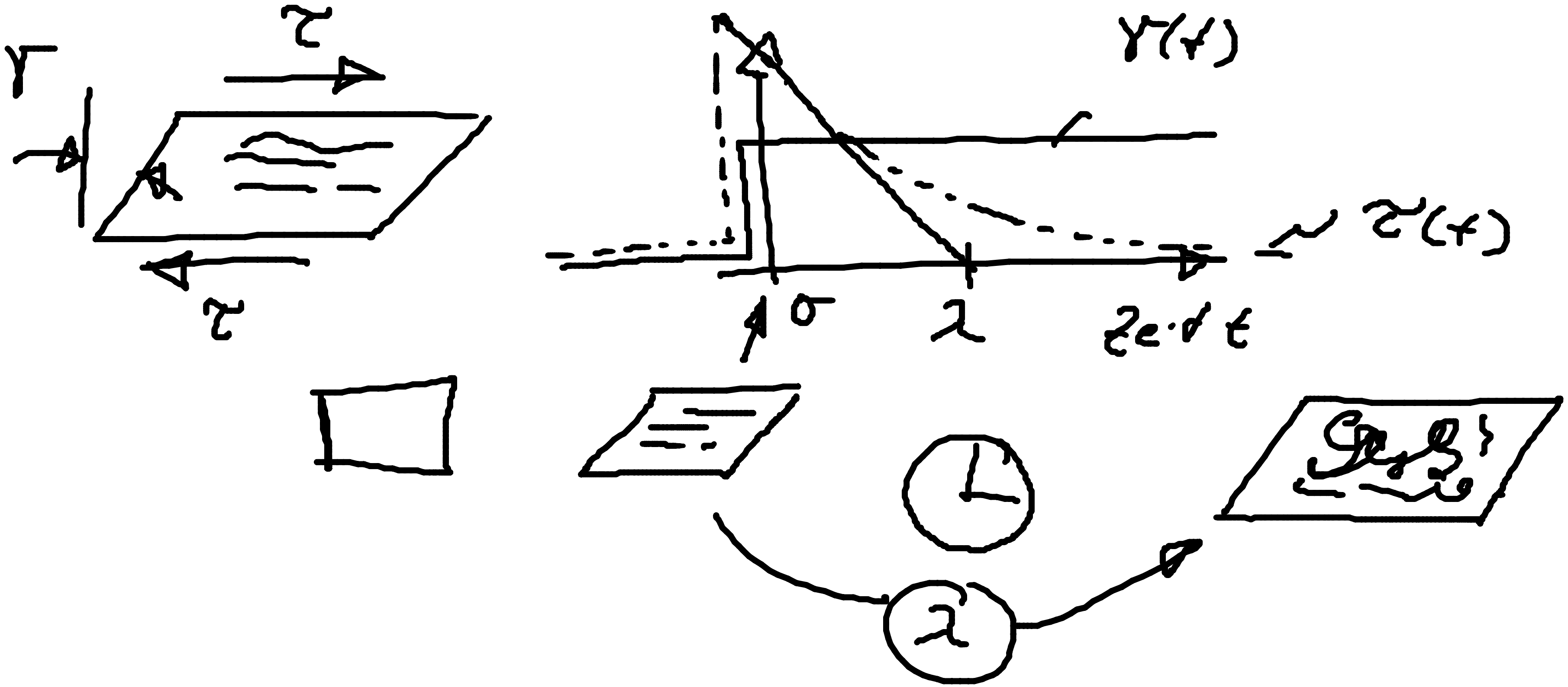
Relaxationsversuch und Maxwellsches Material.



Relaxationszeit.

Deformation = Funktional (Belastungsgeschichte)

$$\dot{\gamma}(t) = \frac{1}{\mu}\Big(\underbrace{\tau(t)}_{\text{Newtons.}} + \underbrace{\lambda\,\dot{\tau}(t) + \ldots}_{\text{Belastung}}\Big)$$

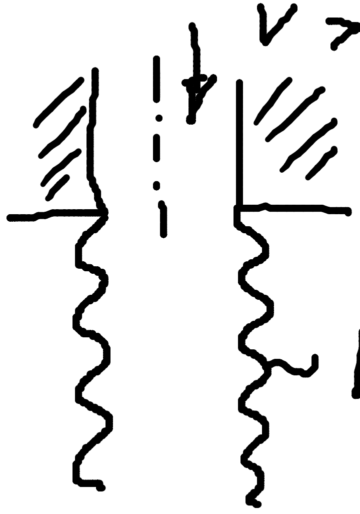
Maxwellsches Materialmodell

$$\Rightarrow \boxed{\tau(t) + \lambda\,\dot{\tau} = \mu\,\dot{\gamma}}$$

Abltg Folie letzte Vorlsg.

Produktionsprozess

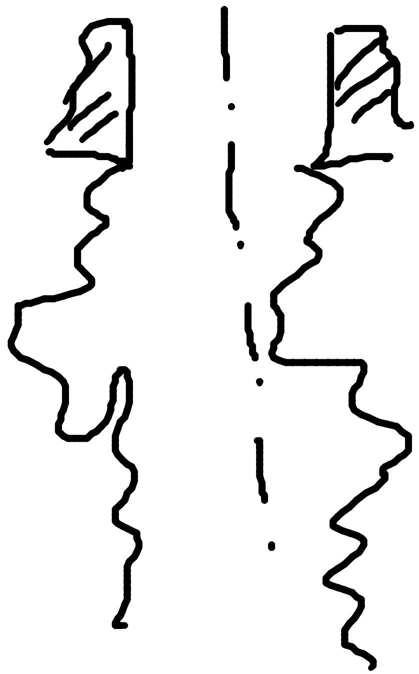
$\dot{V} > \dot{V}_{critical}$



Haifischhaut

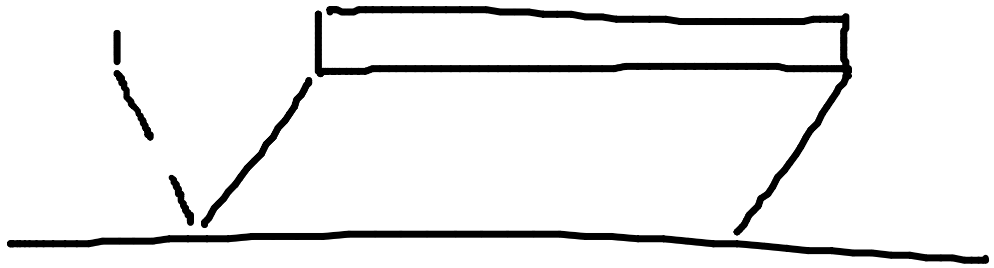
λ

$\dot{V} \gg \dot{V}_{krit}$



Viskoelastische Turbulenz

$$\hat{\gamma} e^{i\Omega t} \qquad \hat{\tau} e^{i\Omega t}$$



$\hat{\gamma}, \hat{\tau}$ komplexe Amplitude.

