T3.6 - Modelling

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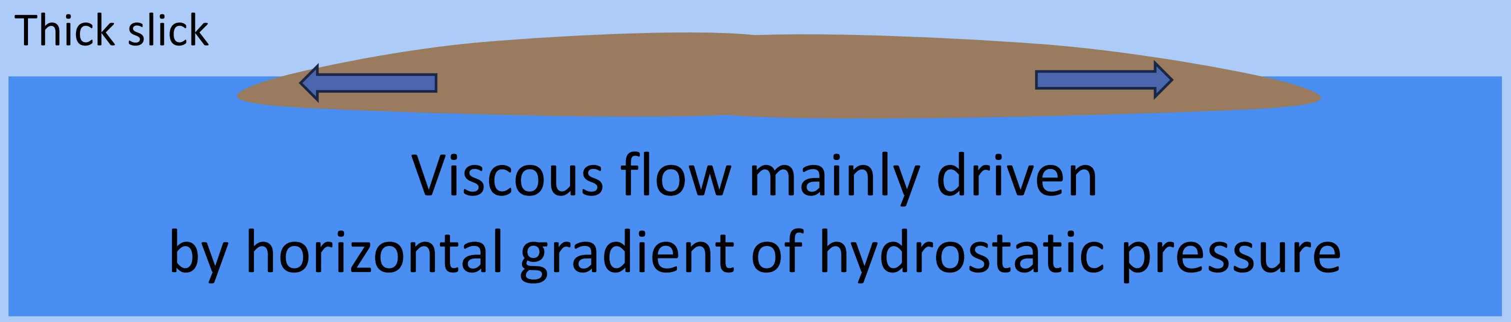
Could **viscoelasticity** explain the unexpected behaviours of the VLSFO slicks ?

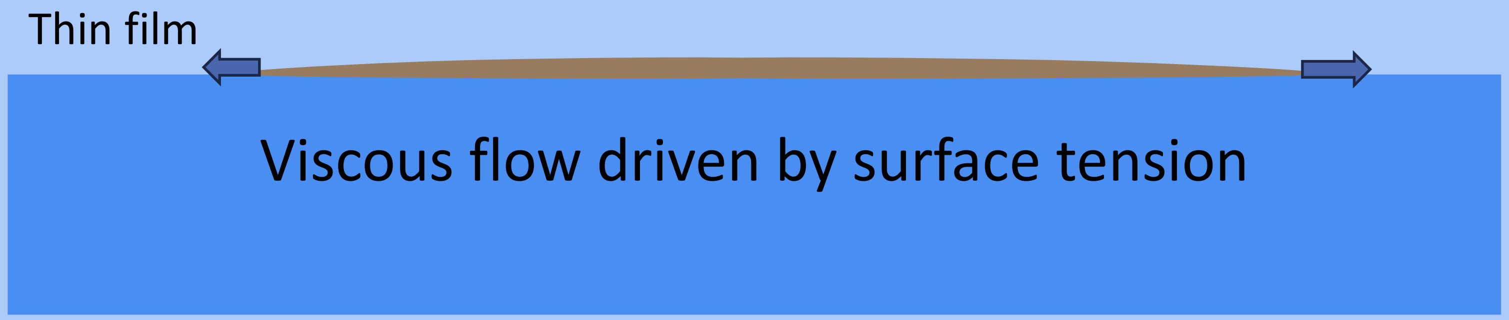
Classical interpretation:

oil slick behaves as a viscous liquid!

