

ZUG

$\sigma_{zug} \leq \sigma_{zul}$

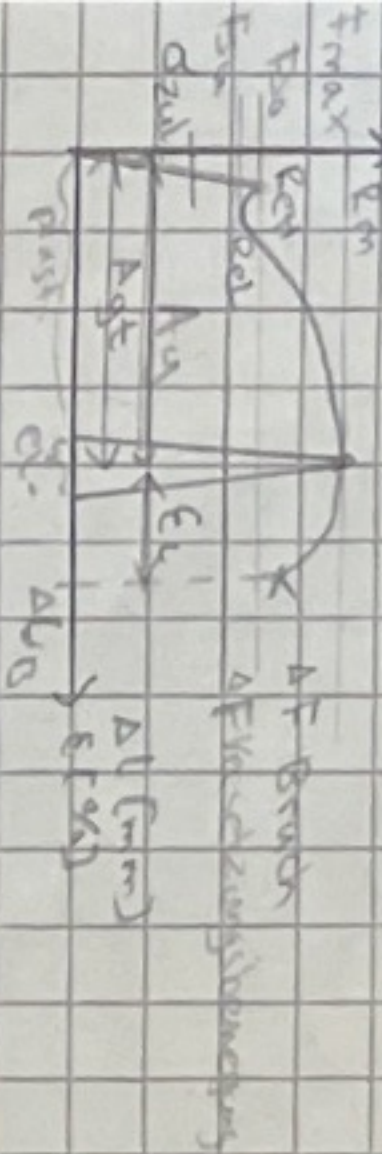
$R_m = \frac{F_{max}}{A}$
 $E = \frac{\Delta L}{\Delta \epsilon}$
 $E_{OL} = \frac{R_m}{\epsilon}$
 $\mu = \frac{\epsilon_{OL}}{\epsilon}$
 $\sigma = E \cdot \epsilon$

Fließbeginn $\sigma_{max} = R_e = \sigma_{z}$
 $\epsilon_{ad} = \epsilon_{OL} + \epsilon_{el}$
 $\epsilon_{OL} = \frac{R_m}{E}$
 $\sigma = E \cdot \epsilon$

Brechbeginn
 $A = \frac{A_0}{100\%}$
 $Z = A - A_0 \cdot 100\%$

Rechnen gegen Versagen

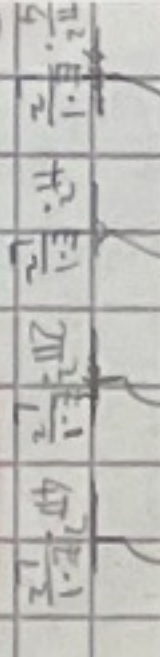
zäh Fließen	$\sigma_{zul} = \frac{R_m}{SF}$	$SF = 1,2-2$	1,5
zäh Bruch	$\sigma_{zul} = \frac{R_m}{SF}$	$SF = 2-3$	2
späd Bruch	$\sigma_{zul} = \frac{R_m}{SF}$	$SF = 4-9$	4



Druck

$\sigma_d \leq \sigma_{d,zul}$; $F \leq \frac{F_r}{SF}$
 $\sigma_d = -\frac{F}{A}$
 $\sigma_{d,zul} = -\frac{R_{eH}}{SF}$
 $\lambda = L \cdot \gamma \cdot \frac{1}{A}$
 $\Delta L = \frac{\sigma_d}{E} \cdot L_0$

Knicklast



Rechnen gegen Versagen

zäh Fließen	$\sigma_{zul} = -\frac{R_{eH}}{SF}$	$SF = 1,2-2$	1,5
Knicken	$\sigma_{zul} = -\frac{R_{eH}}{SF}$	$SF = 2,5-5$	3,5
Bruch	$\sigma_{zul} = -\frac{R_{mH}}{SF}$	$SF = 4-9$	4

Biegung

$\sigma_b \leq \sigma_{b,zul}$
 $M_{b,max} = \frac{F \cdot l}{4}$
 $\sigma_b = \frac{M_b}{W_b}$
 $\sigma_{b,zul} = \frac{R_{eH}}{SF}$
 $\sigma_{b,zul} = \frac{R_{mH}}{SF}$

Spannung $\sigma(v) = \frac{F}{A}$
 $\sigma_{b,zul} = \frac{R_{eH}}{SF}$
 $\sigma_{b,zul} = \frac{R_{mH}}{SF}$