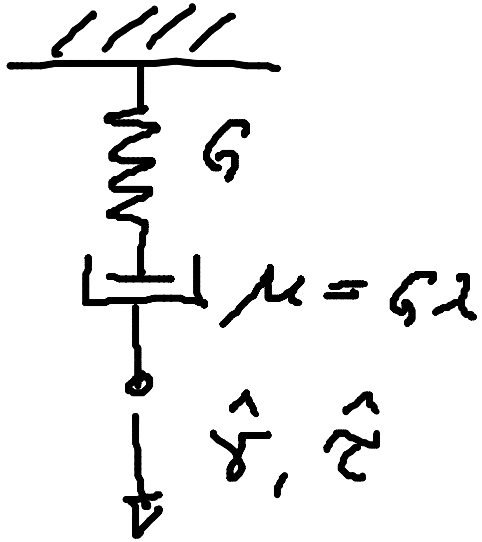
Einsetzen in das Maxwellsche Gesetz:

$$\hat{\tau} \cancel{e^{i\Omega t}} + \lambda i\Omega \hat{\tau} \cancel{e^{i\Omega t}} = \mu \hat{\gamma} i\Omega \cancel{e^{i\Omega t}}$$

$$\hat{G} := \frac{\hat{\tau}}{\hat{\gamma}} = \frac{\mu \, i\Omega}{1 + i\Omega\lambda}$$

G, λ

$\mu := G\lambda, \lambda$



$$\hat{G} = G\,\frac{i\Omega\lambda}{1 + i\Omega\lambda} = G' + i\,G'' = |\hat{G}|\,e^{i\delta}$$

G' Realteil des komplexen Moduls: Speichermodul

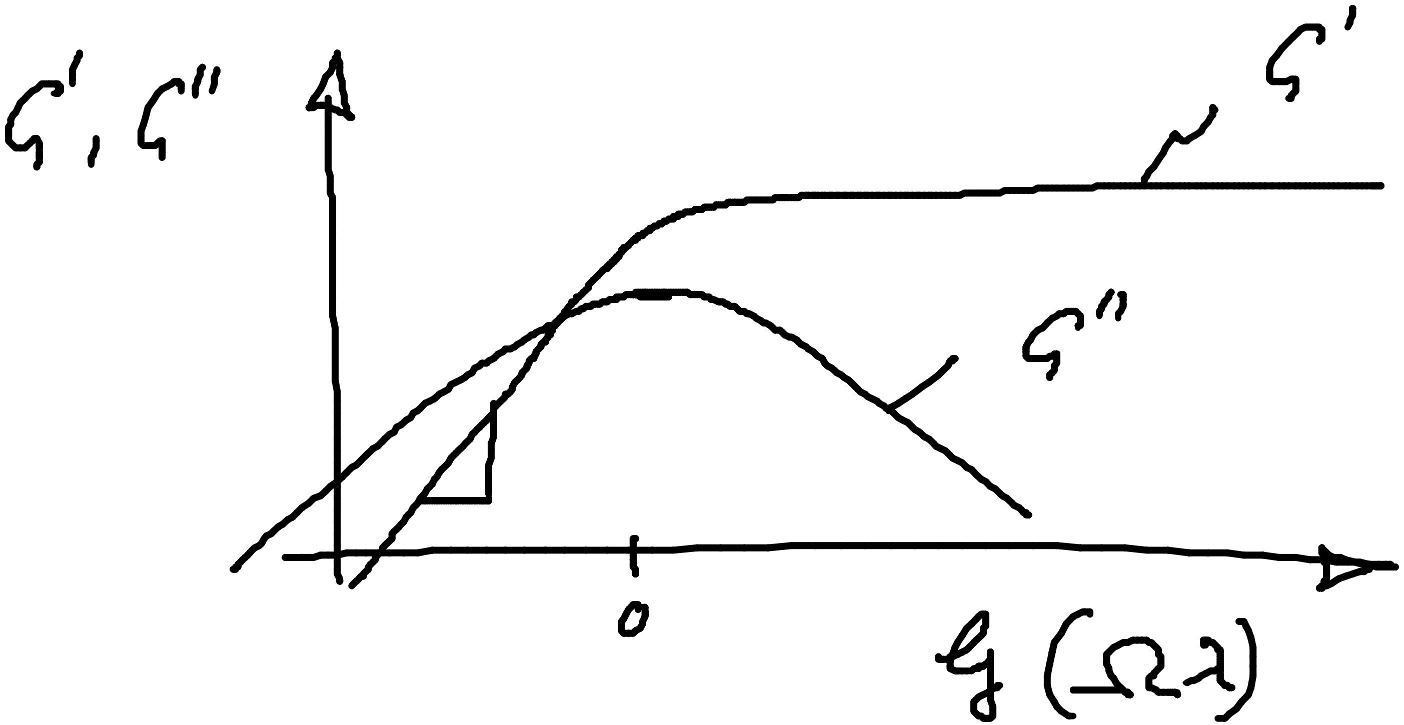
G'' Imaginärteil " : Verlustmodul

$\delta = \arctan \dfrac{G''}{G'}$ Verlustwinkel.

