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Mode III Dynamic Crack Growth and asymptotically Vanishing Hardening Rate

Talk given at the 7th International Congress on Fracture (ICF7), Houston, TX. USA, Orationem Meam

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1989

Document Version:
Publisher's PDF, also known as Version of record

Link to publication

Citation for published version (APA):
Ståhle, P. (1989). Mode III Dynamic Crack Growth and asymptotically Vanishing Hardening Rate: Talk given at the 7th International Congress on Fracture (ICF7), Houston, TX. USA, Orationem Meam.

Total number of authors:
1

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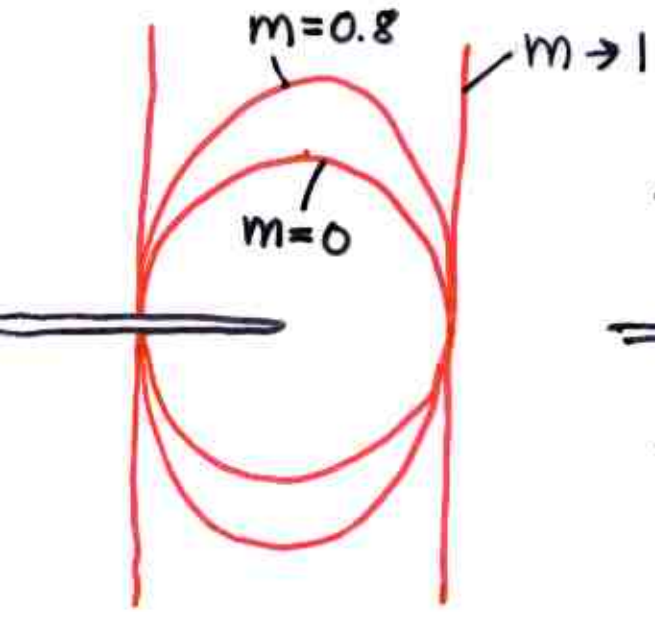
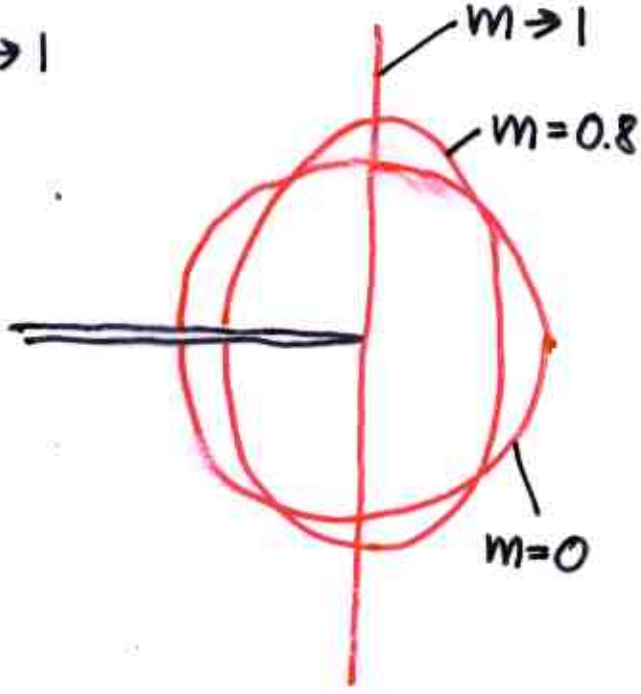
Download date: 12. Oct. 2024

Mode III - High Strain Rates (Ståhle, 1989)



Constant K_{III}



Constant G

Shape of the plastic zone:

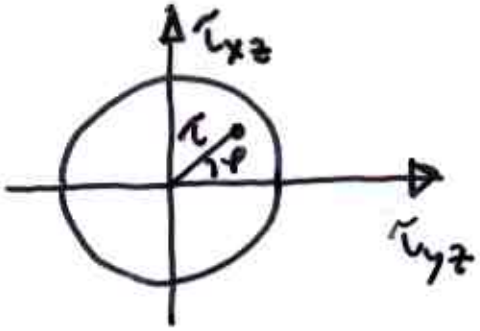
$$4\tau^4x^4-4\alpha^2\tau^2x^3+4\tau^2x^3-4\alpha^2x^2-y^2-2\alpha^2y^2+$$
$$+\alpha^4y^2+4\tau^2xy^2-4\alpha^2xy^2+8\tau^4x^2y^2+4\tau^4y^4=0$$