Rechnen gegen Versagen
 $\sigma_{b,zul} = \frac{R_{eH}}{SF}$
 $\sigma_{b,zul} = \frac{R_{mH}}{SF}$

Schub

$\tau \leq \tau_{zul}$

$G = \frac{F}{\Delta \gamma}$
 $\tau_{zul} = \frac{R_{eH}}{SF}$
 $\tau_{zul} = \frac{R_{mH}}{SF}$

Rechnen gegen Versagen
 $\tau_{zul} = \frac{R_{eH}}{SF}$
 $\tau_{zul} = \frac{R_{mH}}{SF}$

zäh Bruch $\tau_{zul} = \frac{R_{eH}}{SF}$
 $\tau_{zul} = \frac{R_{mH}}{SF}$

Torsion $\tau \leq \tau_{zul}$
 $\tau_{zul} = \frac{R_{eH}}{SF}$
 $\tau_{zul} = \frac{R_{mH}}{SF}$

Rechnen gegen Versagen
 $\tau_{zul} = \frac{R_{eH}}{SF}$
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zäh Fließen $\tau_{zul} = \frac{R_{eH}}{SF}$
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späd Bruch $\tau_{zul} = \frac{R_{eH}}{SF}$
 $\tau_{zul} = \frac{R_{mH}}{SF}$

Schwing Bd. $\sigma_a \leq \sigma_{a,zul}$
 $\sigma_{a,zul} = \frac{R_{eH}}{SF}$
 $\sigma_{a,zul} = \frac{R_{mH}}{SF}$

Rechnen gegen Versagen
 $\sigma_{a,zul} = \frac{R_{eH}}{SF}$
 $\sigma_{a,zul} = \frac{R_{mH}}{SF}$

Obertendenz $\sigma_a \leq \sigma_{a,zul}$
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Rechnen gegen Versagen
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Kombi

$\sigma_{max} \leq \sigma_{d,zul}$
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Rechnen gegen Versagen
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Druck

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$$\frac{N}{A} = \frac{M \cdot R}{I} \cdot \frac{y}{R} = \frac{M \cdot y}{I}$$

Schnur

$$\sigma_{\text{max}} = \frac{M_{\text{max}}}{W_b} = \frac{6 \cdot F \cdot L}{b \cdot h^2}$$

f_1, f_2 bei Würfeln

$$\tau = \frac{F}{A}$$

$$\tau = \frac{F}{A} = \frac{F}{b \cdot h}$$

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Zug	Max. Spannung	Zugspannung	Stahl
$\sigma_z = \frac{F}{A}$	$\sigma_z = \frac{F}{A}$	$\sigma_z = \frac{F}{A}$	

Biege	$\sigma_b = -\frac{M}{I} \cdot y$	$\sigma_b = -\frac{M}{I} \cdot y$	Re
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Biege	$\sigma_b = \frac{M}{I} \cdot y$	$\sigma_b = \frac{M}{I} \cdot y$	Re
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Schub	$\tau_{\text{max}} = \frac{F}{A}$	$\tau_{\text{max}} = \frac{F}{A}$	Re
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Torsion	$\tau_t = \frac{M_t}{I_p}$	$\tau_t = \frac{M_t}{I_p}$	Re
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Zug	$\sigma_z = \frac{F}{A}$	$\sigma_z = \frac{F}{A}$	Re
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Druck	$\sigma_d = -\frac{F}{A}$	$\sigma_d = -\frac{F}{A}$	Re
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Knick	$\sigma_k = \frac{M}{I} \cdot y$	$\sigma_k = \frac{M}{I} \cdot y$	Re
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Biege	$\sigma_b = \frac{M}{I} \cdot y$	$\sigma_b = \frac{M}{I} \cdot y$	Re
-------	----------------------------------	----------------------------------	----

