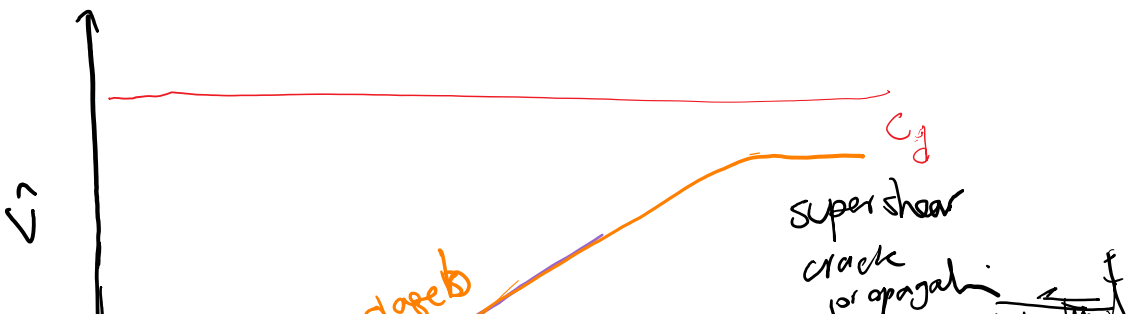
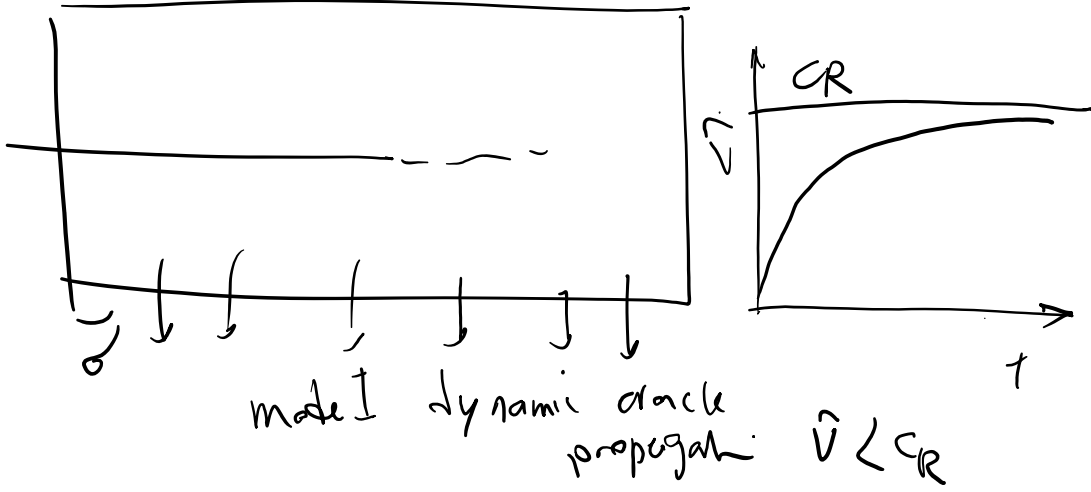
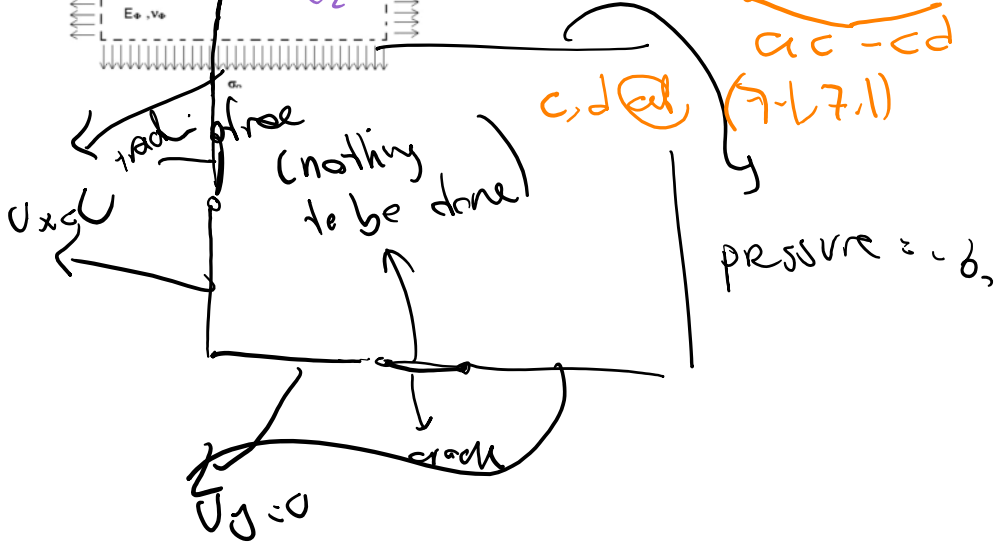