Hodograph transform:

$$\tau_{xz}(x,y),\ \tau_{yz}(x,y) \rightarrow x(\tau_{xz},\tau_{yz}),\ y(\tau_{xz},\tau_{yz})$$

Elastic plastic boundary at:

$$\tau_{xz}^2+\tau_{yz}^2=\tau_Y^2$$



$$(1-m^2\sin^2\varphi)\,\Delta_\tau \dot{w} + m^2\left(\sin\varphi\left[\frac{\partial}{\partial\tau}-\frac{1}{\tau}\right]\frac{\partial\dot{w}}{\tau\partial\varphi} - \cos 2\varphi\,\frac{\partial^2\dot{w}}{\partial\tau^2}\right) =$$

$$= \frac{2\lambda(\tau-\tau_Y)^n}{\tau^4\tau_Y^n}\left\{\frac{(n-1)\tau+\tau_Y}{\tau-\tau_Y}\left(1-m^2\left[1+2\cos^2\varphi+\frac{m^2}{2}\sin^2 2\varphi\right]\right)+\right.$$

$$\left.+m^2\left[1-4\cos^2\varphi-m^2\sin\varphi\right]\right\}\sin\varphi$$

$n=1$

$$\dot{w} = \left\{2\dot{\gamma}_0 r + \left[3v+\dot{\gamma}_0(3r-R)\right]\left(\frac{R}{r}\right)^{1/2}\right\}\frac{\tau_Y\sin\theta/2}{3\mu}$$

$$+ m^2\{\quad\}\frac{\tau_Y\sin\theta/2}{3\mu} + m^2\{\quad\}\frac{\tau_Y\sin 3\theta/2}{3\mu} + O(m^4)$$

$n=2$

$$\dot{w} = \left\{2\dot{\gamma}_0(r+3R) + \left[3v+4\dot{\gamma}_0(3r-2R)\right]\left(\frac{R}{r}\right)^{1/2}\right\}\frac{\tau_Y\sin\theta/2}{3\mu} +$$

