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CTOA COME PARAMETRO DI MECCANICA DELLA FRATTURA ELASTO PLASTICA: MISURA E APPLICAZIONI.

La cinematica della frattura fornisce semplici relazioni geometriche che correlano i parametri di deformazione macroscopica di una provetta al CTOA (Crack Tip Opening Angle).

In questa trattazione il CTOA viene pertanto assunto come parametro metallurgico caratterizzante la propagazione della frattura in campo elasto-plastico.

Per la pratica applicazione di questo concetto si procede in due direzioni. Da una parte, attraverso prove di laboratorio, si sta verificando la variazione del CTOA durante il procedere della frattura in diversi tipi di provette sia lungo il legamento che lungo lo spessore. Inoltre si valuta l'influenza dello spessore e della velocità di applicazione del carico sulla misura.

Dall'altra parte si stanno studiando le possibili applicazioni ingegneristiche in particolare nel campo della propagazione della frattura duttile nei gasdotti ed in quello dell'instabilità di difetti circonferenziali nelle tubazioni.

10.3.1983

SENB 3 SPECIMEN

① CUT BROKEN SPECIMENS IN TWO OR MORE PARTS

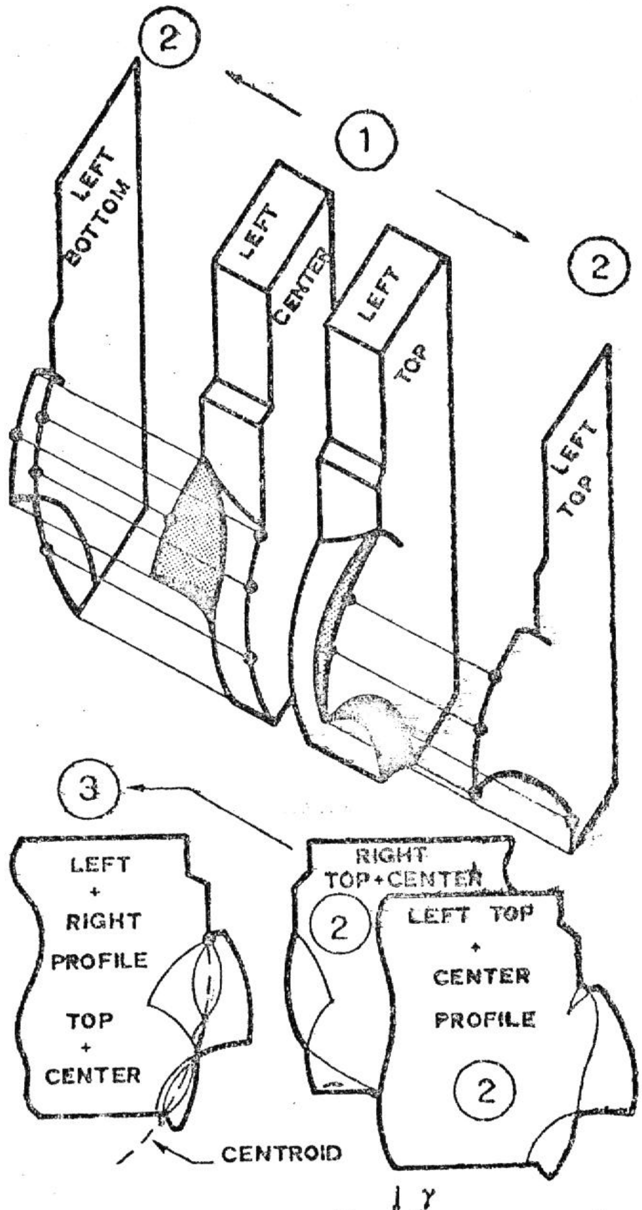
② DRAW THE RIGHT AND THE LEFT FRACTURE PROFILES

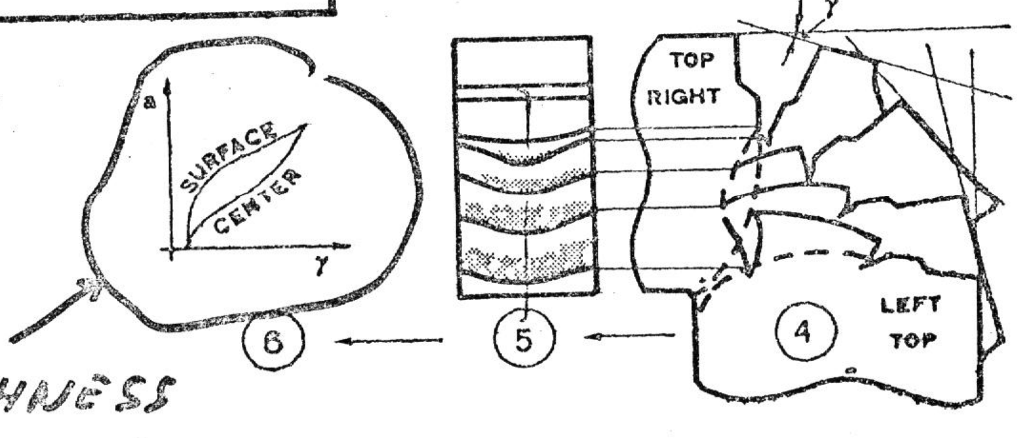
③ USING ITERATIVE PROCEDURE DRAW THE CENTROIDS

④ MADE ROTATE THE FRACTURE PROFILES ON THE CENTROIDS

⑤ DRAW THE FRACTURE FRONTS

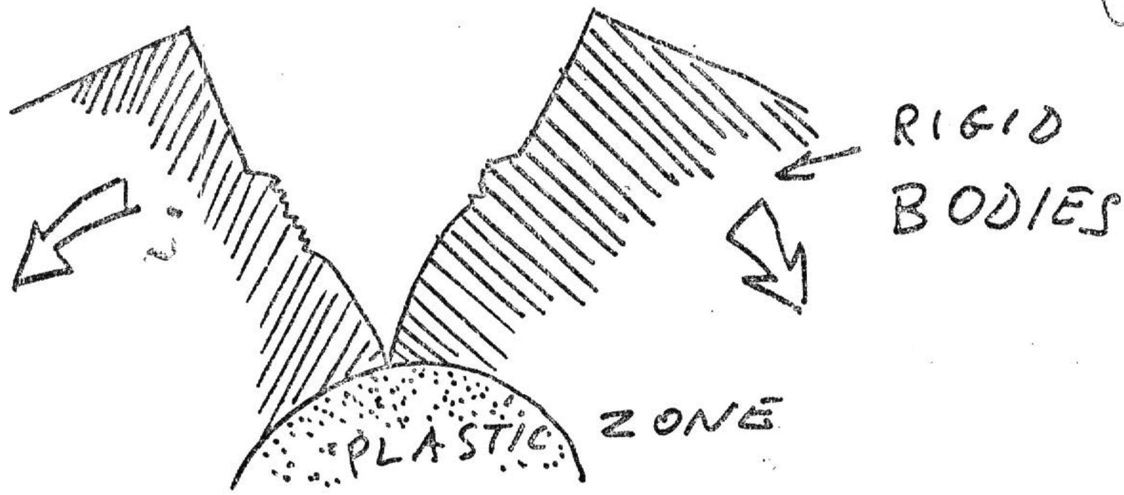
⑥ ASSOCIATE THE FRACTURE FRONT TO THE BENDING ANGLE OR TO THE SPECIMEN DISPLACEMENT