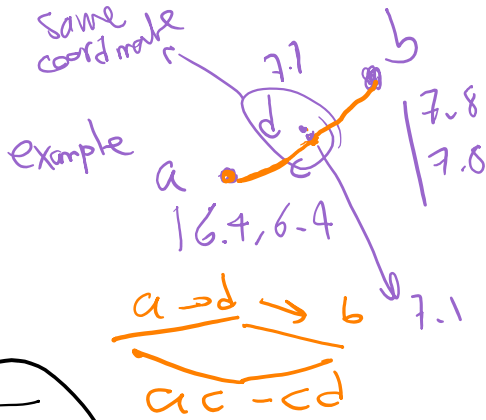
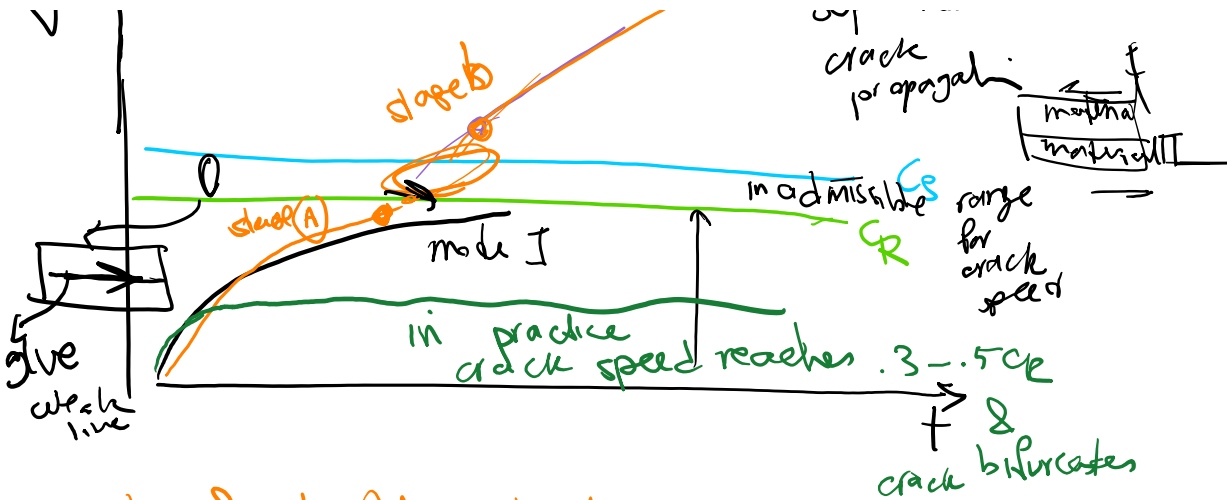


