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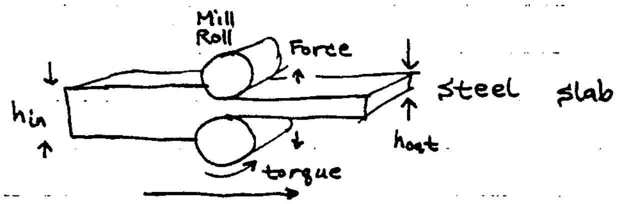
Description of Reversing Mill Setup Problem



When we roll a slab, we can calculate the torque and force required. The equation for force is (note: there are probably small errors in these eqns):

force $P = \sigma_o' \, b \, L_p \, Q_g$

constrained yield stress $\sigma_o' = \frac{2}{\sqrt{3}} \sigma_o \, X_{\sigma\epsilon} \, X_{\sigma\dot{\epsilon}} \, X_{\sigma x} \, X_{\sigma T}$

strain correction $X_{\sigma\epsilon} = 1 + k_{\sigma\epsilon} \frac{\epsilon - \epsilon_{nom}}{\epsilon_{nom}}$ $k_{\sigma\epsilon}$ = constant

strain $\epsilon = (1-r) \ln \frac{1}{1-r} + \ln \frac{h_o}{h_{in}}$ ϵ_{nom} = nominal $\epsilon = \ln 2$

reduction $r = \frac{\Delta h}{h_{in}}$ nominal $r = .35$

draft $\Delta h = h_{in} - h_{out}$

thickness or gauge h_{in} = entry ~~exit~~ gauge h_o = initial gauge = 8.6"
h_{out} = exit gauge

σ_o = nominal yield stress for steel = 7.0 tons/in^2

strain rate correction $X_{\sigma\dot{\epsilon}} = 1 + k_{\sigma\dot{\epsilon}} \frac{\dot{\epsilon} - \dot{\epsilon}_{nom}}{\dot{\epsilon}_{nom}}$ $k_{\sigma\dot{\epsilon}}$ = constant

strain rate $\dot{\epsilon} = \frac{2\pi\omega R}{L_p} \ln \frac{1}{1-r}$ $\dot{\epsilon}_{nom} = 2\pi\sqrt{21} \ln \frac{1}{.65} = 12.4/s$

mill speed ω = rotation rate in rotations/sec

roll radius R = mill roll radius in inches nominal $R = 21"$

contact arc length $L_p = \sqrt{\Delta h \, R}$

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hardness correction $X_{\sigma x} = 1 + k_{\sigma x} \dfrac{x - x_{nom}}{x_{nom}}$ $k_{\sigma x}$ = constant

hardness x = # in range [0, 100] $x_{nom} = 25$

temperature correction $X_{\sigma T} = 1 + k_{\sigma T} \dfrac{T - T_{nom}}{T_{nom}}$ $k_{\sigma T}$ = constant

temperature T = °F range [1700, 2300] $T_{nom} = 2100$ °F

width b = width in inches

geometry factor $Q_g = -\dfrac{\zeta}{2} + \gamma \left[\zeta \tan^{-1} \gamma^{-1} - \beta \dfrac{m}{2} \ln \dfrac{h_n^2}{h_{in} h_{out}} \right]$

reduction factor $\gamma = \sqrt{\dfrac{1-r}{r}}$

radius-gauge factor $\beta = \sqrt{\dfrac{R}{h_{out}}}$

inclined plane shear factor $\zeta = \dfrac{\pi}{2}$

neutral pt gauge $h_n = h_{out} + R\theta_n^2$

neutral angle $\theta_n \approx \dfrac{1}{\beta} \left[\dfrac{1}{4\beta m} \ln \gamma^{-1} + \zeta \tan^{-1} \dfrac{1}{1-r} \right]$

Neutral pt. is where roll speed = slab speed in roll bite. Bar moves faster as gauge reduced.

friction factor m = # in range [0, 1] nominal $m = 1$

The equation for torque is:

$$\tau = 0.46 \, L_p \, P$$

Setup problem: Given slab parameters, find max Δh that satisfies force limit P_{max} and torque limit τ_{max}. The above eqns give us force (or torque) as a func of Δh, T, x, etc. We want the inverse func that gives us Δh as a func of P_{max}, T, x, etc.