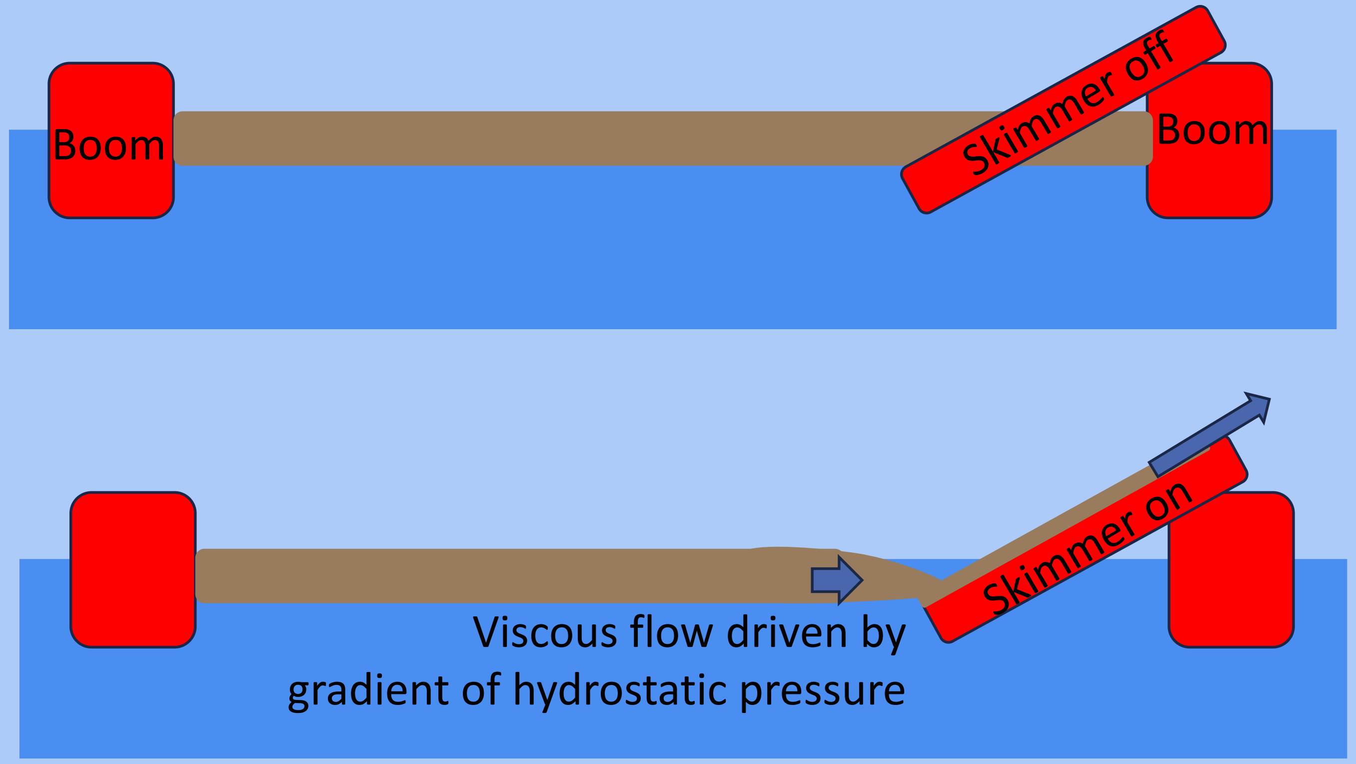
Spreading on a calm water body

(no current, no wave)