Assumptions  
 $\nu_p = \nu_w = 1/3$   
 $\frac{E_w}{E_p} = 10.0$   
 $\alpha_2 = \alpha_1 = 1$   
 $\sigma_0 = 1.0$   
 $c = 3$



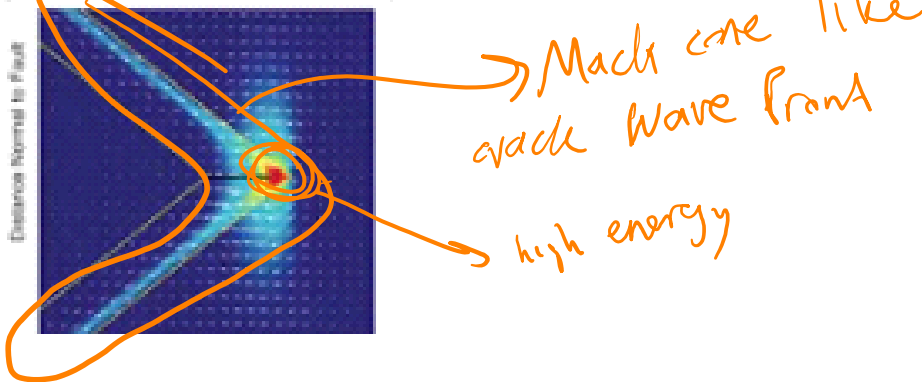


mother & daughter crack

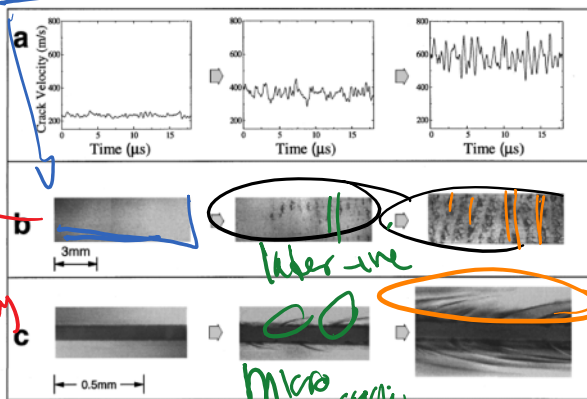


### Multiple successes of ea

Supershear rupture  
(Dinmami and Archuleta, 2005)



Sharon Fineberg:  
mirror, mist, hackle patterns as the crack accelerates

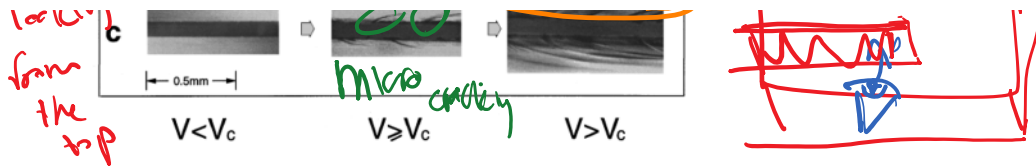


$$v_C = 340 \text{ m/s}$$

(or  $0.36 V_R$ )

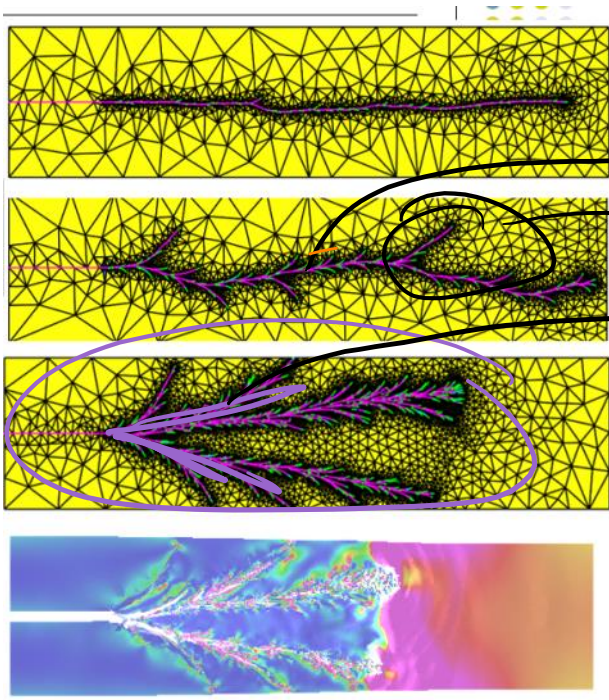
looking from ...





