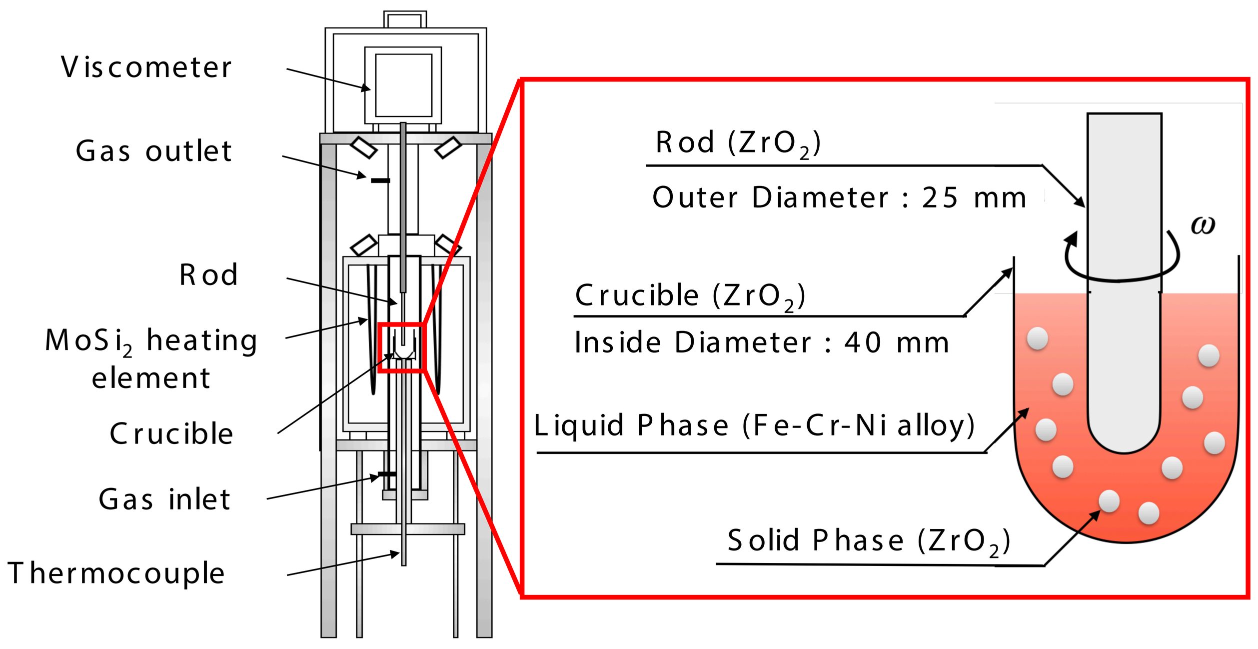
To address this, samples with a minimal density difference between the solid and liquid phases were selected, aiming to study the detail of the flow behavior of high-temperature suspensions.