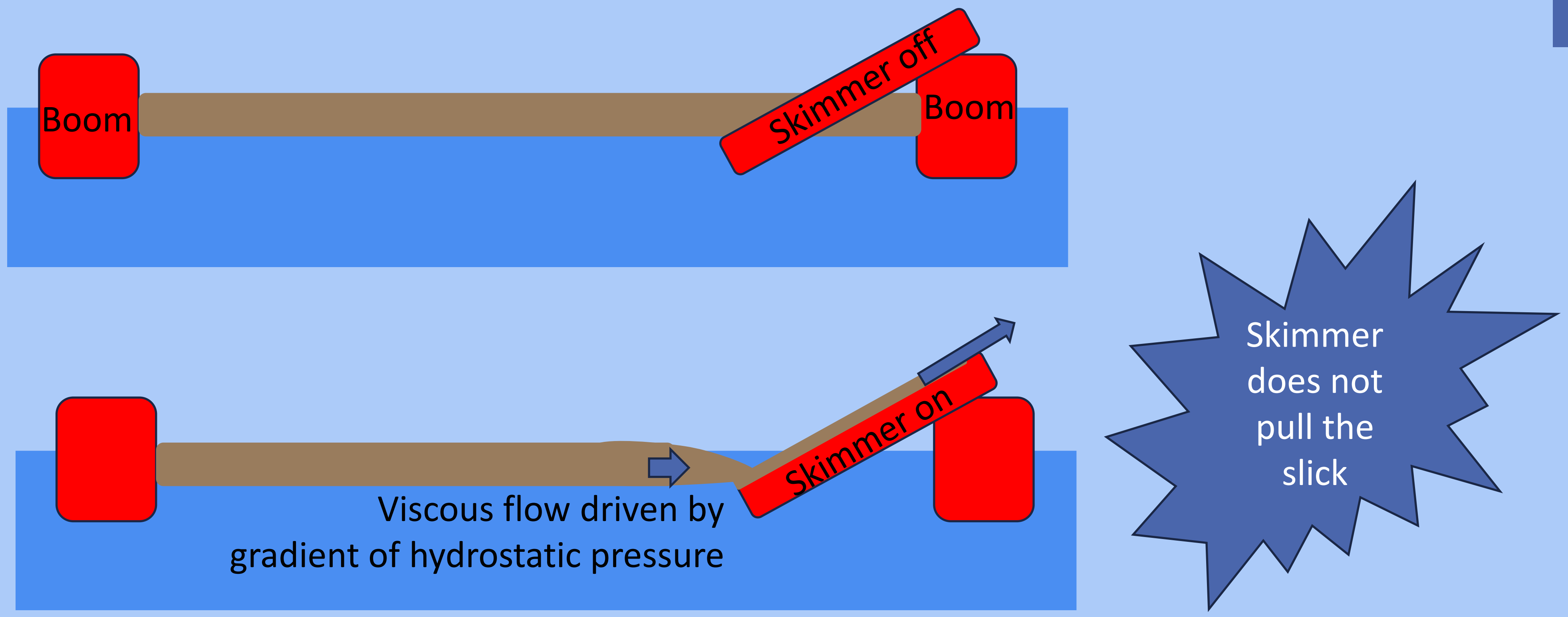




Skimmer efficiency

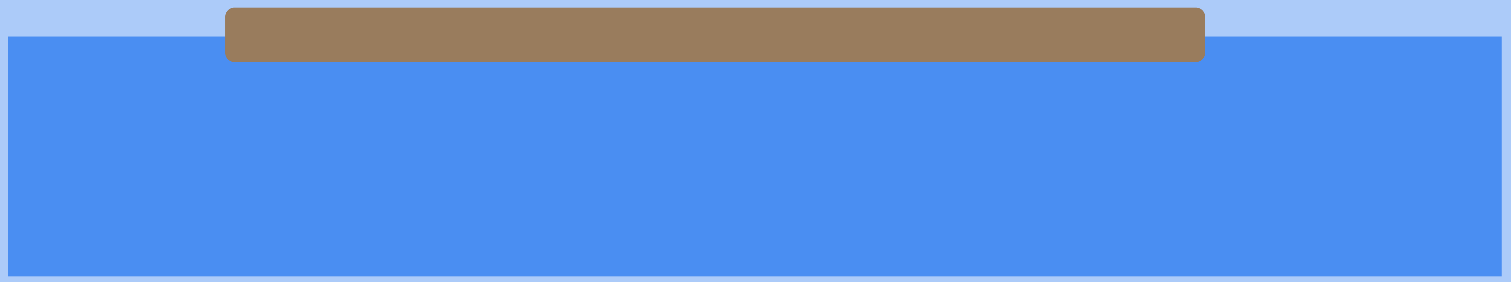


Skimmer efficiency

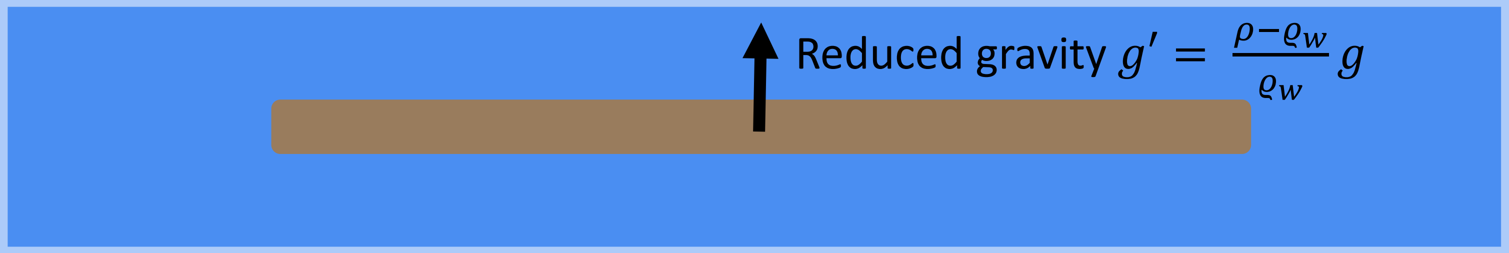


What if the oil slick behaves as a solid?