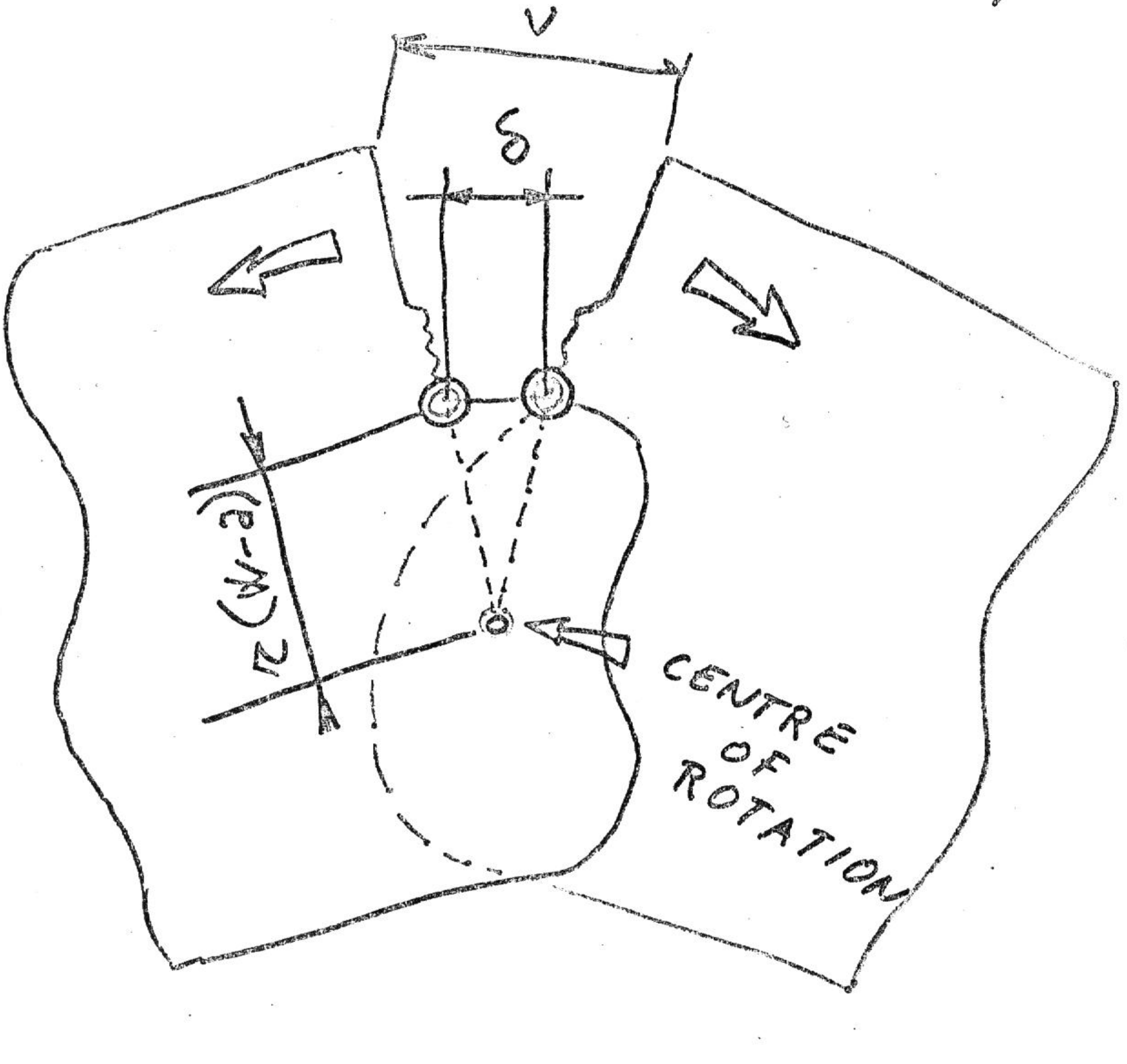
TOUGHNESS

$\frac{d\delta}{da}$ or $\frac{d\gamma}{da}$



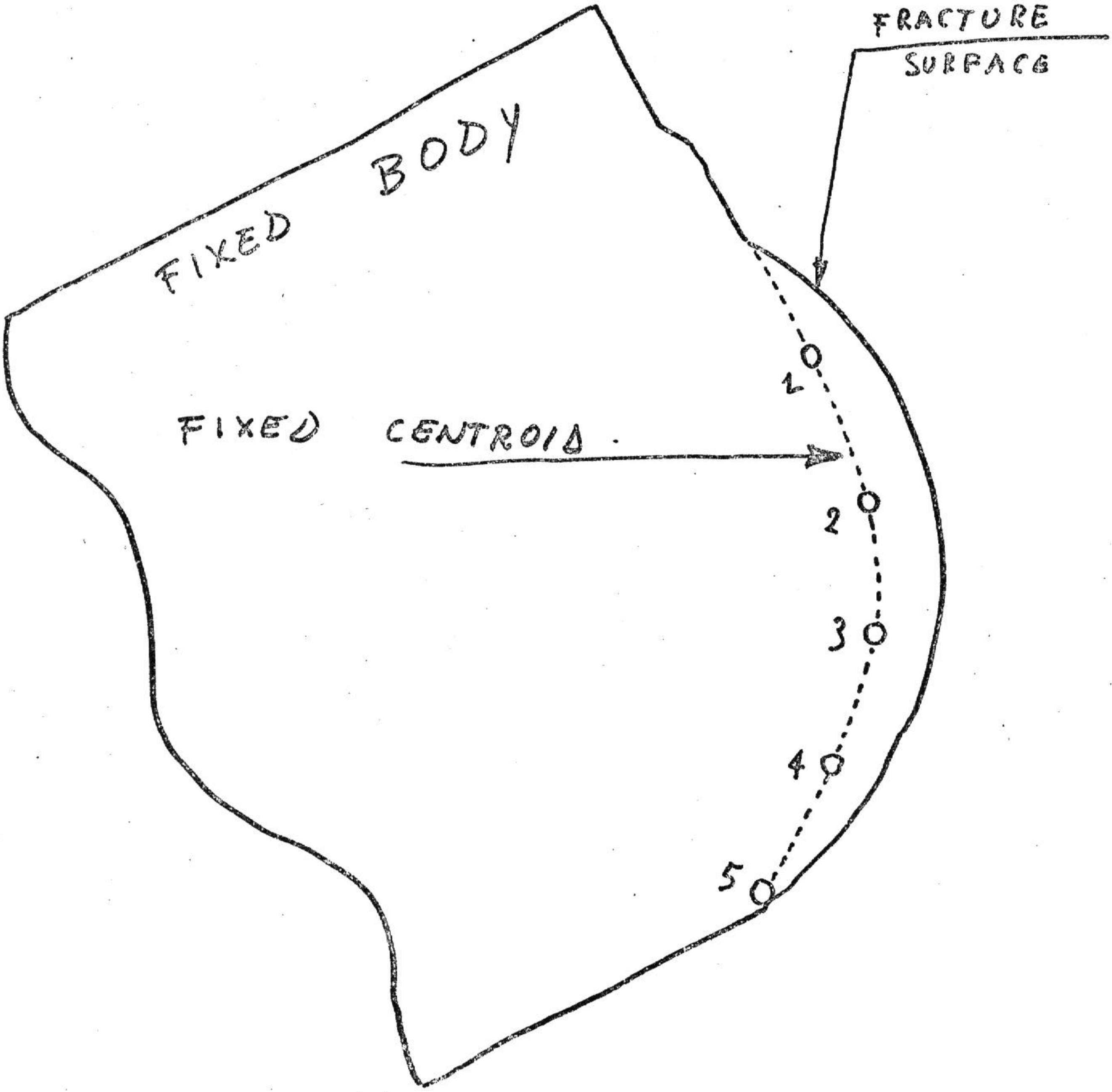
THE MOTION OF TWO RIGID BODIES IS KNOWN WHEN THE RELATIVE DISPLACEMENT OF TWO POINTS AND THE CENTRE OF ROTATION ARE KNOWN AT EACH INSTANT