$$\hat{G} = G\,\frac{i\Omega\lambda}{1+(\Omega\lambda)^2}\,(1-i\Omega\lambda)$$

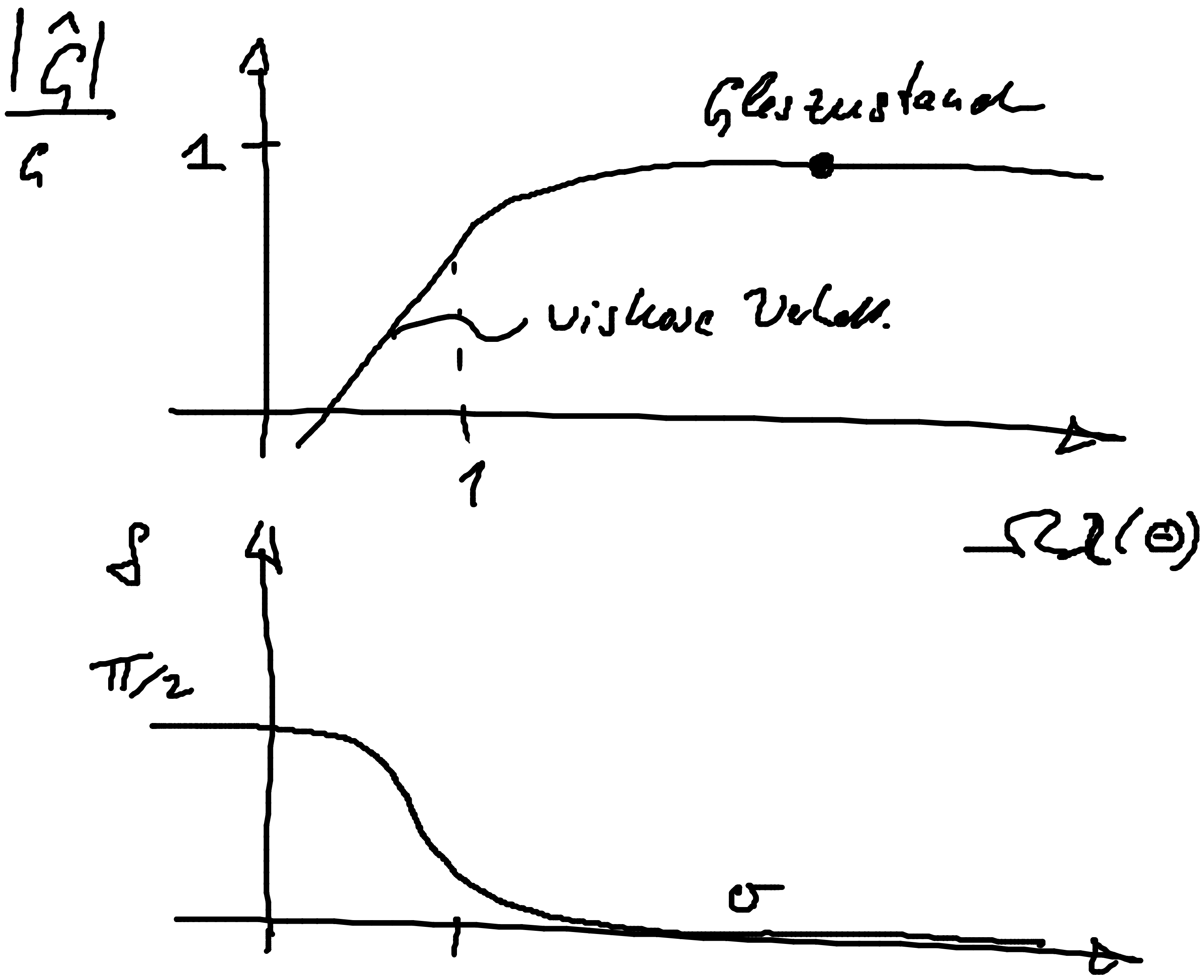
$$(1+i\Omega\lambda)(1-i\Omega\lambda) = 1+(\Omega\lambda)^2 \quad \checkmark$$

$$= \underbrace{G\,\frac{(\Omega\lambda)^2}{1+(\Omega\lambda)^2}}_{G'} + i\,\underbrace{G\,\frac{\Omega\lambda}{1+(\Omega\lambda)^2}}_{G''}$$



$\Omega\lambda >> 1$, dann $G' \to$ constant: rein elastisches Verhalten

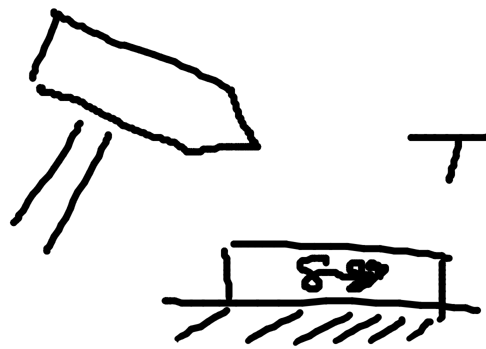
$\Omega\lambda << 1$, dann liegt rein viskoses Verhalten vor.


$|\hat{G}| / G$
1
Glaszustand
viskose Verh.
1
$\Omega \lambda(\Theta)$
δ
$\pi/2$
σ