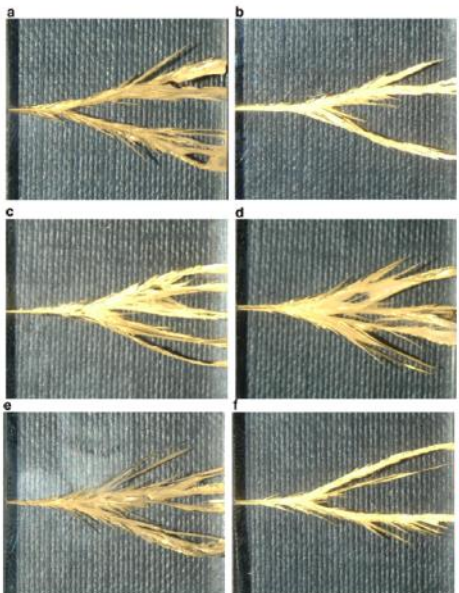
looking from the top

- Crack starts oscillating well before reaching Rayleigh wave speed  $V_R (c_R)$
- Crack speed does not reach  $V_R (c_R)$ !
- For this material critical speed  $v_c = 0.36 V_R$



oscillation  
micro cracking  
bifurcation  
higher amplitude band

### Sample fracture patterns for brittle materials?



Sample simulation

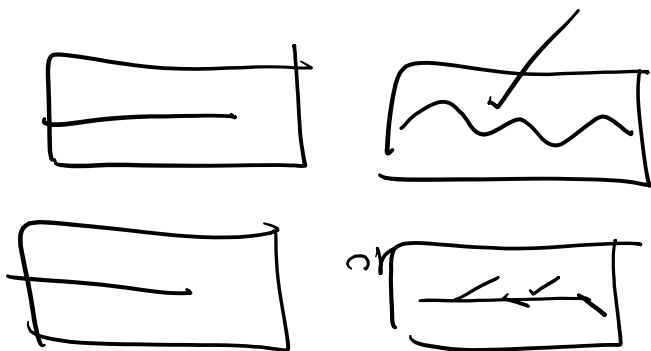
Why cracks bifurcate and we get microcracks for brittle materials?

Murphy 2006

Why many cracks (micro cracking or bifurcation) instead of 1 crack?

or why crack oscillates

Because material dissipates more energy



**SURFACE ROUGHENING AND BRANCHING INSTABILITIES IN DYNAMIC FRACTURE**

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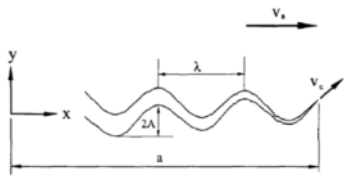


Fig. 1. A cosine wave crack propagating at local velocity  $v_s$  and apparent velocity  $v_a$ . The fracture surface is roughened with parameters  $\Delta$  and  $\lambda$ .

wavy pattern is energetically more favorable at higher crack speeds

Int J Fract (2007) 143:245–271  
DOI 10.1007/s10704-007-9061-z

ORIGINAL PAPER

**Theory of dynamic crack branching in brittle materials**

E. Katzav · M. Adão-Bella · R. Arias

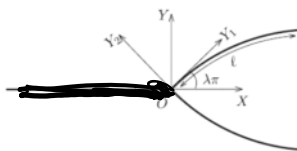
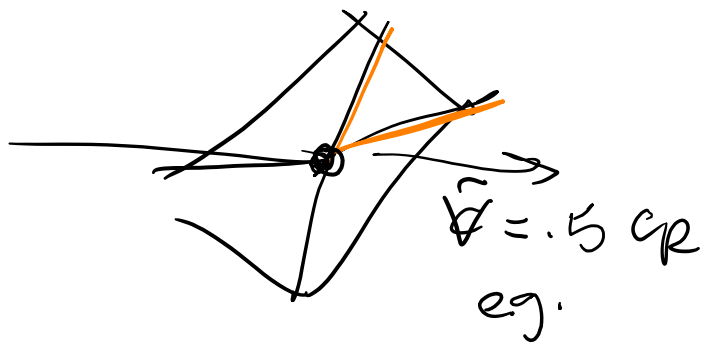


Fig. 1 Schematic representation of a straight crack with two symmetrically branched curved extensions

Why and when the cracks bifurcate?