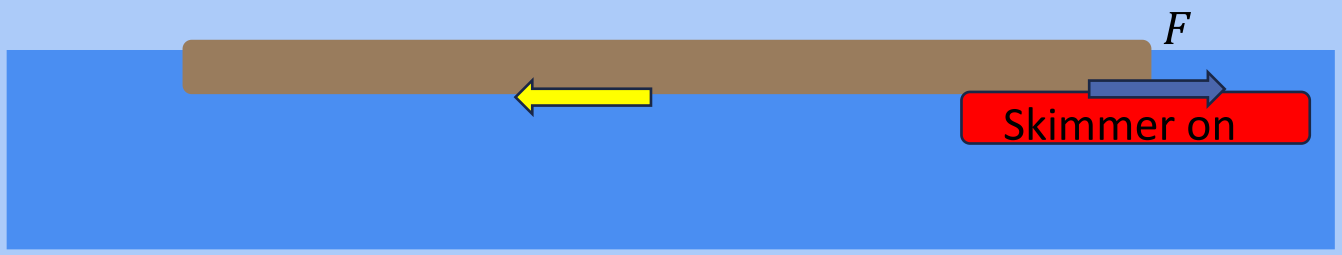
No spreading
on a calm water body



Shape preserved
if slick entrained under water

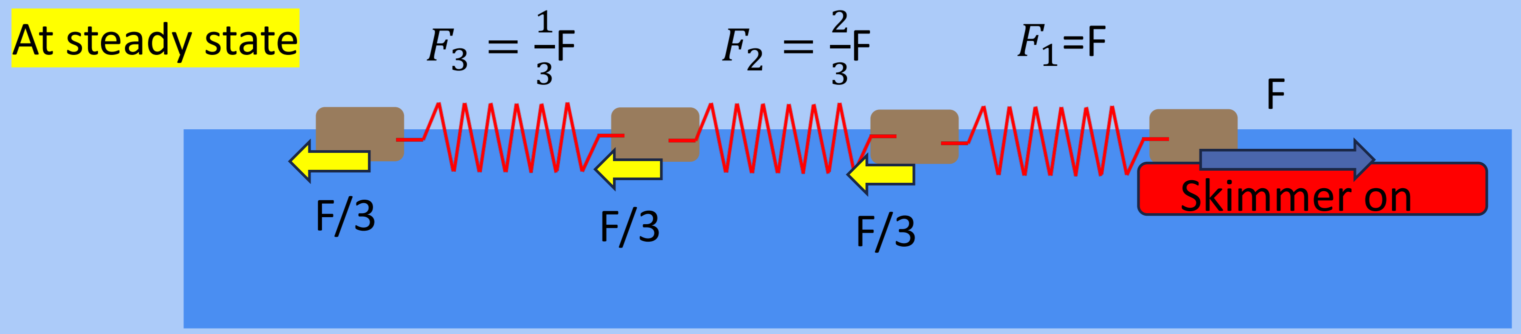


Skimmer for rigid solid slick



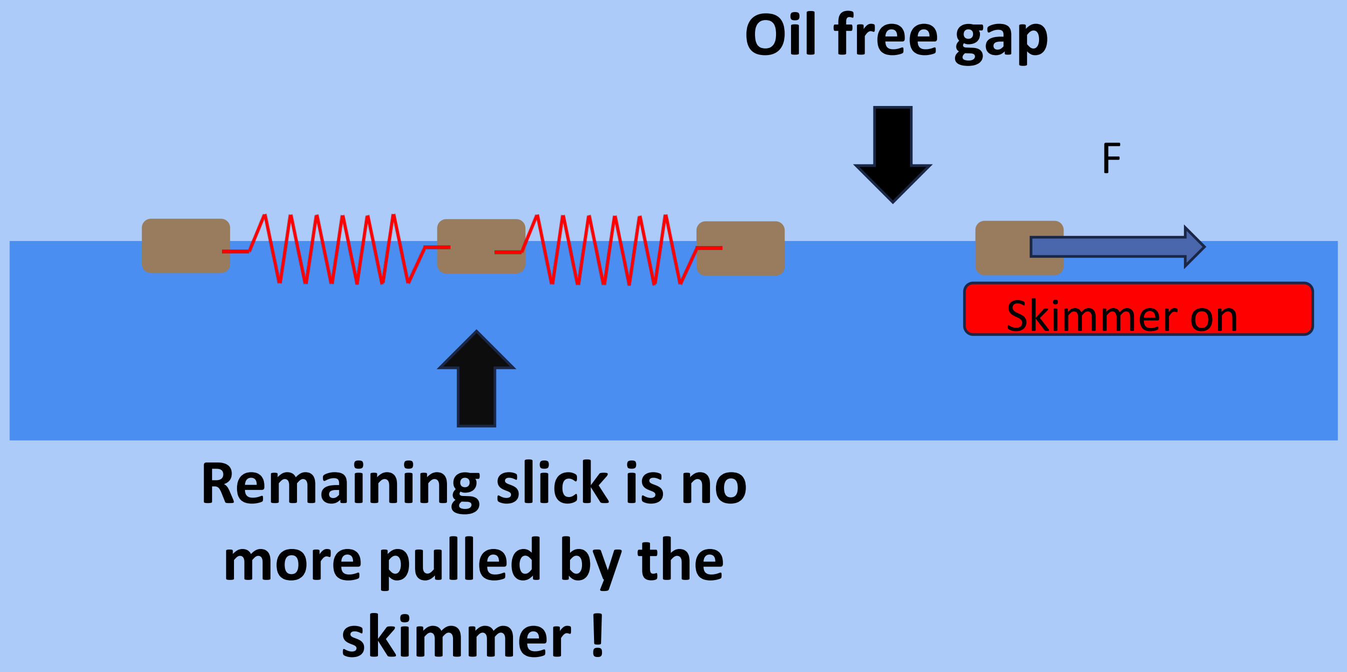
Skimmer must entrain the whole slick, what means compensating the shear stress due to the slick movement on the water surface

Skimmer for elastic solid slick



The internal stress $\sigma (= \frac{F_i}{S})$ is maximal just at the skimmer mouth

Short oil occurs when the internal stress exceeds the maximal stress tolerated before fracture of the slick.