Zwei Zugänge zum Glaszustand. $\lambda\Omega$

1. konstante Relaxationszeit λ, aber hohe Frequenz Ω bzw. kurze Belastungszeit

$$T = \frac{2\pi}{\Omega}$$



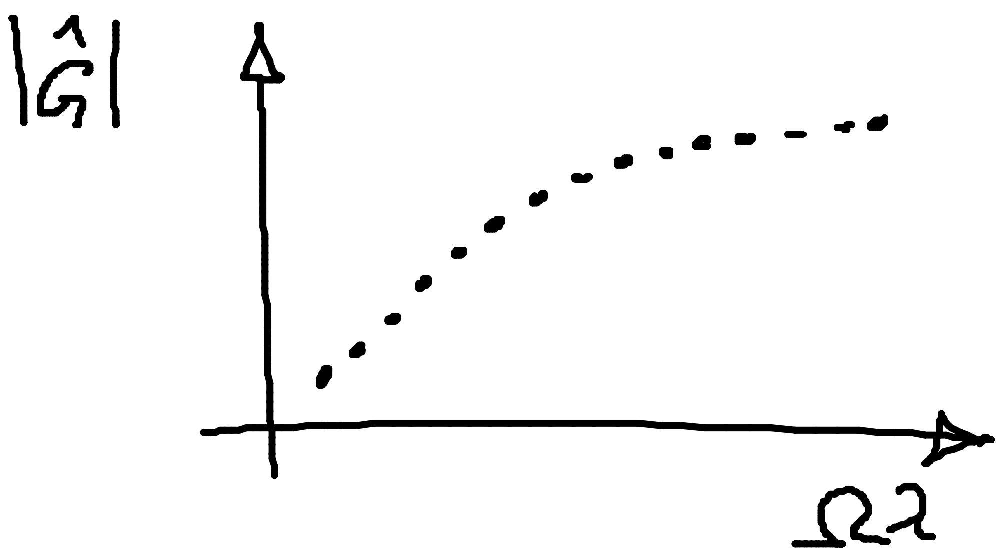
T „kurz" $\ll \lambda$

2. Belastungszeit $T = \frac{\Omega}{2\pi}$ ist konstant, aber die Relaxationszeit wird verändert.

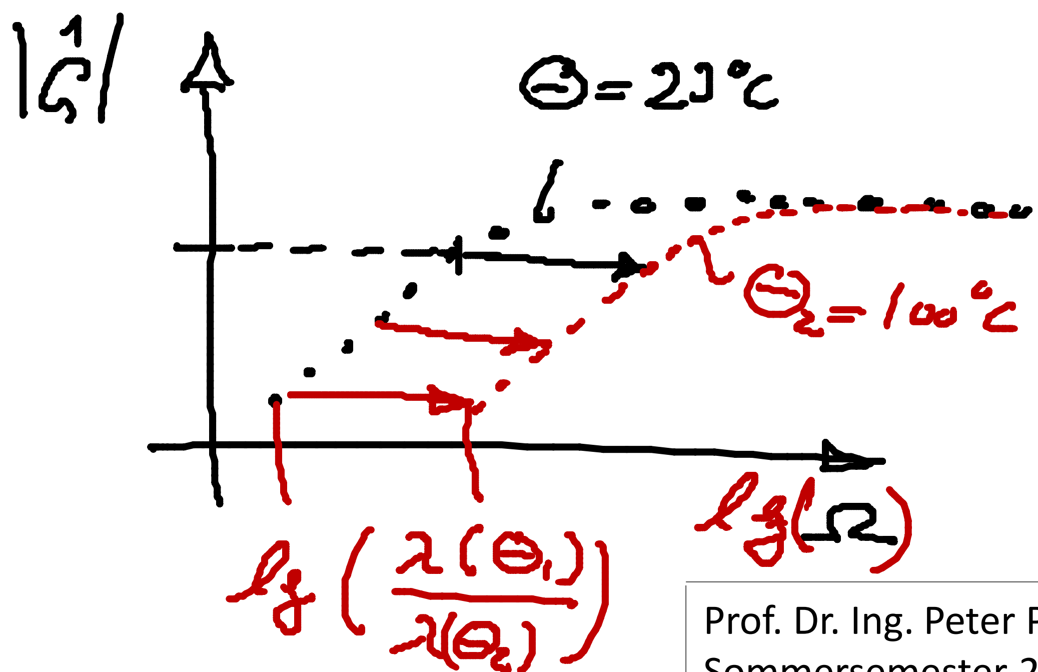
$$\lambda(\Theta).$$

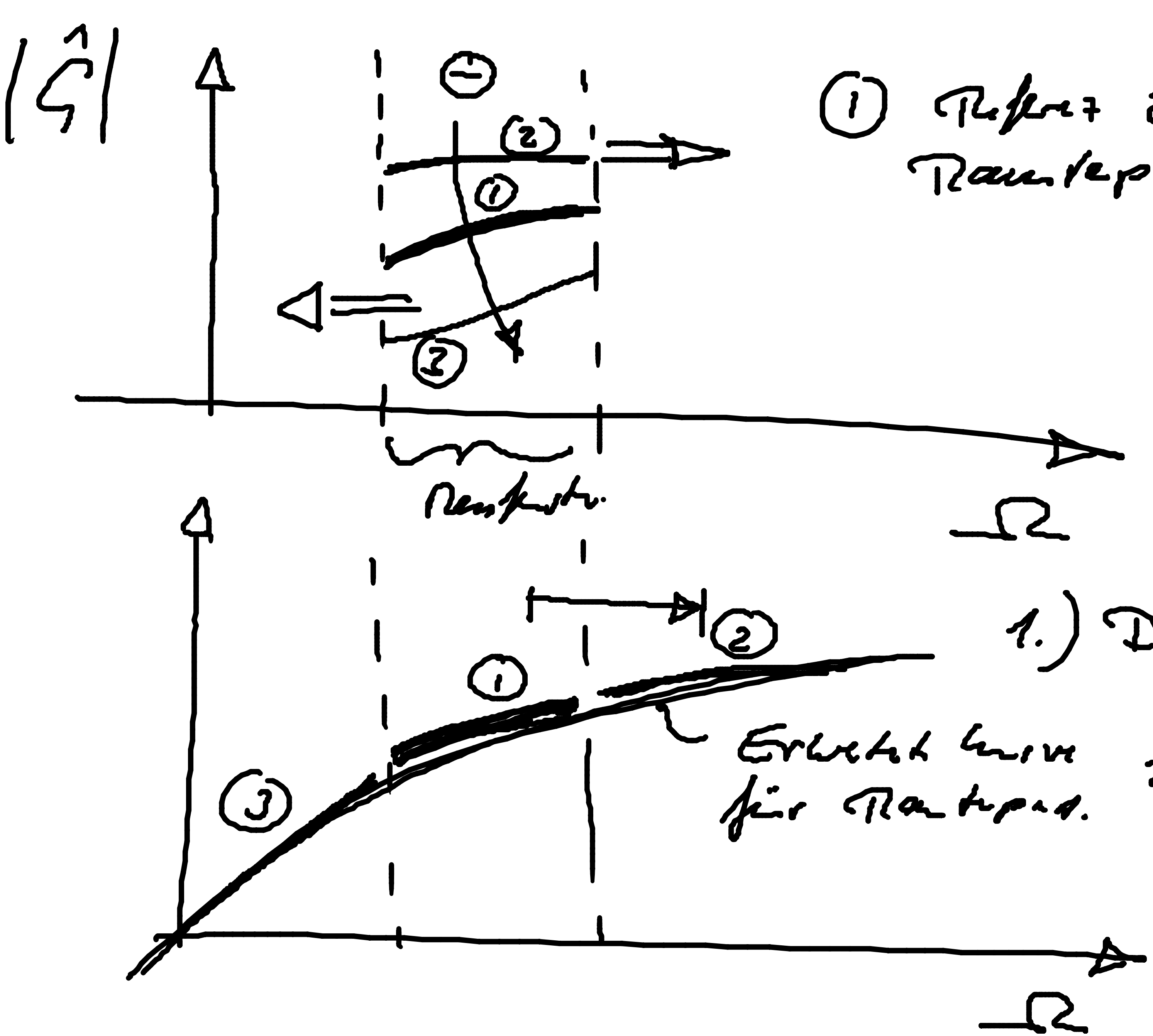
Äquivalenz ist Folge davon, dass λ und Ω nur als Produkt auftaucht.

Zeit-Temperatur-Verschiebungsprinzip.
(thermorheologisch einfache Materialien)



dimensionslose Achse.