The crack bifurcates when energetically 2 cracks dissipate more energy & is energetically favorable to crack?

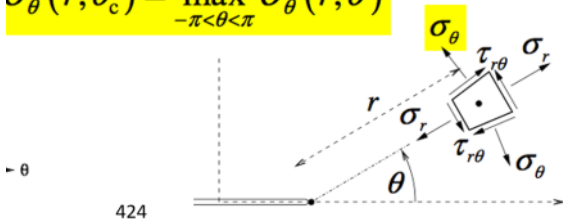


— Energy is one explanation why we get oscillation, microcracking, & macrocracking (bifurcation) at higher crack speeds.

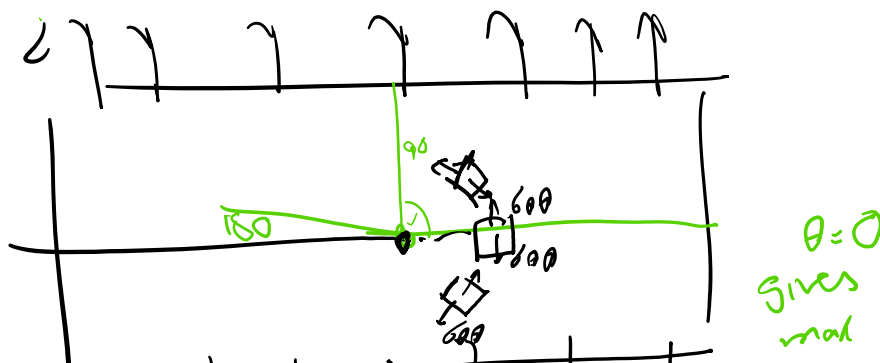
Another point of view is that the straight crack path simply becomes more unstable!

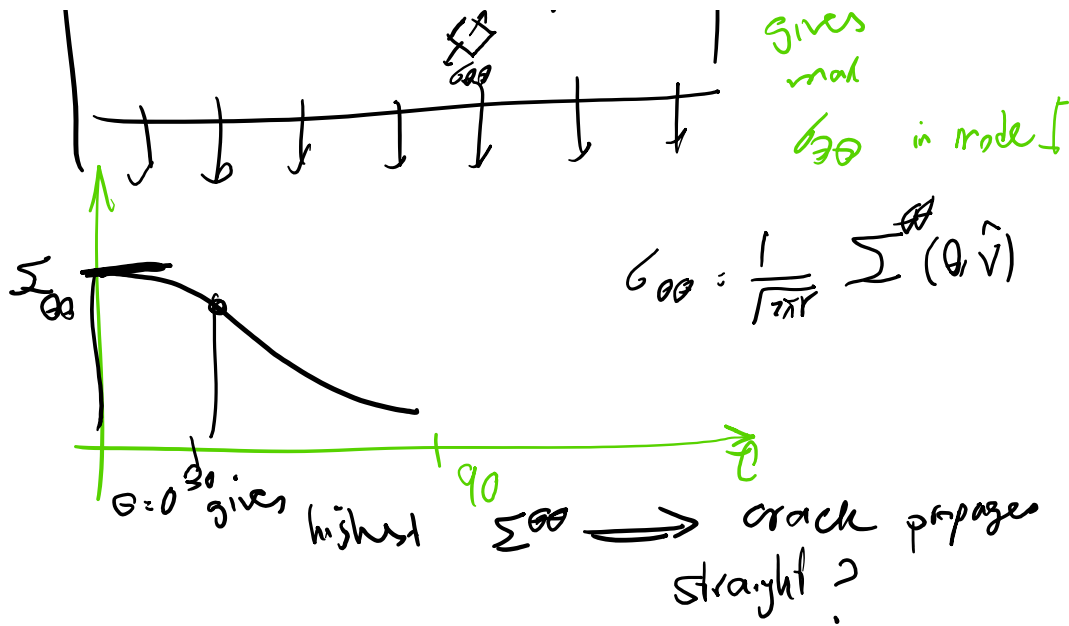
Maximum circumferential stress:

$$\sigma_{\theta}(r, \theta_c) = \max_{-\pi < \theta < \pi} \sigma_{\theta}(r, \theta)$$