Schub	$\tau_s = \frac{F}{A}$	$\tau_s = \frac{F}{A}$	Re
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Torsion	$\tau_t = \frac{M_t}{I_p}$	$\tau_t = \frac{M_t}{I_p}$	Re
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Schub	$\tau_s = \frac{F}{A}$	$\tau_s = \frac{F}{A}$	Re
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Torsion	$\tau_t = \frac{M_t}{I_p}$	$\tau_t = \frac{M_t}{I_p}$	Re
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Schub	$\tau_s = \frac{F}{A}$	$\tau_s = \frac{F}{A}$	Re
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Torsion	$\tau_t = \frac{M_t}{I_p}$	$\tau_t = \frac{M_t}{I_p}$	Re
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Schub	$\tau_s = \frac{F}{A}$	$\tau_s = \frac{F}{A}$	Re
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Torsion	$\tau_t = \frac{M_t}{I_p}$	$\tau_t = \frac{M_t}{I_p}$	Re
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Schub	$\tau_s = \frac{F}{A}$	$\tau_s = \frac{F}{A}$	Re
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Torsion	$\tau_t = \frac{M_t}{I_p}$	$\tau_t = \frac{M_t}{I_p}$	Re
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Stahl	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Re	Re	Re	Re
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Konstruktion Stahl

geg: $\sigma_{\text{zul}} = 100 \text{ N/mm}^2$

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Verallgemeinerung des Hookeschen Gesetzes

einachsige: $\sigma_x = \frac{E}{1-\mu} \epsilon_x$, $\epsilon_y = -\mu \frac{E}{1-\mu} \epsilon_x$, $\epsilon_z = -\mu \frac{E}{1-\mu} \epsilon_x$

$\sigma_x = E \cdot \epsilon_x$, $\sigma_y = 0$, $\sigma_z = 0$

Zweiachsig: σ_x, σ_y
 $\epsilon_x = \frac{1}{E} [\sigma_x - \mu \sigma_y]$, $\epsilon_y = \frac{1}{E} [\sigma_y - \mu \sigma_x]$, $\epsilon_z = -\frac{\mu}{E} (\sigma_x + \sigma_y)$

$\sigma_x = \frac{E}{1-\mu^2} [\epsilon_x + \mu \epsilon_y]$, $\sigma_y = \frac{E}{1-\mu^2} [\epsilon_y + \mu \epsilon_x]$, $\sigma_z = 0$

dreiachsig: $\sigma_x, \sigma_y, \sigma_z$
 $\epsilon_x = \frac{1}{E} [\sigma_x - \mu (\sigma_y + \sigma_z)]$, $\epsilon_y = \frac{1}{E} [\sigma_y - \mu (\sigma_x + \sigma_z)]$, $\epsilon_z = \frac{1}{E} [\sigma_z - \mu (\sigma_x + \sigma_y)]$

$\sigma_x = \frac{E}{1+\mu} [\epsilon_x + \frac{\mu}{1-2\mu} \epsilon]$, $\sigma_y = \frac{E}{1+\mu} [\epsilon_y + \frac{\mu}{1-2\mu} \epsilon]$, $\sigma_z = \frac{E}{1+\mu} [\epsilon_z + \frac{\mu}{1-2\mu} \epsilon]$
 $\epsilon = \epsilon_x + \epsilon_y + \epsilon_z$

$\tau_{xy} = G \cdot \gamma_{xy}$

$\neq 0$

einachsige: $\sigma \leq \sigma_{zul} = \frac{R_e}{S_F} = \frac{R_m}{S_B} = \frac{\sigma_w}{S_D}$

zweiachsig: $\tau \leq \tau_{zul} = \frac{R_{eT}}{S_F} = \frac{\tau_{Bz}}{S_B}$

dreiachsig: $\sigma_v \leq \sigma_{zul}$
 $\hookrightarrow \text{Fließen}$

1) N/A: $\sigma_v = \sigma_{max}$ ohne plast-Verformung

$\sigma_y = R_m$ | $\sigma_{va} = \sigma_w$
 bei der 2. dreiachsigen Zug

2) SH: $\sigma_v = \sigma_{max} - \sigma_{min} = \sigma_1 - \sigma_3 = 2 \cdot \tau_{max}$
 $\sigma_v = R_e$ | $\sigma_{va} = \sigma_w$

bei Zähl

Minimale Spannungskreis:

$\tau_{max} = \tau_k$
 einachsige: $\sigma_1 = R_e$
 zweiachsig: $\sigma_1 = R_e + \sigma_3$