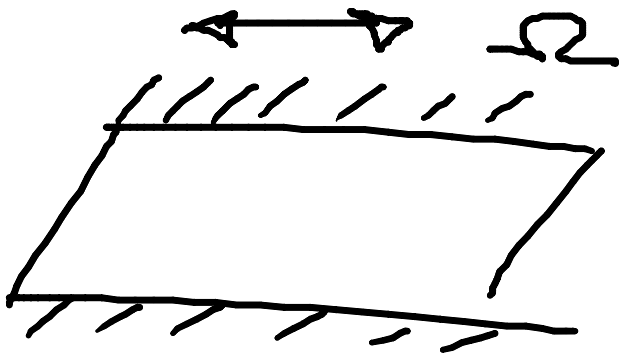


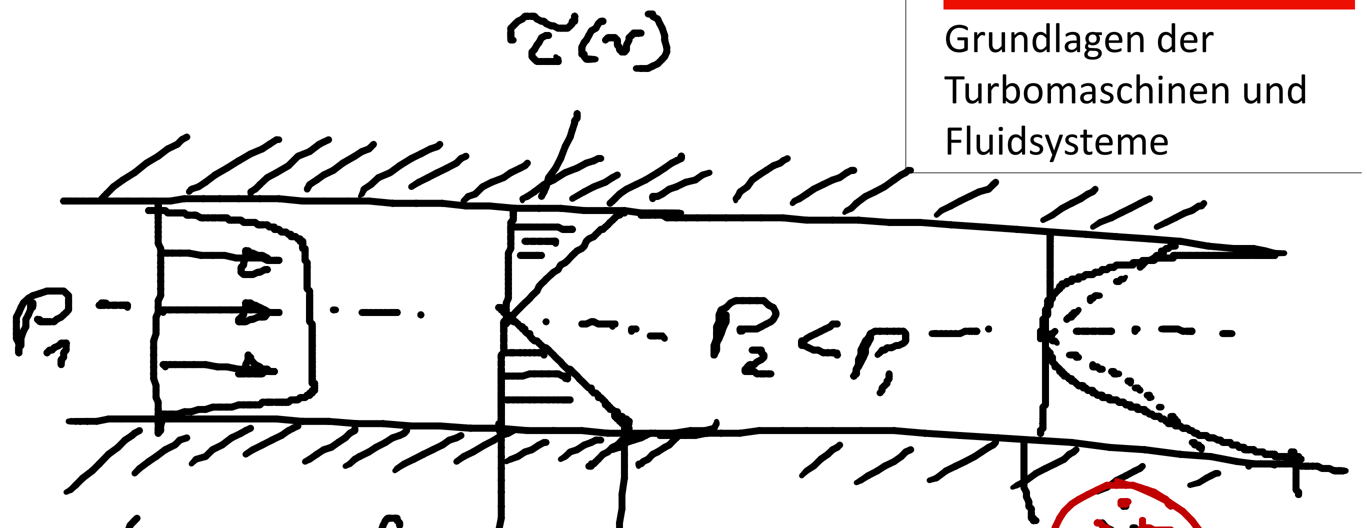
① Referenz z.B. Raumtemperat.

1.) Das Messfenster ist wesentlich erweitert

2.) Information über die Temperaturabhängigkeit

Warum machen Information bei oszillierender Strömung für stationäre Strö.





Oszillierende Strömung

$$\underbrace{\hat{\tau} \quad \hat{\gamma} \quad \Omega}$$

$$|\hat{G}| = \left|\frac{\hat{\tau}}{\hat{\gamma}}\right| ; \quad |\hat{\dot{\gamma}}| = |\hat{\gamma}|\,\Omega$$

stationäre Strö.

τ_w Wandschubspannung.

$\dot{\gamma}_w$

Geschwindigkeits-profil

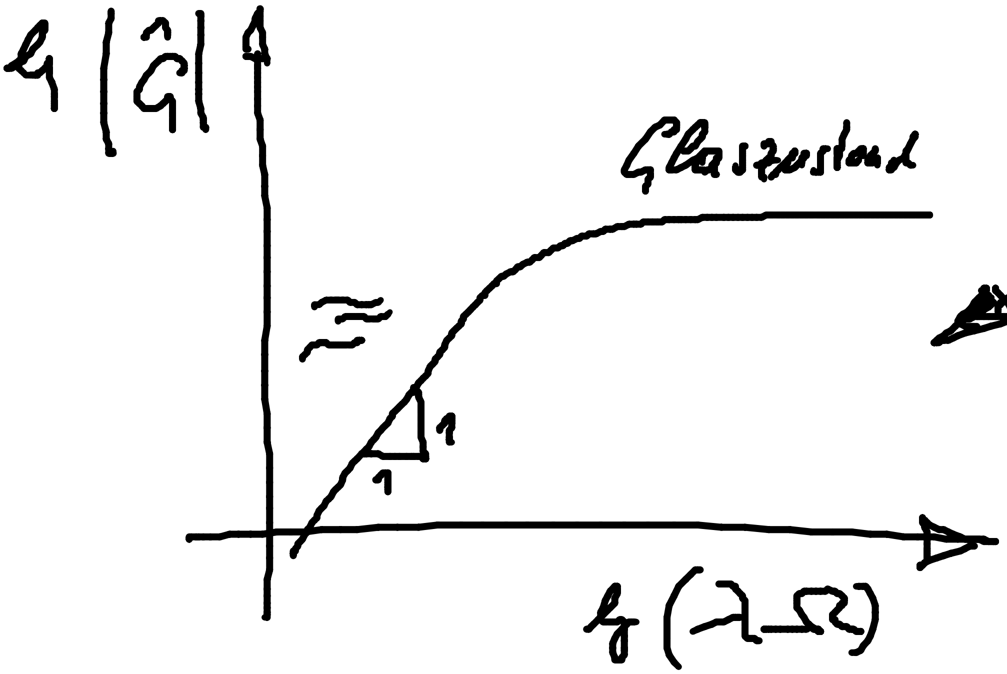
Schubspannungs-vert.

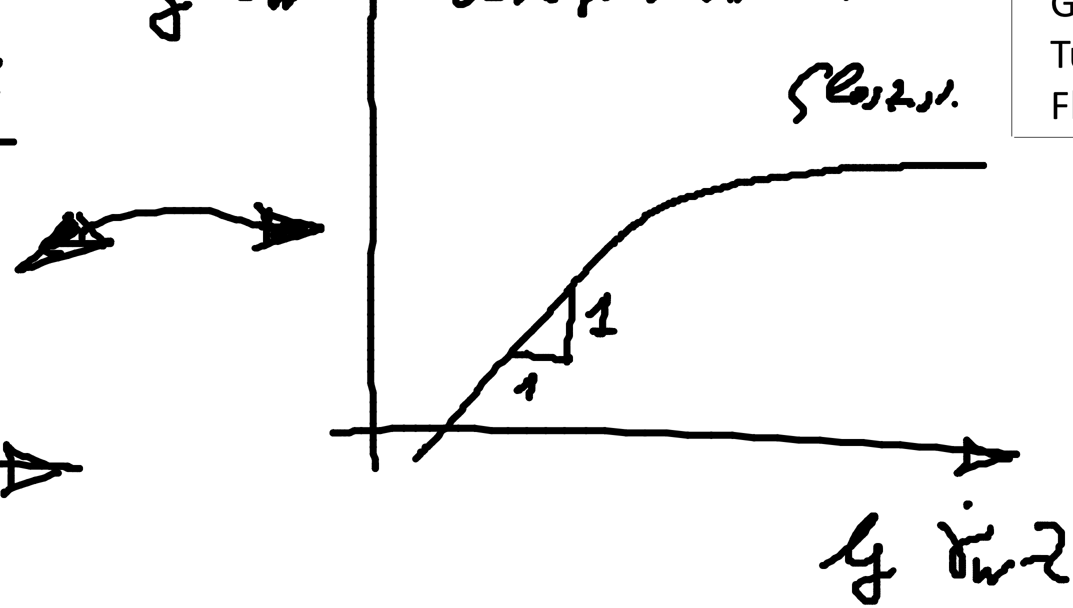
Scherrate-verteil.