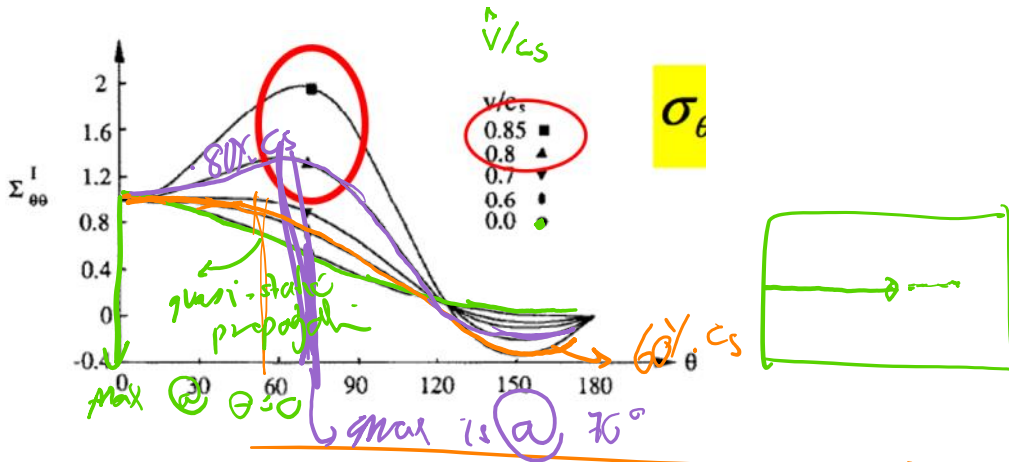
crack propagates in the direction that  $\sigma_{\theta}$  is maximum.