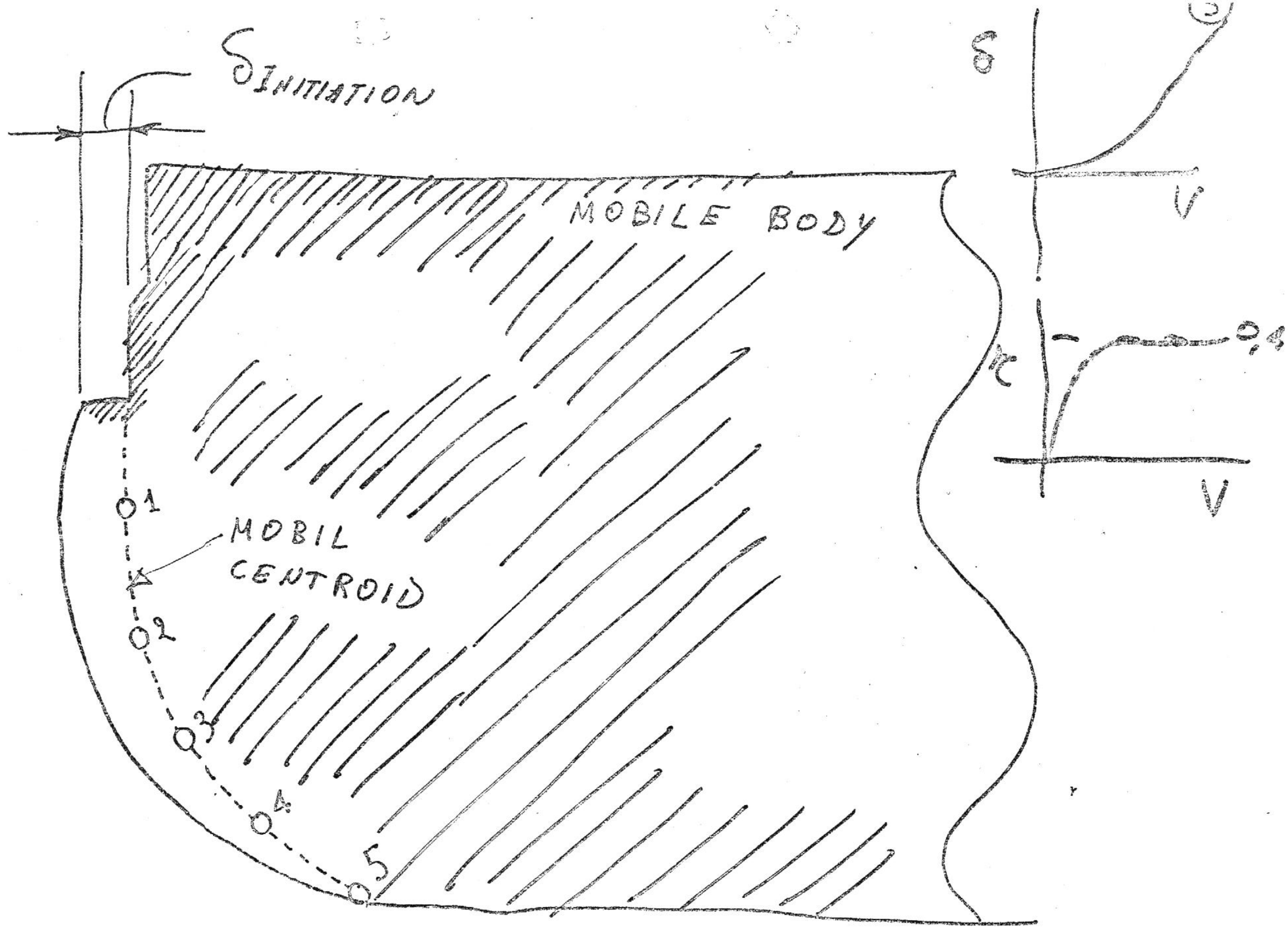
FOR A SPECIMEN WHEN:
δ AND $r(W-a)$ ARE KNOWN FROM A COD CALIBRATION: or V, δ.



THE MOTION OF TWO RIGID BODIES IS DEFINED BY PURE ROTATION OF THE MOBILE CENTROID ON THE FIXED ONE

THE CENTROIDS ARE THE ~~LOCUS~~ LOCI OF THE CENTRES OF ROTATION.