Oszillierend $\gamma < \hat{\gamma} << \infty$

stationär $\gamma \to \infty$

Schubspannungsdiagramm.



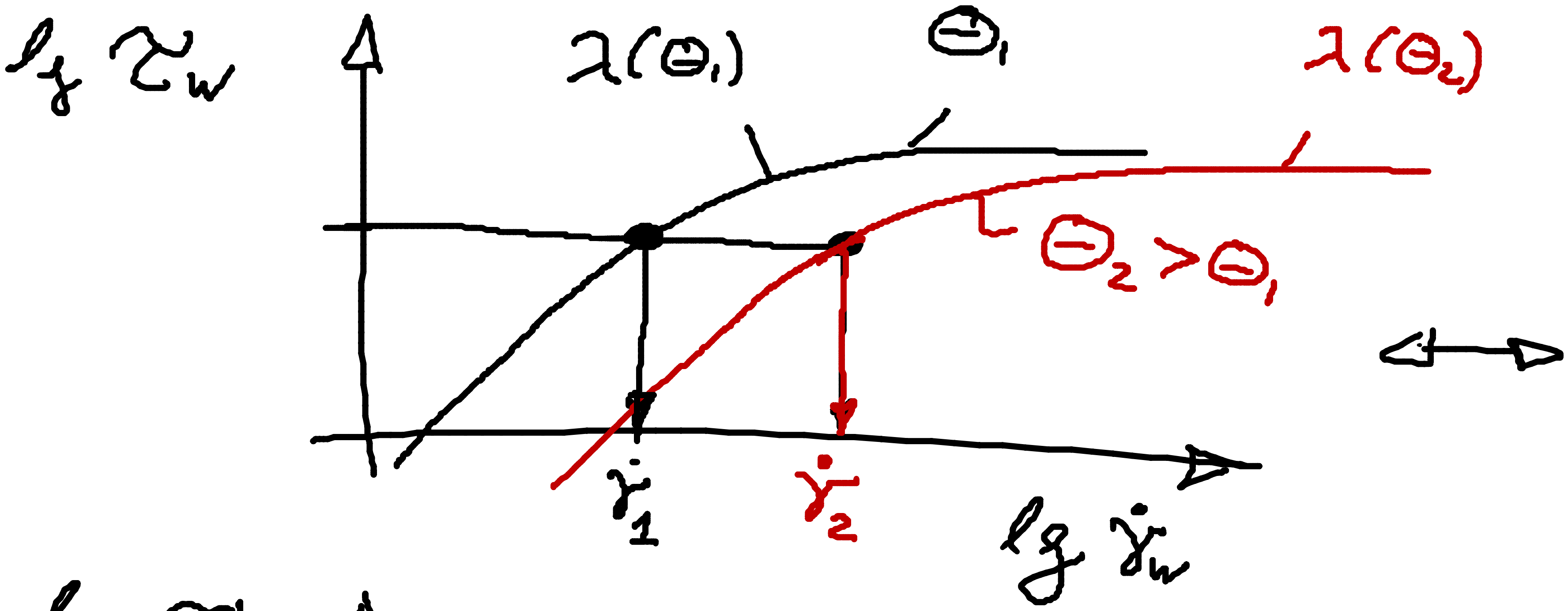


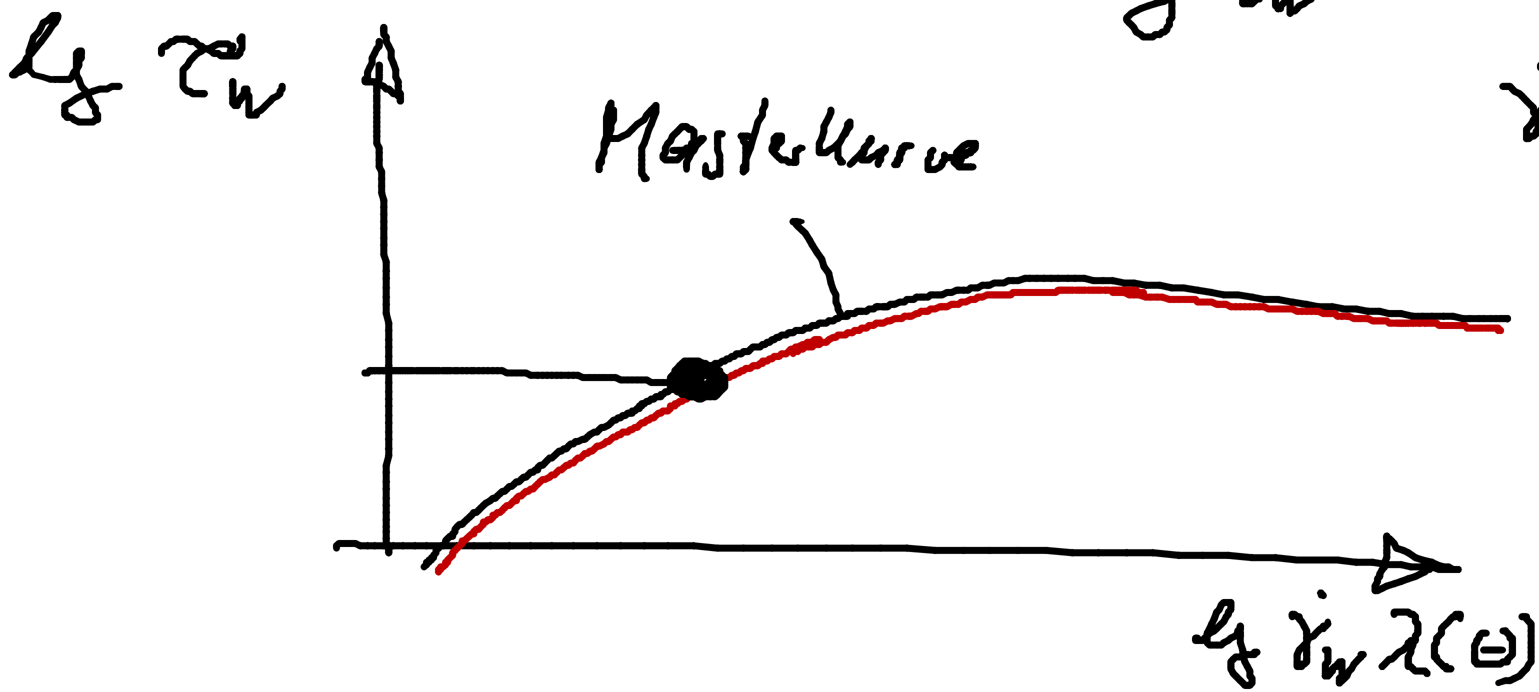
$$\tau_w = |\hat{G}|$$

für $\lambda\Omega = \dot{\gamma}_w \lambda$

Cox-Merz-Relation.
Empirische Bezieh.