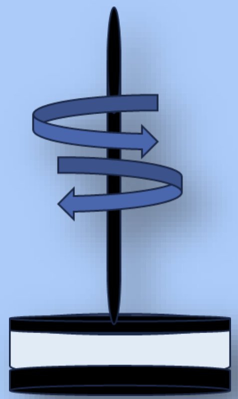


Hypothesis:
VLSFO slicks might sometimes behave as a viscous fluid, sometimes as an elastic solid

Rheology:
Do VLSFO slicks behave as a viscoelastic material?

Stress-controlled rheometer

MCR 702 (Anton Paar)



Controlled parameters of the sinusoidal oscillation:

- τ : maximal stress [Pa]
- ω : angular frequency [s^{-1}]

Measures the response of the sample in terms of

- γ : relative deformation [%], proxy for strain ϵ
- $\dot{\gamma}$: relative deformation rate [% s^{-1}], proxy for strain rate $\dot{\epsilon}$
- δ : phase lag [radian]

G'= shear elastic modulus [Pa]

capacity of the sample to store energy by elastic deformation

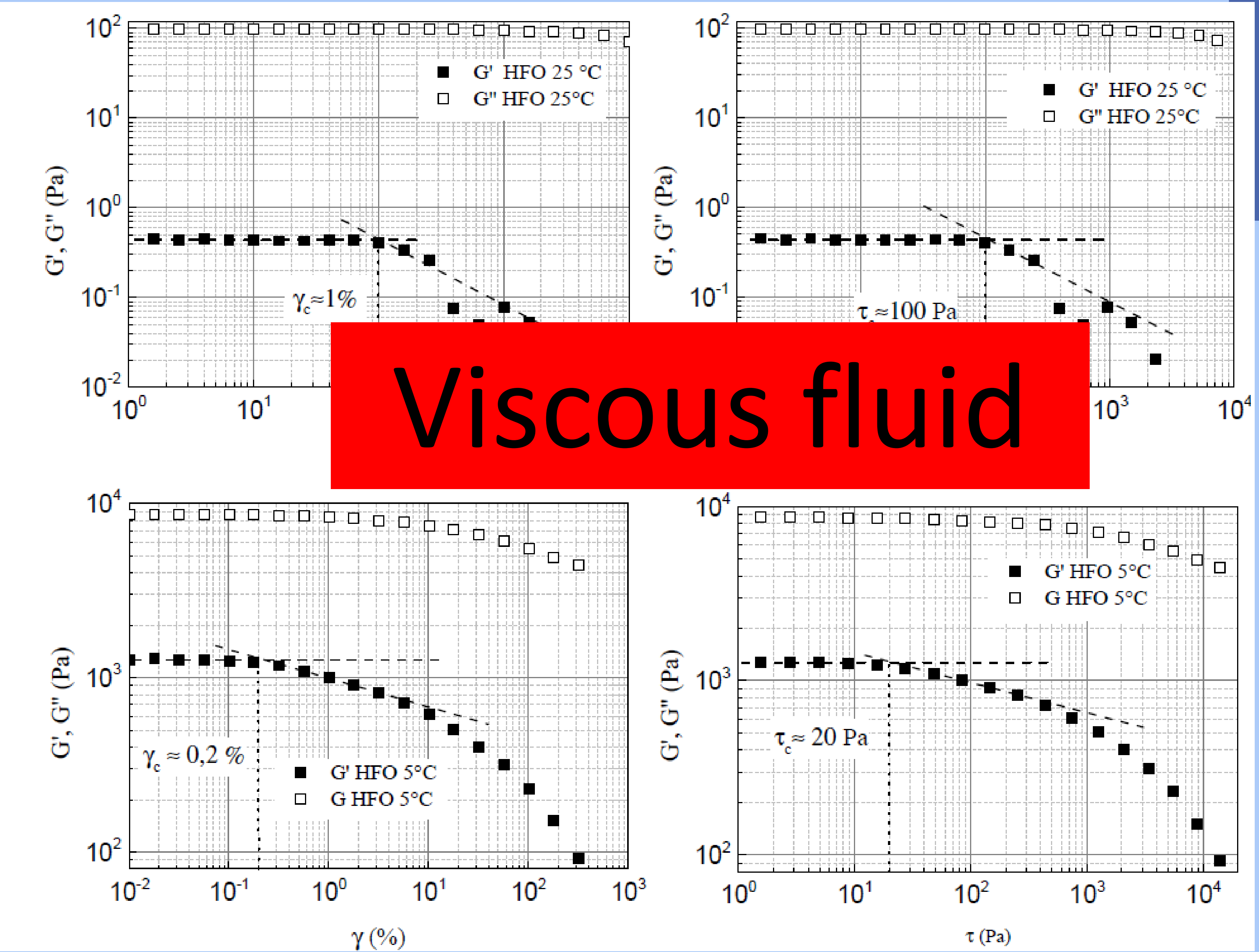
G'' = viscous modulus [Pa]