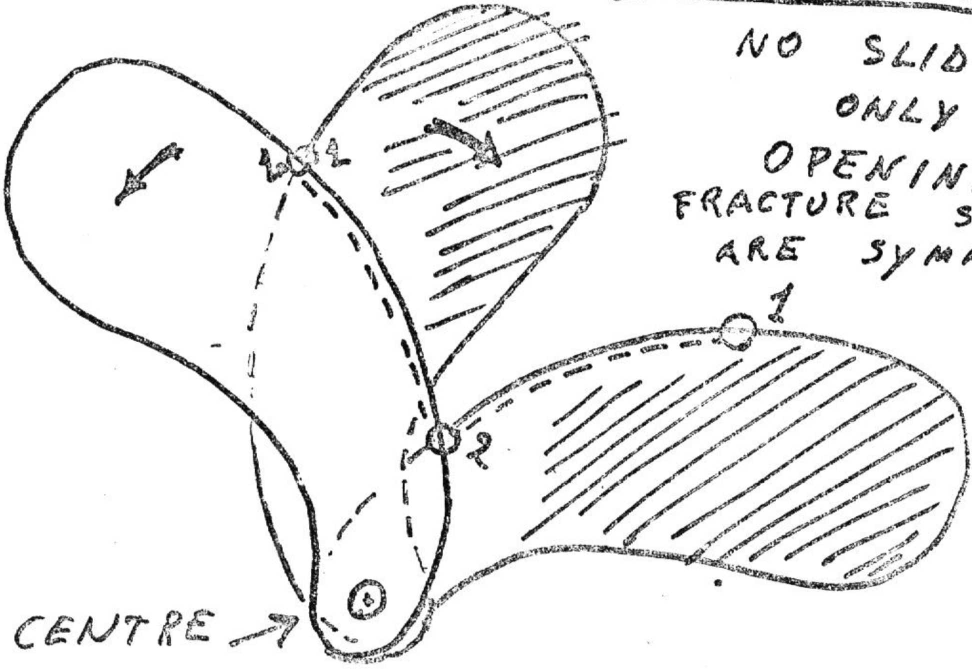




δ INITIATION
MOBILE BODY
MOBIL
CENTROID
1
2
3
4
5
δ
V
κ
0,4
V

MODE I OPENING

NO SLIDING
ONLY
OPENING
FRACTURE SURFACES
ARE SYMMETRIC

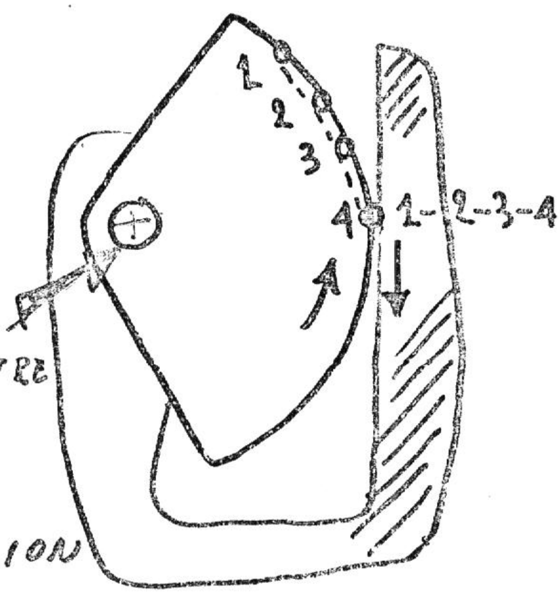


CENTRE
OF ROTATION

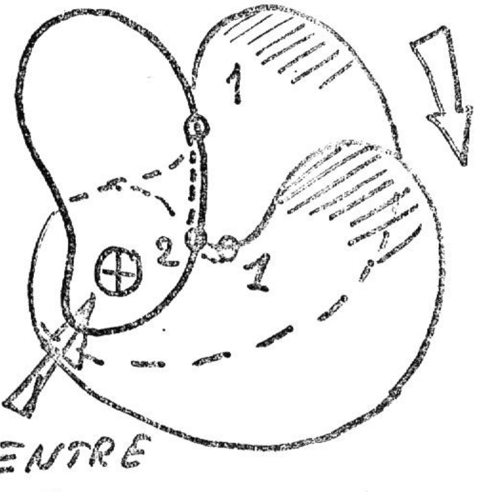
MODE I + II

MODE II OPENING

PURE SLIDING



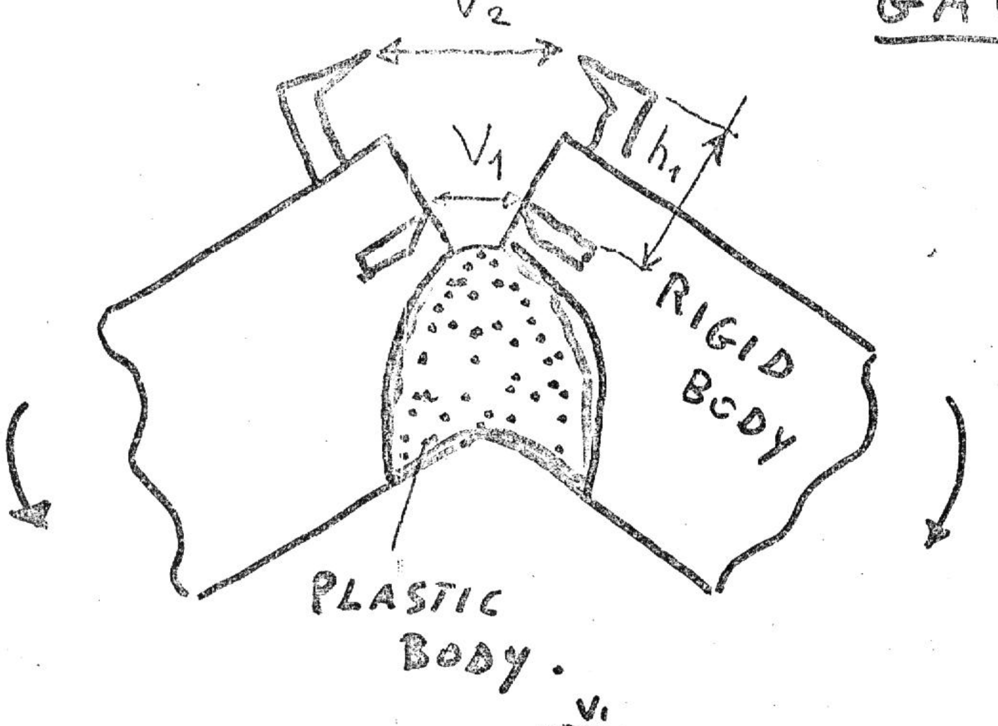
CENTRE