Experimental



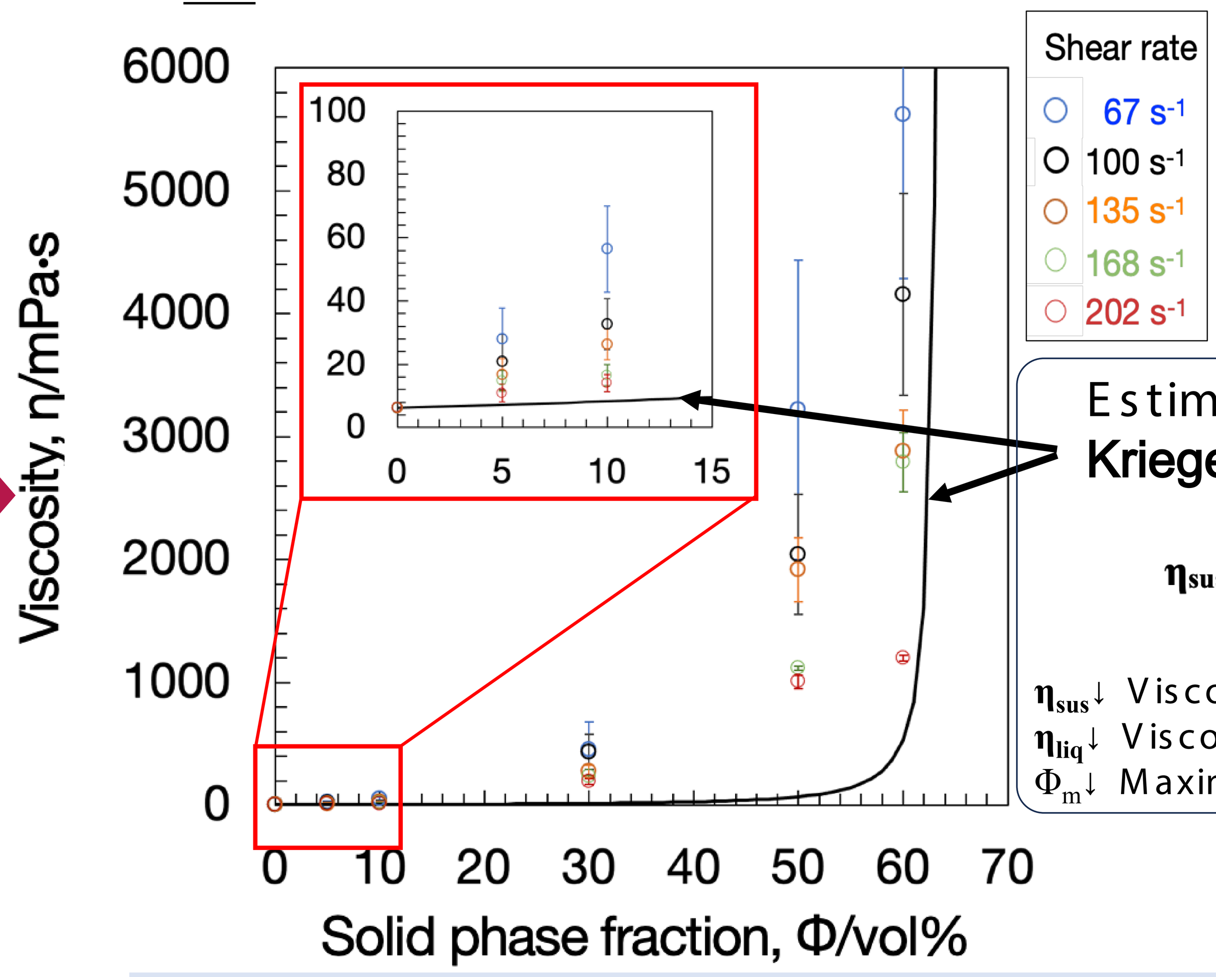
Viscosity measuring device with concentric cylinder method

Measuring conditions

Sample	ZrO_2 beads dispersed in molten Fe-Cr-Ni alloy
Solid phase (ZrO_2 beads)	5 vol% to 60 vol%
Shear Rates	67 s^{-1} to 202 s^{-1}
Temperature	1773 K
Gas Flow	Ar-5%H_2 (2 L/min)

Results and Discussions

Viscosity dependence on the solid phase in ZrO_2 dispersed molten Fe-Cr-Ni alloy



Estimated viscosity from **Krieger-Dougherty Equation**[2)]

$$\eta_{sus} = \eta_{liq}\left(1-\frac{\Phi}{\Phi_m}\right)^{-2.5\Phi_m}$$

η_{sus}: Viscosity of suspension

η_{liq}: Viscosity of liquid phase(= 6.3 mPa•s[3)])

Φ_m: Maximum packing fraction(= 0.64[4)])