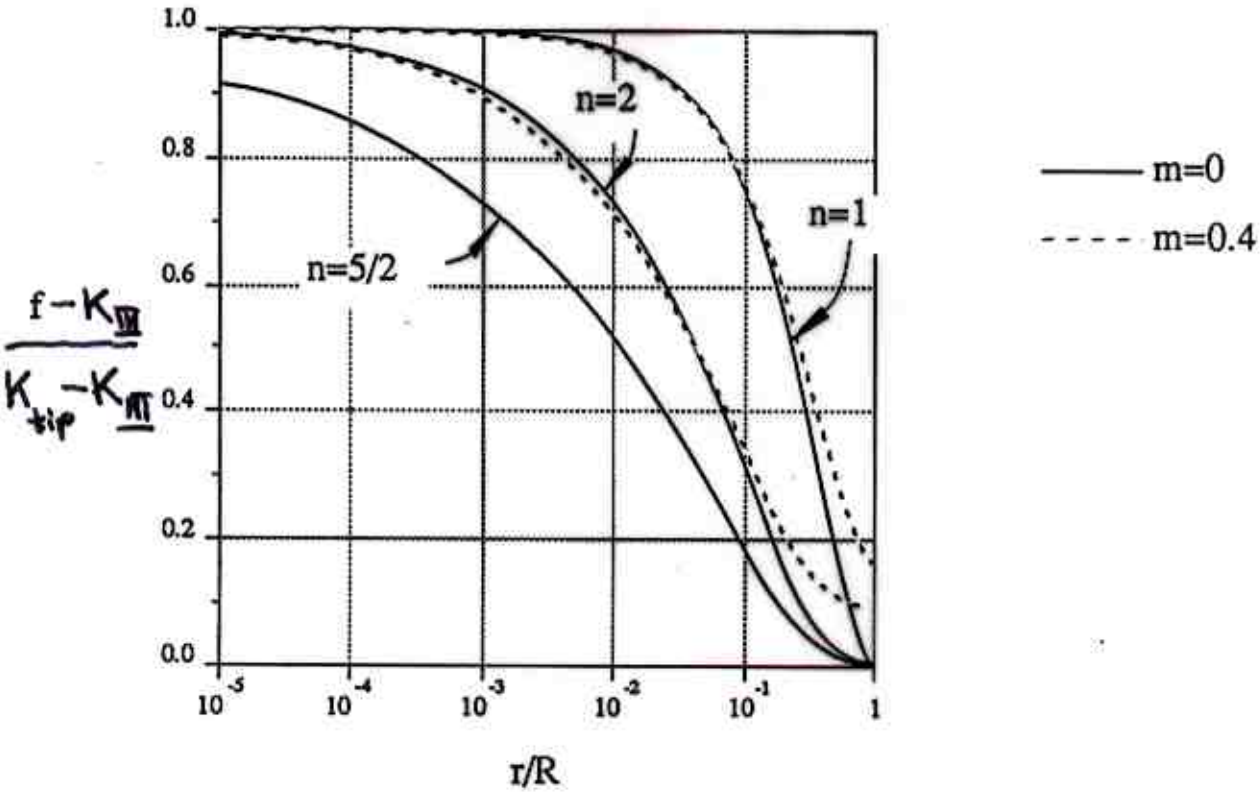
$$+ O(m^2)$$

$n=2.5$

$$\dot{w} = \left\{\dot{\gamma}_0 R(33z^5+40z^3+15z) + (12v-15\dot{\gamma}_0 R\tan^{-1}z)\left(\frac{R}{r}\right)^{1/2}\right.\frac{\tau_Y\sin\theta/2}{3\mu} +$$

$$+ O(m^2) \quad ; \quad z = \left[(R/r)^{1/2}-1\right]^{1/2}$$

$$f = \frac{\dot{w}\sqrt{2\pi r}}{v \sin\theta/2} \Rightarrow f \to \begin{cases} K_{III} & \text{as } r \to \infty \text{ and } \theta \to 0 \\ K_{tip} & \text{as } r \to 0 \text{ and } \theta \to 0 \end{cases}$$