OF
ROTATION

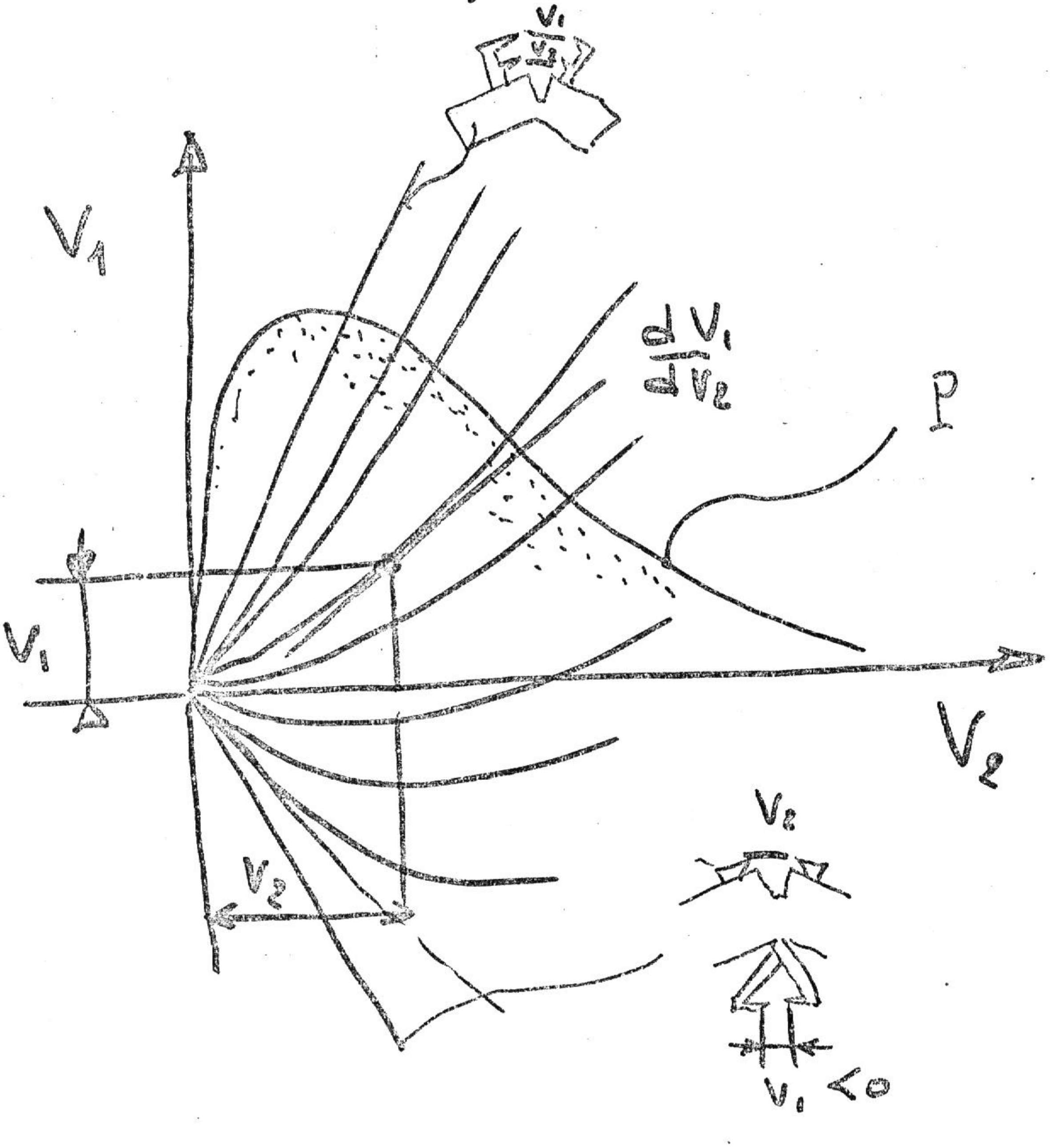


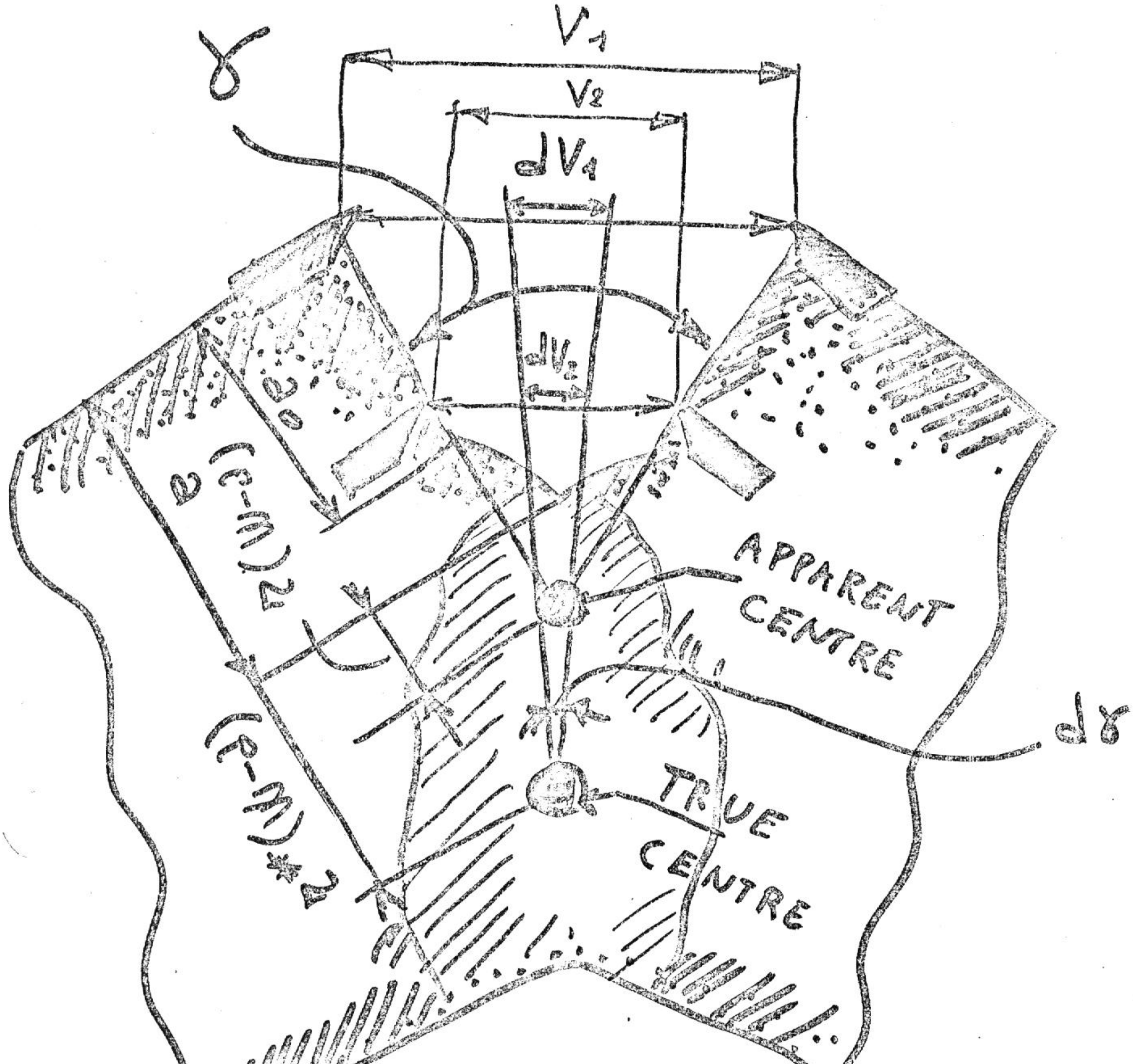
CENTRE
OF
ROTATION

SLIDING
AND
OPENING.

TWO CLIP GAUGES.






V_1
V_2
γ
dV_1
dV_2
$90°$
$(\rho-M)2$
$(\rho-M)^*2$
APPARENT
CENTRE
$d\gamma$
TRUE
CENTRE

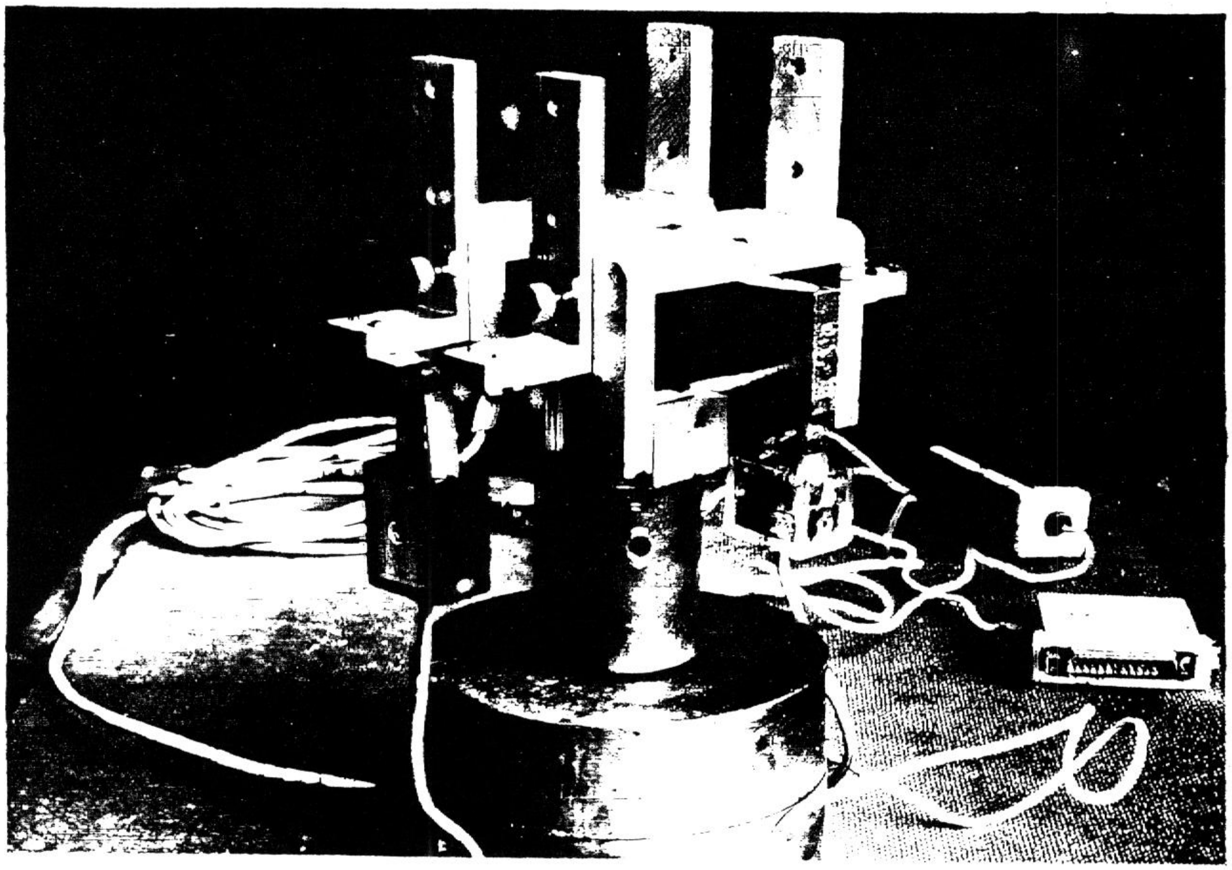


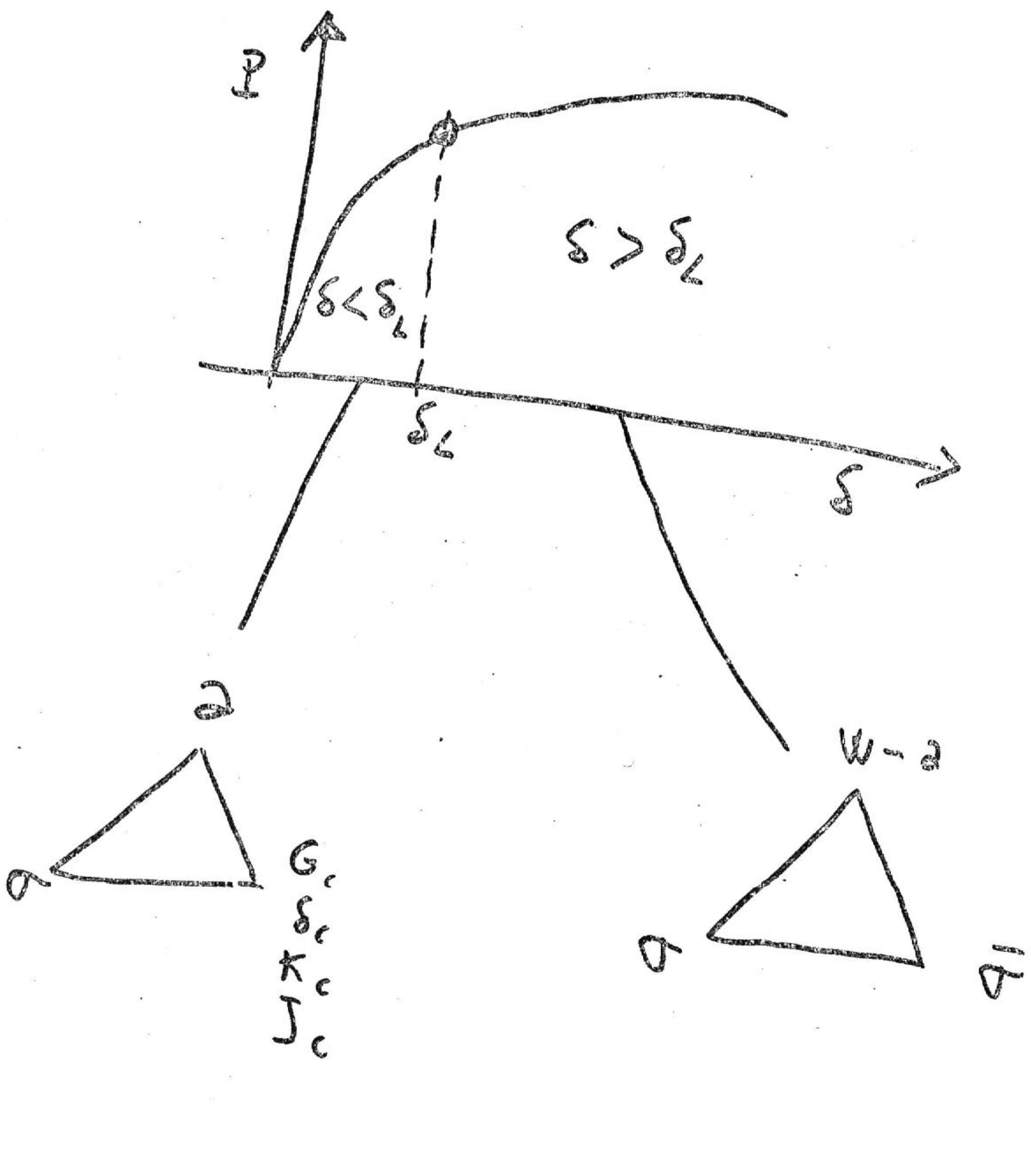
Photo 1 - Experimental assembling.