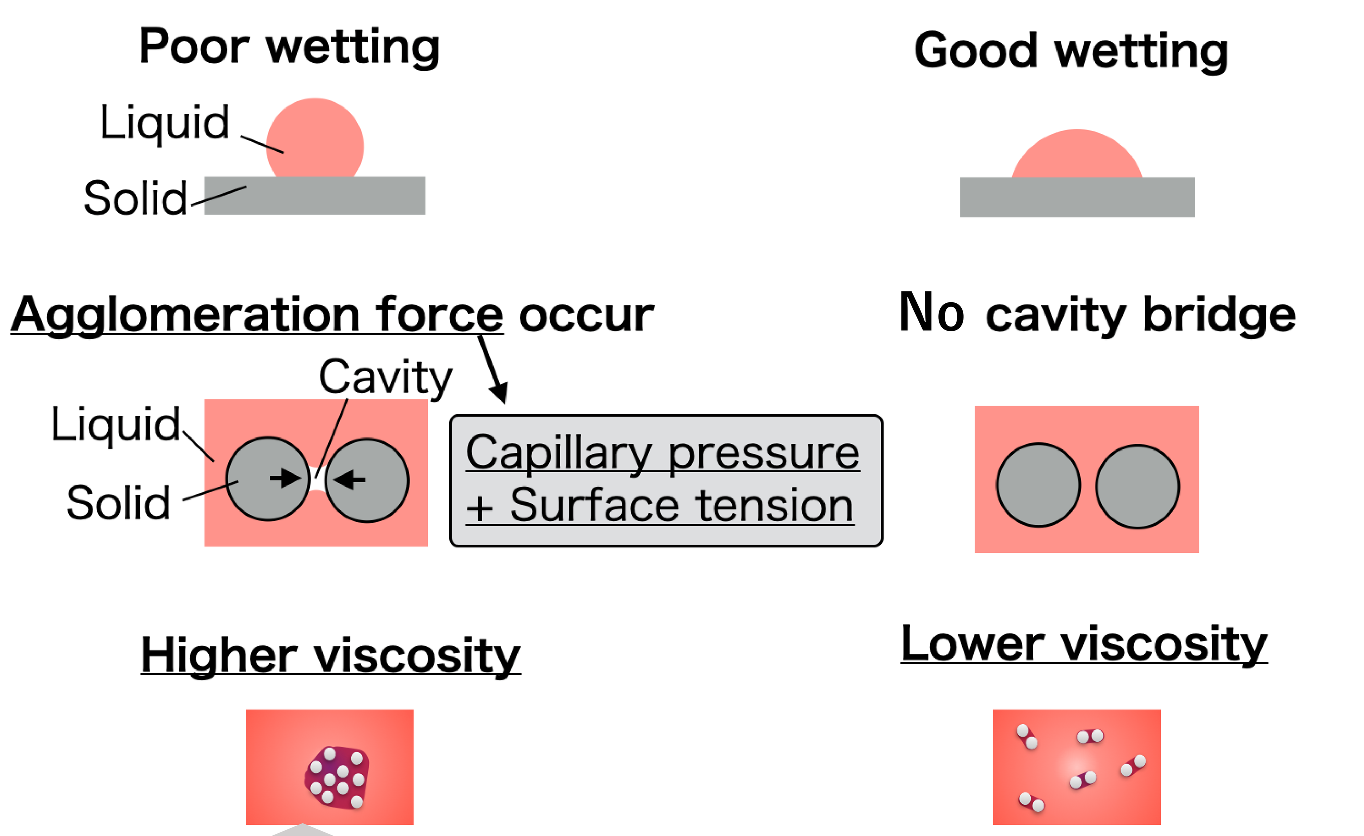
Viscosity increased with an increase in solid phase fraction

Measured viscosity > Estimated viscosity by KD equation

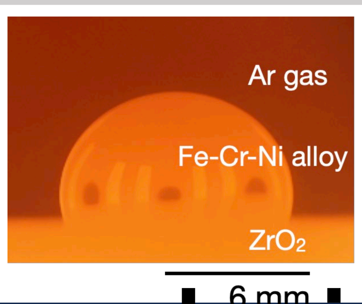
The KD equation neglects interactions between solid phases

The significant deviation from estimations is due to the lack of consideration for solid-liquid interfacial properties.