= $\mu\omega$

capacity of the sample to dissipate energy by viscous fluid

HFO $(\omega = 1\ Hz)$

T = 25°C
G'' >> G'
μ* ~ 10^2 Pa.s



Viscous fluid

T = 5°C
G''>G'
μ* ~ 10^4 Pa.s

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IM-27 $(\omega = 1\ Hz)$

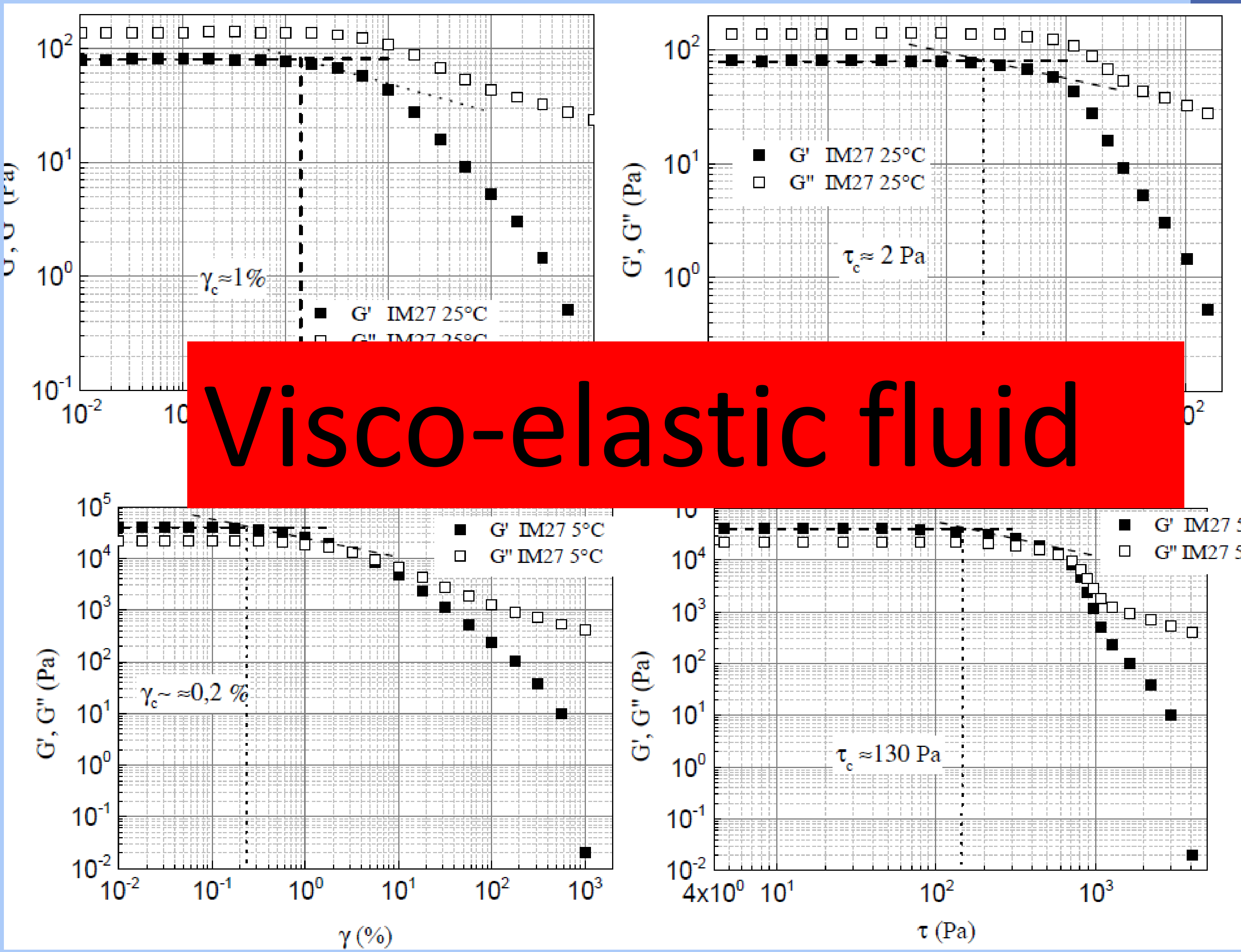
Wax content ~ 7.5 %

Pour point ~ 9°C

T = 25°C

G'' ≥ G'