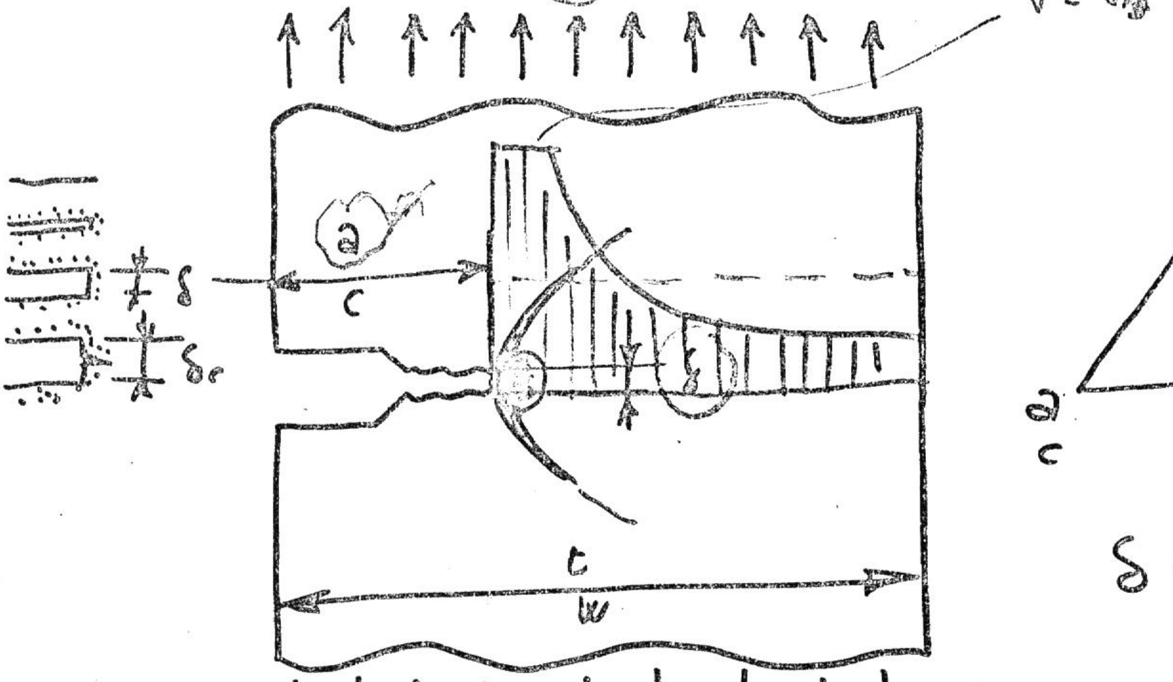
AT CUSP

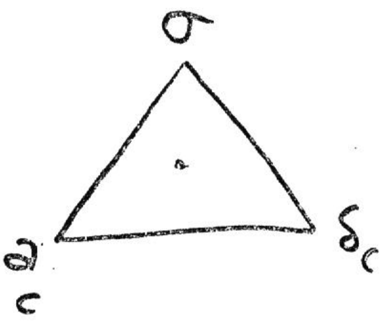
$$\delta \doteq \pi \, \varepsilon_y \, a \left(1 - \frac{a}{W}\right)^2$$

We DEFINE δ at cusp

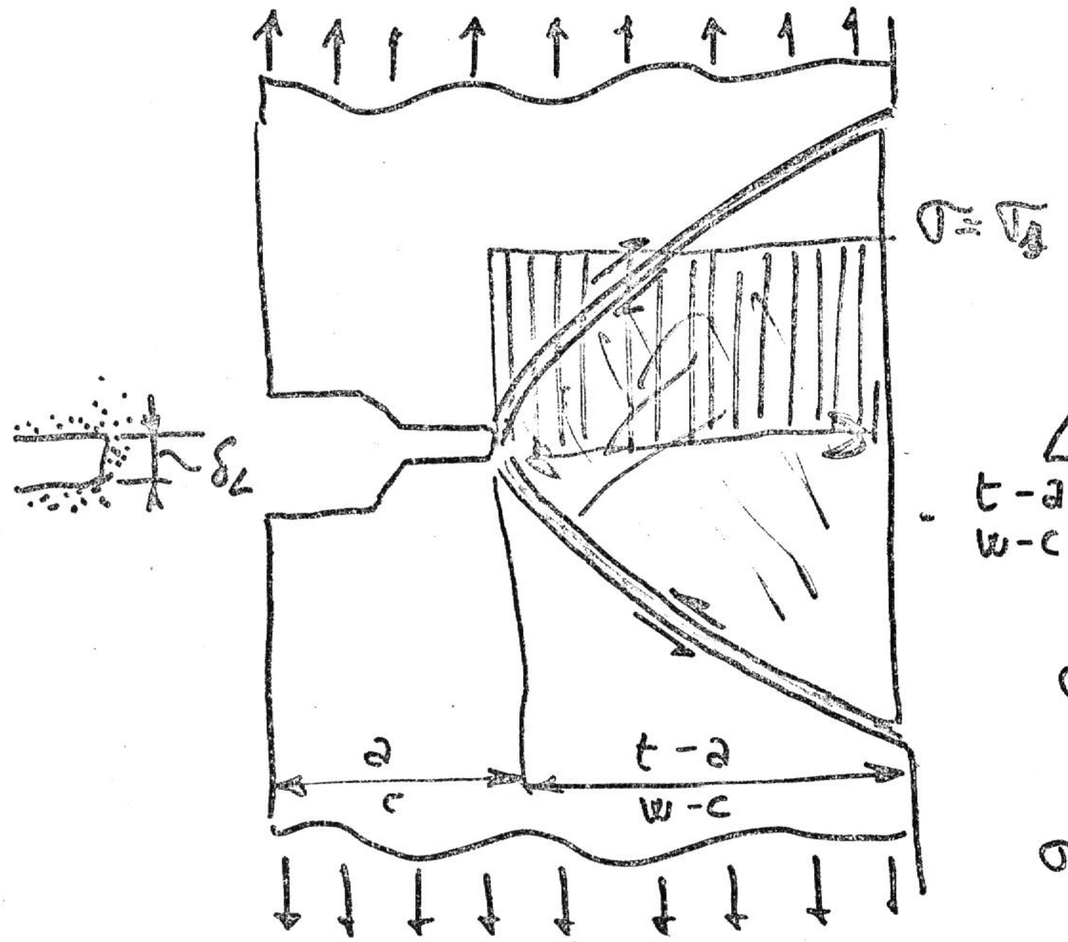
as δ_L (COD LIMIT)