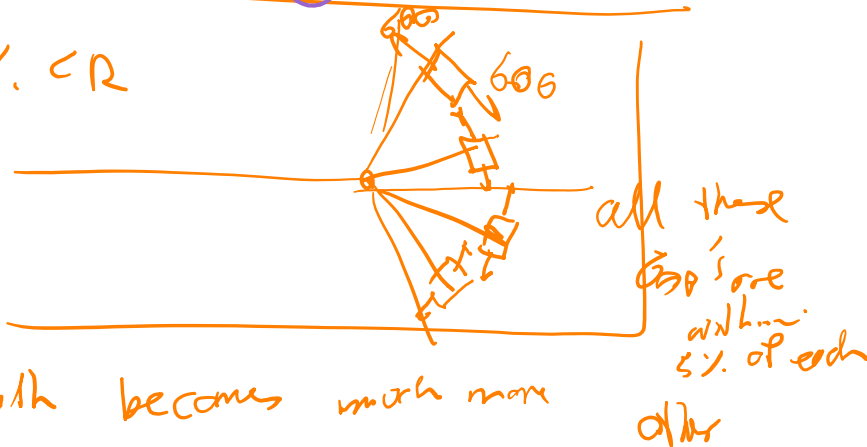


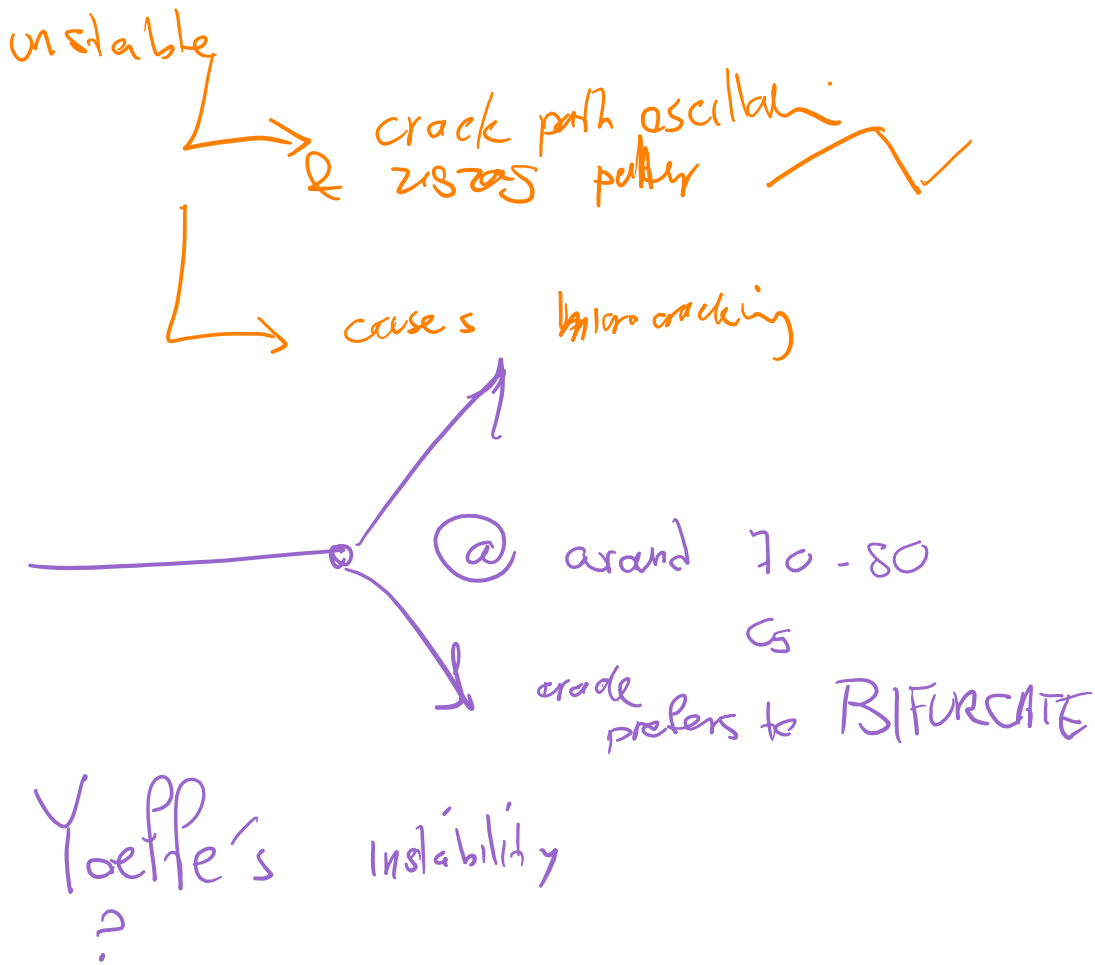
$$\Sigma_{\theta\theta}(\theta, \hat{v})$$

as  $\hat{v} \rightarrow CR$   
 the profile of  $\Sigma_{\theta\theta}$  versus  $\theta$  changes!



@ 60%  $c_r$





Dynamic crack propagation

Griffith criterion

$$G = R$$

← ERR

↗ fracture toughness

crack can propagate

mode I

Static

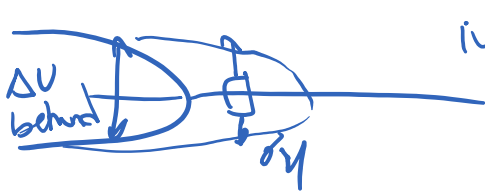
$$G = \frac{K_I^2}{2E'}$$

Dynamic

$$G_d = A(\hat{v}) \frac{K_I^2(\hat{v})}{E}$$

universal

limit of crack speed



if we do this in dynamic we end