μ* ~ [10 – 10^2] Pa.s



Visco-elastic fluid

T = 5°C

G' ≈ G''

μ* ~ [10^3-10^5] Pa.s

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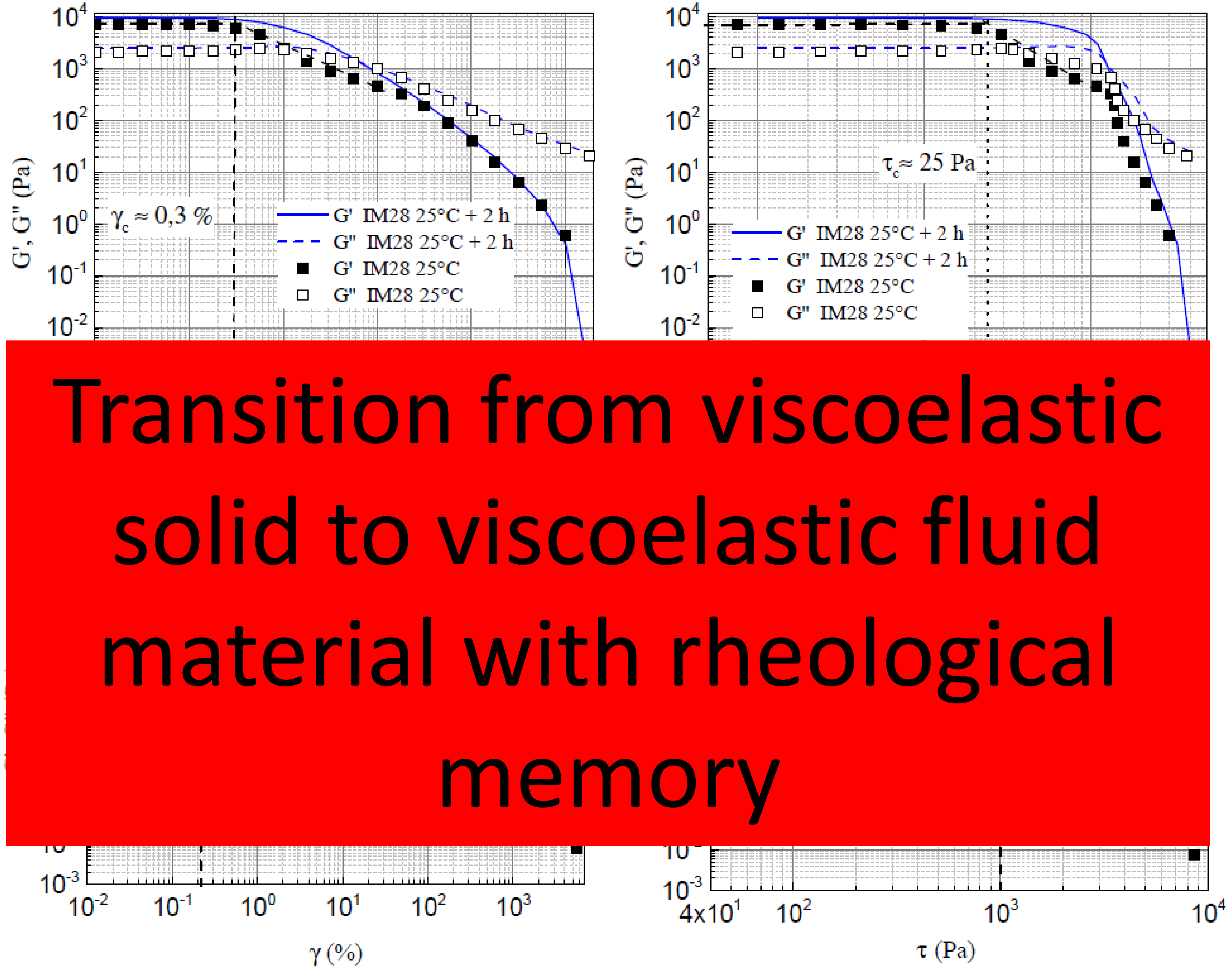
IM-28 $(\omega = 1\ Hz)$

Wax content ~ 15%

Pour point ~ 24°C

T = 25°C
G’ ≥ G’’
μ* ~ [10 – 10^3] Pa.s
λ=1 s

T = 5°C
G’ ≥ G’’
μ* ~ [10 – 10^5] Pa.s
λ=21 s



Transition from viscoelastic solid to viscoelastic fluid material with rheological memory

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IM-21 $(\omega = 1\ Hz)$

Wax content ~ 27%

Pour point ~ 33°C

T = 25°C

G’ > G’’