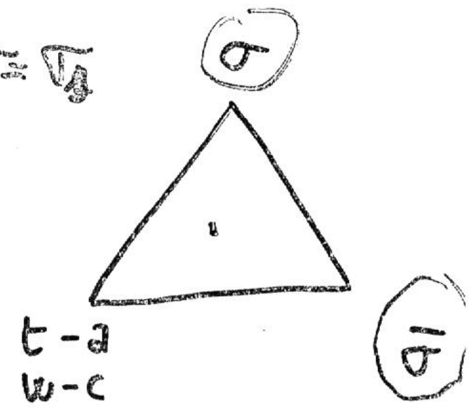






$\delta \Rightarrow \delta_c$



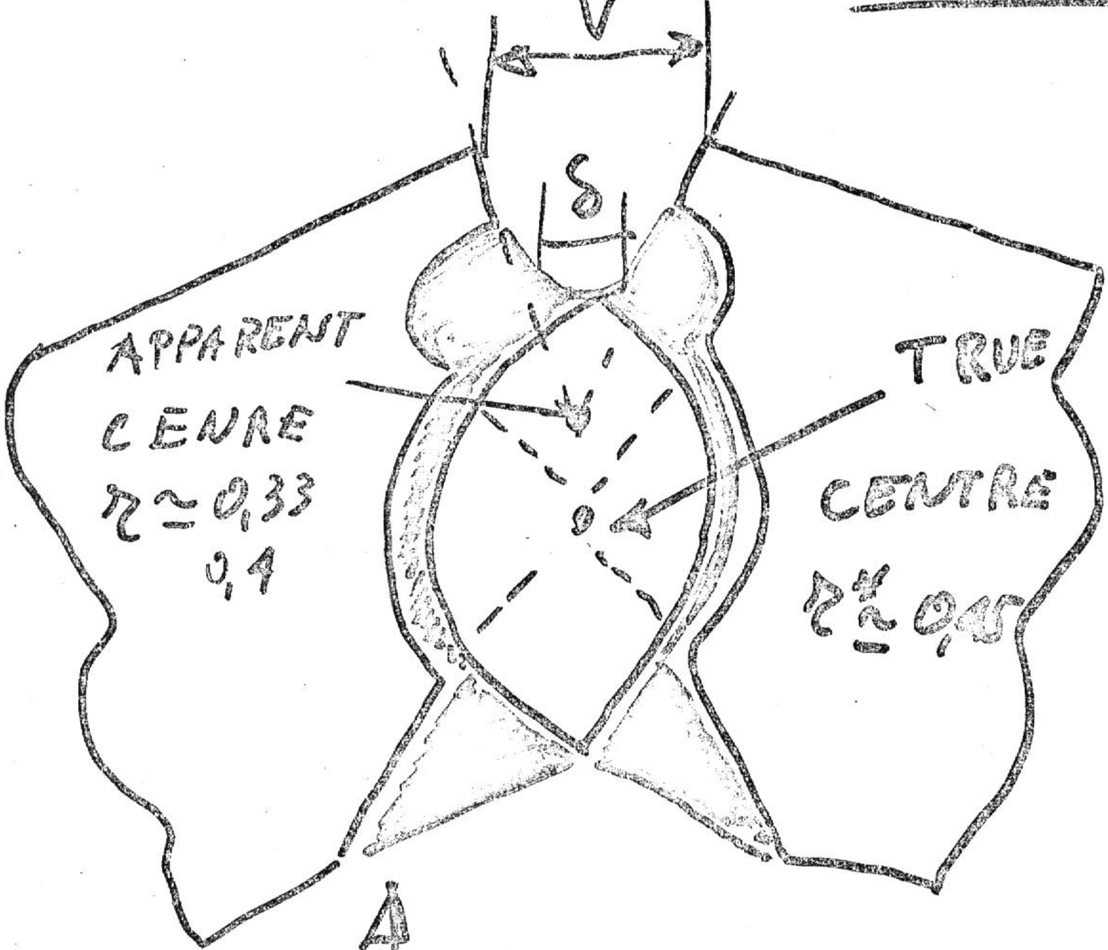


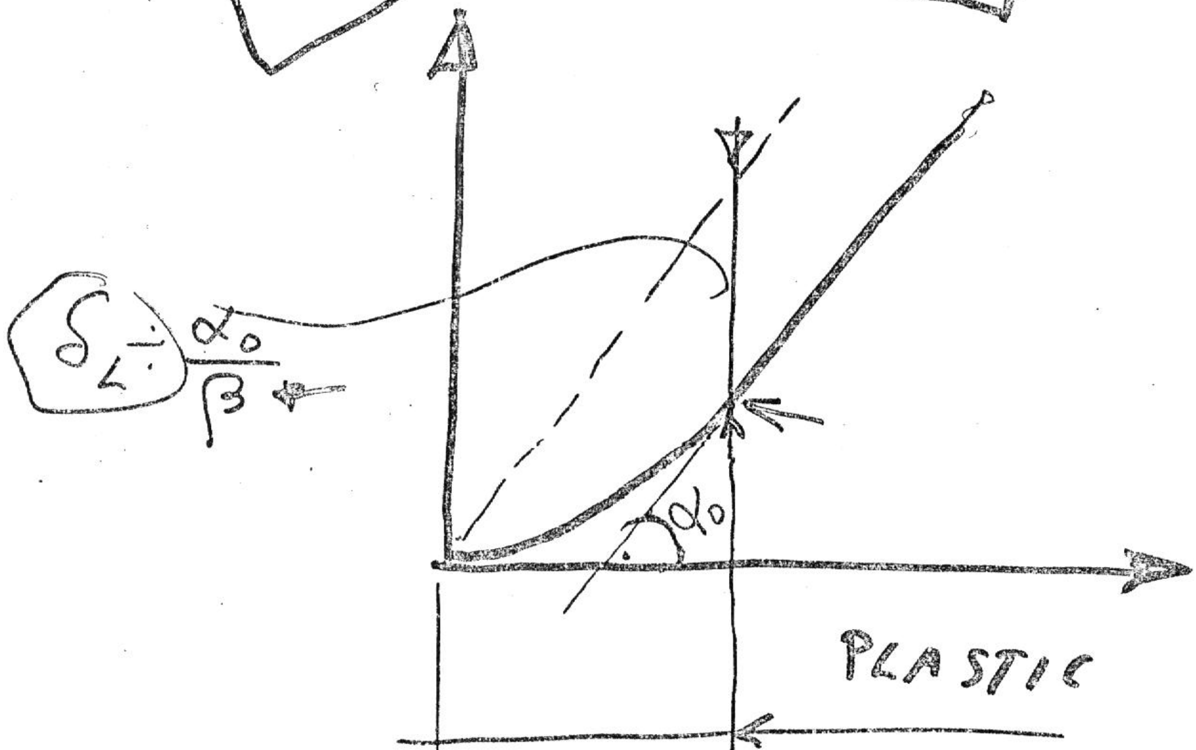
$\sigma_{eff.} \Rightarrow \bar{\sigma}$