TECHNISCHE UNIVERSITÄT DARMSTADT
FLUID SYSTEM TECHNIK
Grundlagen der Turbomaschinen und Fluidsysteme

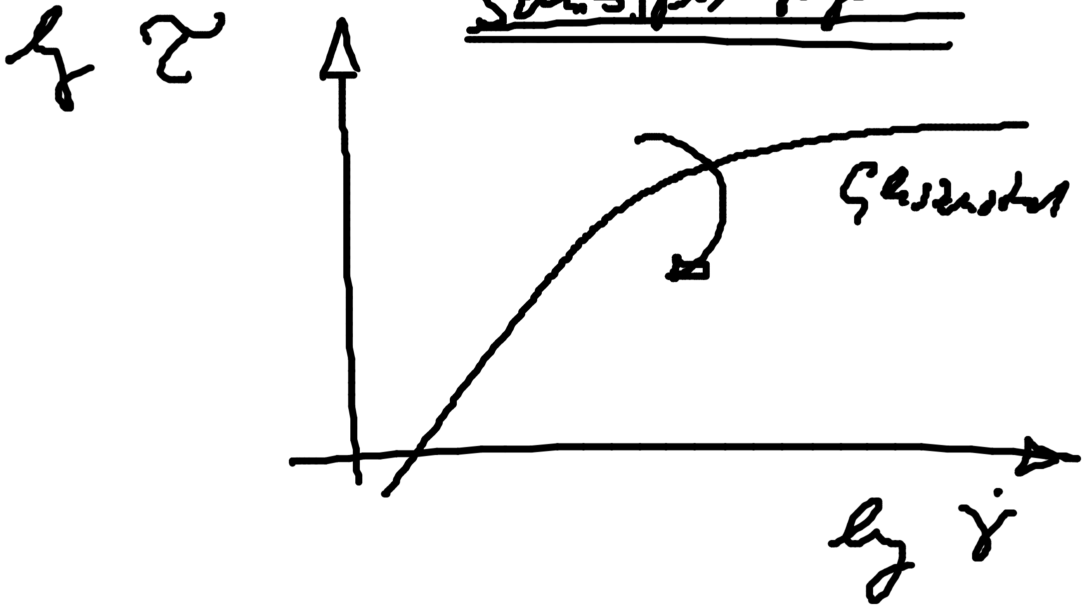




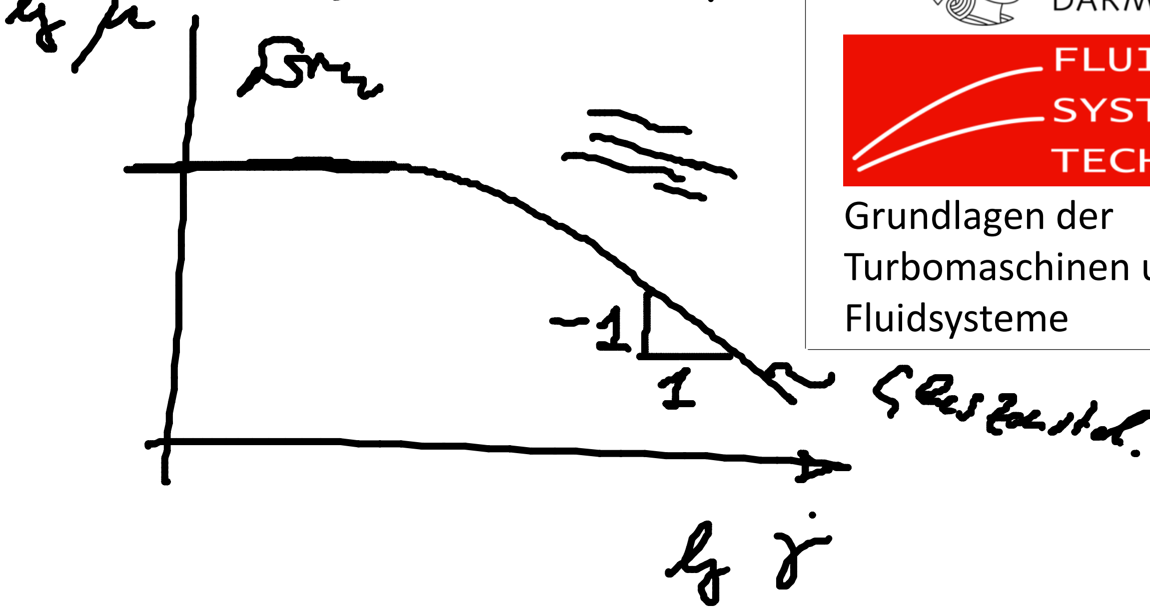
$$\dot{\gamma}_1 \lambda(\Theta_1) = \dot{\gamma}_2 \lambda(\Theta_2)$$

$$\boxed{\frac{\dot{\gamma}_1}{\dot{\gamma}_2} = \frac{\lambda(\Theta_2)}{\lambda(\Theta_1)}}$$

Schubspannungsfunktion.



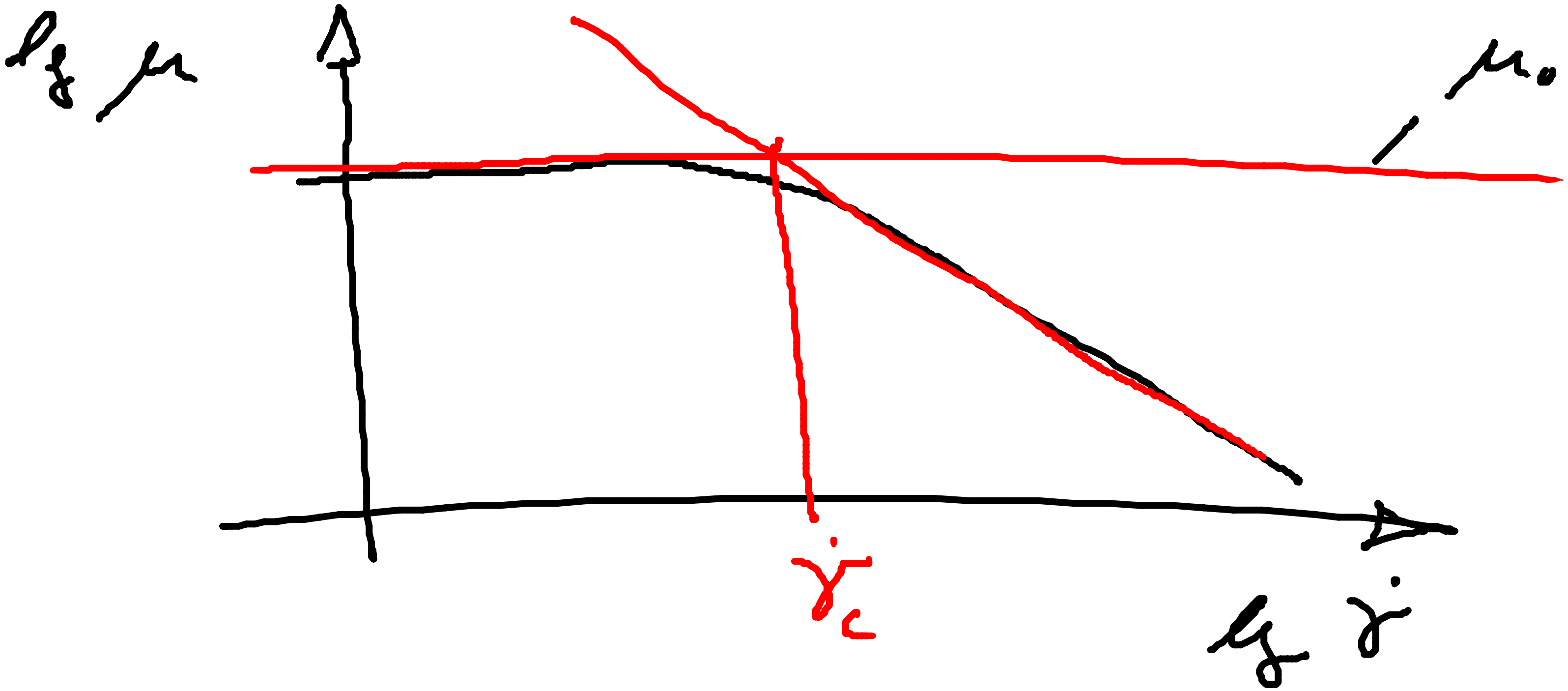
Viskosität.