Fracture toughness

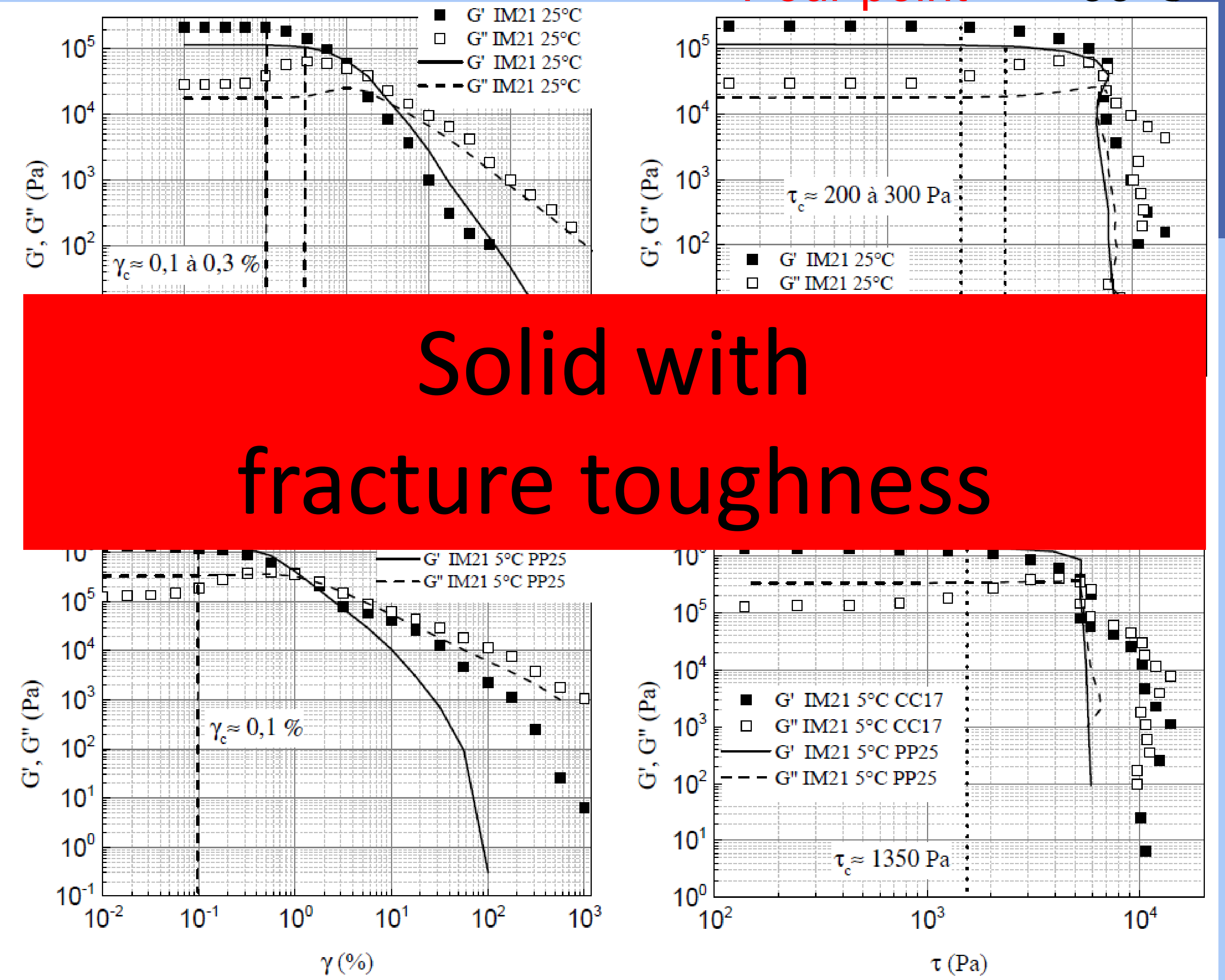
@ 10^3 Pa

T = 5°C

G’ > G’’

Fracture toughness

@ 10^4 Pa



Solid with fracture toughness

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Summary (an attempt calling for future research)

A continuum of possible rheological behaviours

Viscous liquid	Viscoelastic liquid	Viscoelastic solid + transition to liquid	Viscoelastic solid + transition to liquid, with memory	Elastic solid with low fracture toughness	Elastic solid with higher fracture toughness

Continuous liquid spreading slicks or patches of liquid slicks

"solidish" slicks, possibly broken into large lumps/floes, tarballs or pellets as a function of sea state

Could eventually froze in small flocks if water temperature much lower than pour point

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Summary (an attempt calling for future research)

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Classical skimmers should work (maybe with some adjustment)

Short oil behaviour very likely to occur

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Thank you for your attention