3) GEH: $\sigma_v = \frac{1}{\sqrt{2}} \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}$

bei Zähl: $\sigma_v = R_e$ | $\sigma_{va} = \sigma_w$

Dreiachsige Hohlzylinder

$\sigma_a = \frac{p \cdot d_i}{2 \cdot s}$ - äußere Umfang

$\sigma_i = \frac{p \cdot d_i}{4 \cdot s}$ - innere Umfang

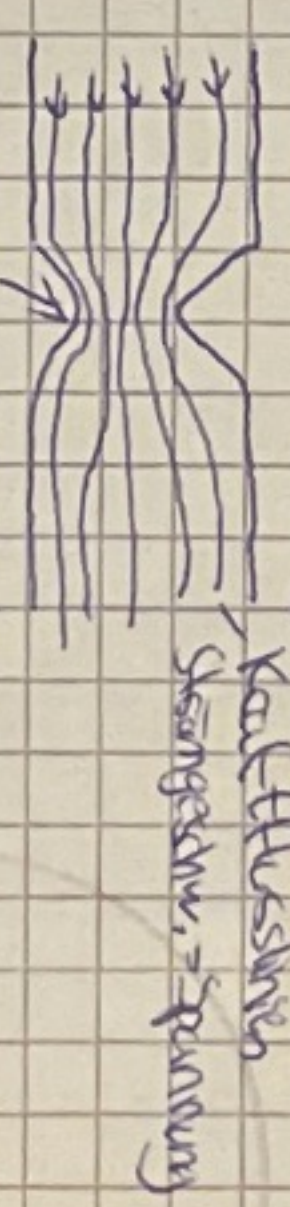
$\sigma_r = -\frac{p \cdot d_i^2}{4 \cdot s^2}$ - radial

$\sigma_v(SH) = \frac{p}{2} \cdot \frac{d_m}{s}$

FB: $\sigma_v(SH) \leq \sigma_{zul} = \frac{R_e}{S_F} = \frac{R_m}{S_B}$

Kahnleitung
 - stufenförmig in glatte Oberfläche
 - Steuerung Kraftflusses

Granulare Spannungsspitze
 - Schweißnahtanalogie:



Spannungskonzentration

σ_{max} im Kehlgund

$\sigma_n = \frac{F}{A_k} = \frac{F \cdot d_k}{A_k}$
 $A_k \rightarrow$ Nennspannung

Formelk: $\sigma_n = \frac{\sigma_{max}}{S_n}$
 $\sigma_{max} \leq R_e$

bei gleicher Geometrie: $\alpha_{T2} > \alpha_{T1} > \alpha_{T3}$

Speed: Versagen: $\sigma_{max} = R_m$

FB: $\sigma_{max} \leq \sigma_{zul} = \frac{R_e}{S_F} = \frac{R_m}{S_B}$
 Fließbeginn: $\sigma_{max} = R_e$
 Stützzeit: $\sigma_{zul} = \frac{R_e}{S_F}$ | $\sigma_{max} = R_e$ | $\sigma_{zul} = \frac{R_e}{S_F}$

ungekettete Stahl

Buch: $S_n = R_m = \frac{F_{max}}{A_0}$
 Schweißnaht: $\sigma_a = \sigma_w$
 gekettete Stahl

Buch: $S_n = R_m = \frac{F_{max}}{A_k}$

FB: $S_n \leq \sigma_{zul} = \frac{R_m}{S_B}$

Schweißnaht: $\sigma_{a,max} = \sigma_w$
 $\sigma_a = \sigma_w$

$\Rightarrow$ Druckfestigkeit: $\sigma_{wk} = \frac{\sigma_w}{\alpha_k}$
 statisch: Verbundzahl β_c :

$\beta_c = \frac{\sigma_w}{\sigma_{wk}} = \frac{\sigma_a}{\sigma_{wk}}$

$1 \leq \beta_c \leq \alpha_k$
 keine Verbundwirkung
 max. Verbundwirkung

Stoß-Verbund: $\beta_c = \frac{\alpha_k}{n \cdot x}$
 $\rightarrow$ dyn. Stützeffekt

Schweißnaht: $\sigma_{a,max} = \sigma_a$

FB: $\sigma_{a,max} \leq \sigma_{zul}$

$\beta_c = \sigma_a = \sigma_{zul}$
 $= \frac{\sigma_a}{S_n}$

für Speed und Zähl

Detmann: $\beta_c = \frac{\alpha_k}{1 + \frac{S_n}{\alpha_k \cdot R_e}}$

Vollplast.: $F_{vpl} = R_e \cdot A_k$
 bei Teilplast.

von 1465

Zäh $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$ $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$ $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$

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Spez $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$ $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$ $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$

Schwingen $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$ $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$ $\sigma_{\text{max}} \leq \sigma_{\text{zul}}$

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