90% obtained at

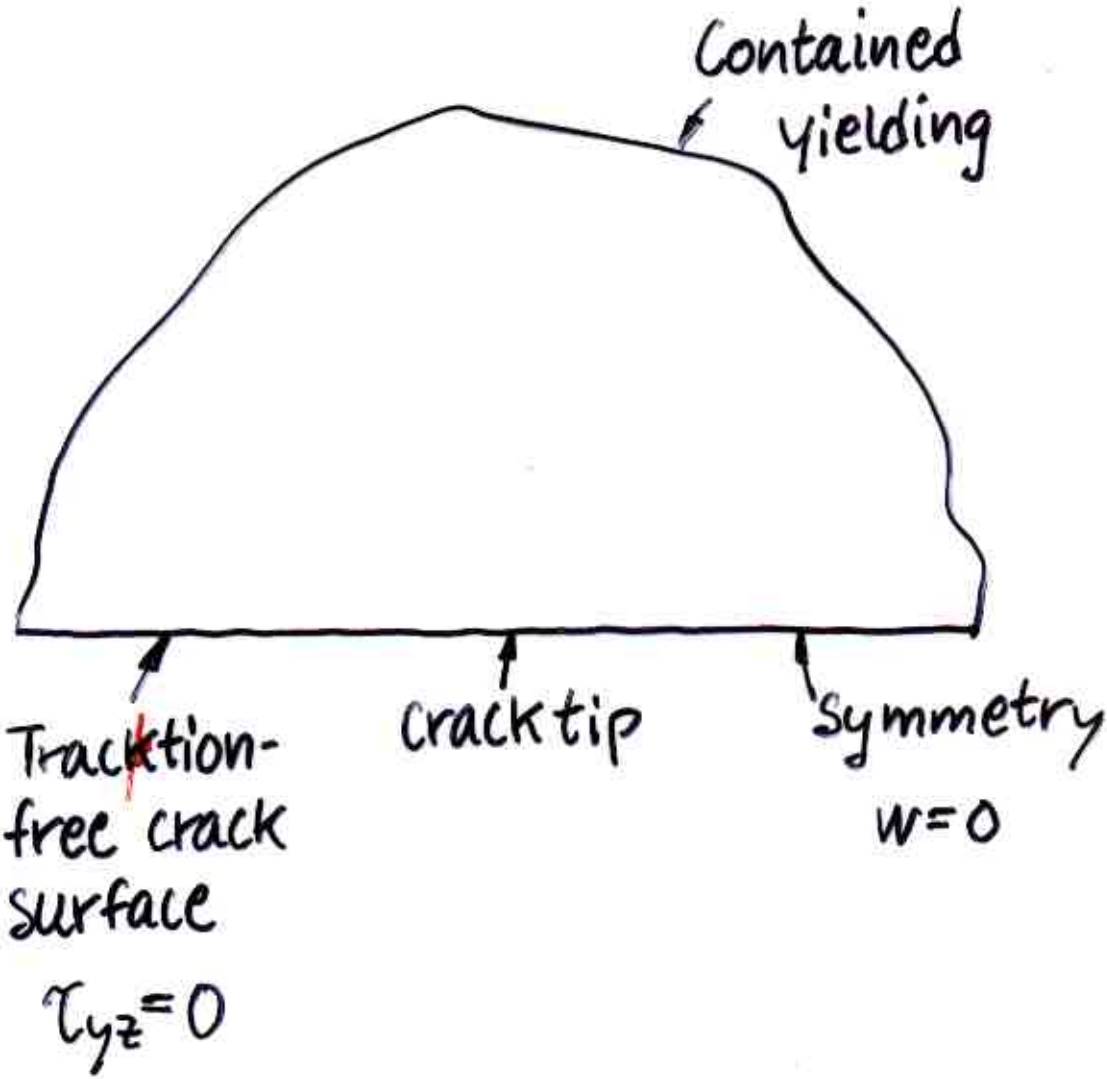
R/30 for n = 1

R/1000 for n = 2

$R/10^5$ for n = 2.5

- Mode III
- Asymptotic Field
- Steady Quasi Static Growth
- Inertia Terms Included

Boundary Conditions



Steady state

$$\dot{(\ )} \equiv -V \frac{\partial}{\partial x}$$

Linear strain hardening

$$G_t \dot{\gamma}_{xz} = \alpha \dot{\tau}_{xz} + (1-\alpha)\tau_{xz}\dot{\tau}\tau^{-1}$$

$$G_t \dot{\gamma}_{yz} = \alpha \dot{\tau}_{yz} + (1-\alpha)\tau_{yz}\dot{\tau}\tau^{-1}$$

Equation of motion

$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} = \rho \ddot{w}$$

Compatibility

$$\frac{\partial \gamma_{xz}}{\partial y} - \frac{\partial \gamma_{yz}}{\partial x} = 0$$

Primary plastic zon

Perfectly plastic $\sigma_t = 0$

$$\tau_{rz} = 0 \qquad \dot{\tau}_{rz} = -kr^{-1}\sin\theta$$

$$\tau_{\theta z} = k \qquad \dot{\tau}_{\theta z} = 0$$

Here

$$\tau_{rz} = kr^{s}T_{rz} \qquad \dot{\tau}_{rz} = kr^{s-1}(-\sin\theta + t_{rz})$$

$$\tau_{\theta z} = kr^{s}(1+T_{\theta z}) \qquad \dot{\tau}_{\theta z} = kr^{s-1}t_{\theta z}$$

Continuity conditions

$\dot{w}$, w

$\dot{\tau}_{sz}$, τ_{sz}