$$\tau = \mu(\dot\gamma)\,\dot\gamma$$

$$\mu(\dot\gamma) = \frac{\tau(\dot\gamma)}{\dot\gamma} = \tau \quad \dot\gamma^{-1}$$

Drehe um 45° im log-log-Plot.



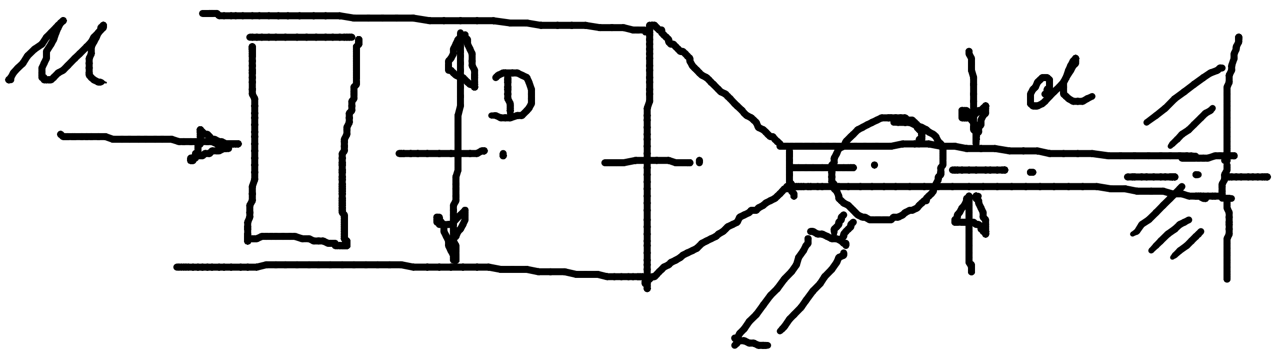
Empfehlung: $\dot\gamma_w < \dot\gamma_c$, dann $\mu = \mu_0 = \text{const}$

$\dot\gamma_w > \dot\gamma_c$, dann $\tau_w = m\,\dot\gamma^{\,n}$ $\quad n < 1$

$n = 1$: Newtonsche Flü.

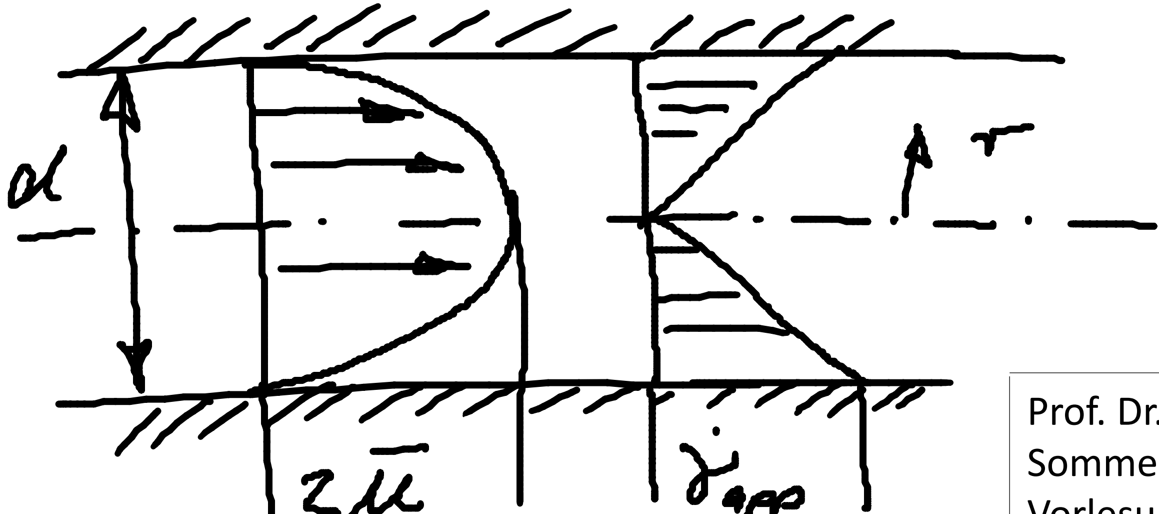
$n = 0$: Gleitzustand ↯

Bei einem kinematisch vorgegeben. Prozess:
u bekannt.



⇝ Volumenstrom $Q = u \frac{\pi}{4} D^2$

$$\bar{u} = \frac{Q}{\frac{\pi}{4} d^2} = u \left(\frac{D}{d}\right)^2$$



$$u(r) = 2\bar{u}\left(1 - \left(\frac{r}{R}\right)^2\right) \; ; \quad R = \frac{d}{2}$$

Poiseuille Profil für ein angenommenes newtonsches Fluid.

$$|\dot{\gamma}| = \left|\frac{du}{dr}\right| = \frac{4\bar{u}}{R}\,\frac{r}{R}\Big|_{r=R} = \frac{8\bar{u}}{d}\,\frac{r}{R}\Big|_{r=R} = \frac{8\bar{u}}{d}$$

$$\dot{\gamma}_{app} = 8\,\frac{\bar{u}}{d}$$ Scheinbare Scherrate an der Wand bei angenommenem newtonschen Fl.