Dependence of suspension viscosity on solid-liquid interfacial property[5,6)]



The volume of the immobilized fluid increases due to the agglomeration, leading to an increase in viscosity



The contact angle between molten alloy and ZrO_2 was 108.8° (Poor wetting) at 1773 K in an Ar atmosphere.

Estimating viscosity with agglomeration force

The agglomeration force F between the solid phases is[7)]

$$F = 2\pi\frac{R_1R_2}{R_1+R_2}2\sigma_{LG}\cos\theta = 870\ \mu N$$

R_1, R_2: Radius of dispersed solid (= 250 μm)

σ_{LG} : Surface tension of liquid phase (= 1.721 N/m[4)])

θ : Contact angle 108.8°

The agglomeration force F between the solid phases is much larger than Van der Waals force (10^{-5} μN[5)]) and buoyancy force (0.51 μN[5)]).

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The apparent solid fraction Φ_{eff} during cluster formation is[6)]

$$\Phi_{eff} \fallingdotseq \Phi\left(1+\left(\frac{F/R^2}{\dot{\gamma}\,\eta_{sus}}\right)^{1/3}\right)^{3-f}$$

$\dot{\gamma}$: Shear rate

η_{sus} : Viscosity of suspension

f : Fractal dimension (1 < f < 3)

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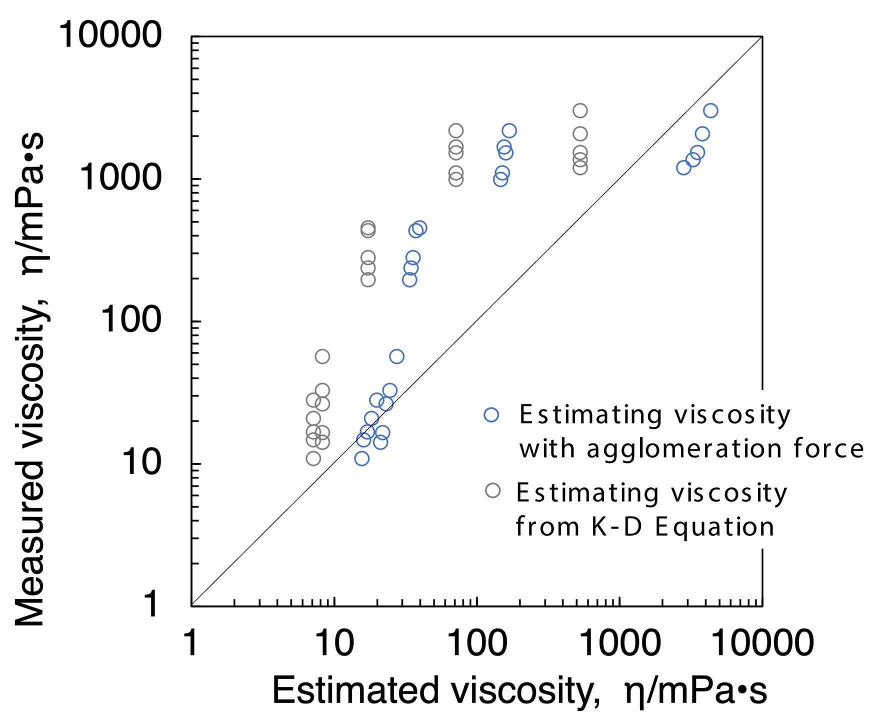
Estimating viscosity



Considering the agglomeration force leads to a better

Conclusion

- The measured viscosity increased with an increase in solid phase fraction.
- The findings indicated that the measured viscosity was higher than predicted by the KD equation.
- It is hypothesized that these cohesive forces lead to agglomeration, which contribute to the increased viscosity.
- The potential influence of interfacial properties between solid and liquid phases on the viscosity of suspensions has been suggested. Further research is required to consider maximum packing fraction(Φ_m) to get better estimation of the suspension viscosity.

Reference

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