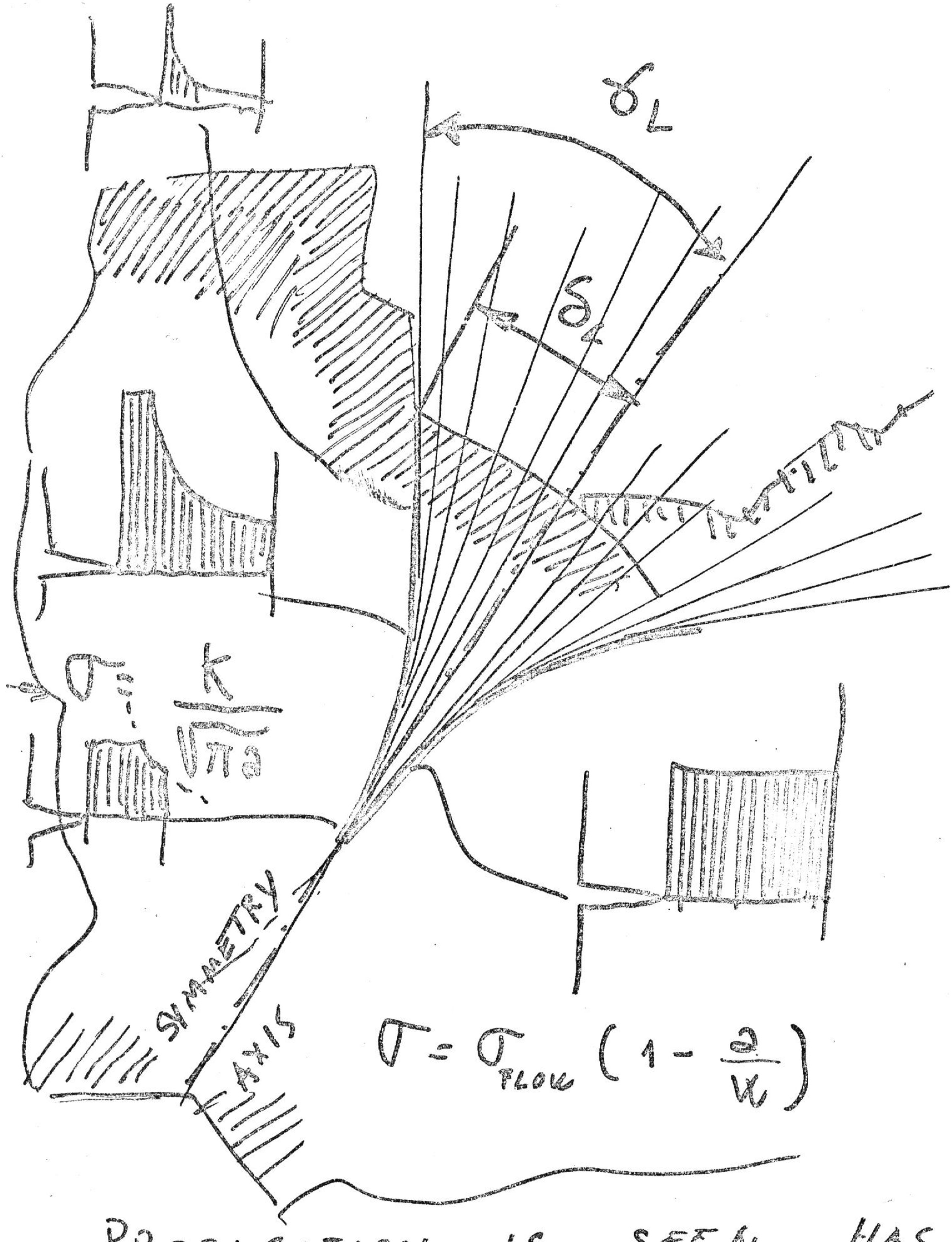
$$\sigma_{eff} = \frac{\sigma}{\frac{t-a}{t}}$$

$$\sigma_{eff} = \frac{\sigma}{\frac{w-c}{w}}$$

r^* { EXPERIMTAL / THEORETIC { KINEMATICS / CUSP / SLIP LINES

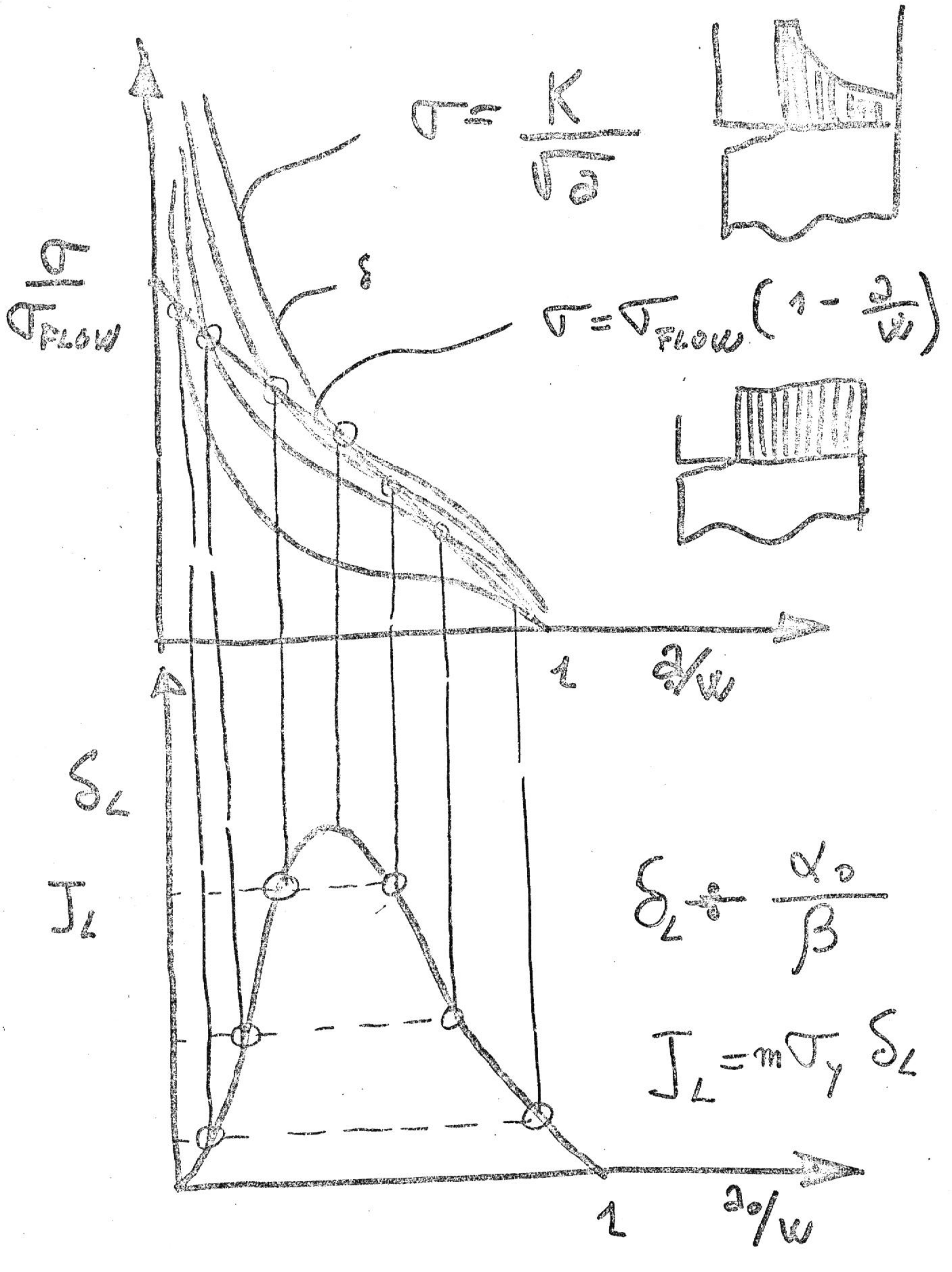






PROPAGATION IS SEEN HAS A CONTINUOS RINITIATION

1) η^* 2) LIMIT LOAD (6)

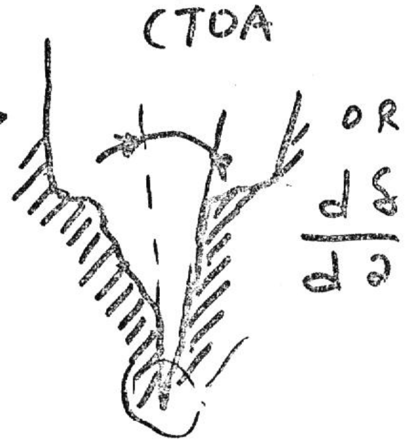


$$\delta_L = \pi \varepsilon_y a \left(1 - \frac{a}{w}\right)^2$$

$$J_L = \pi \sigma_y^2 a \left(1 - a/w\right)^2.$$

Before initiation After initiation (steady state)

$$\Longleftarrow \delta_L \Longrightarrow$$



$$\boxed{\delta_i + \Delta a \frac{d\delta}{da}}$$

$$G = R = J_R = m\sigma_y \delta \Longrightarrow m\,\sigma_y (W-a)\frac{d\delta}{da}$$

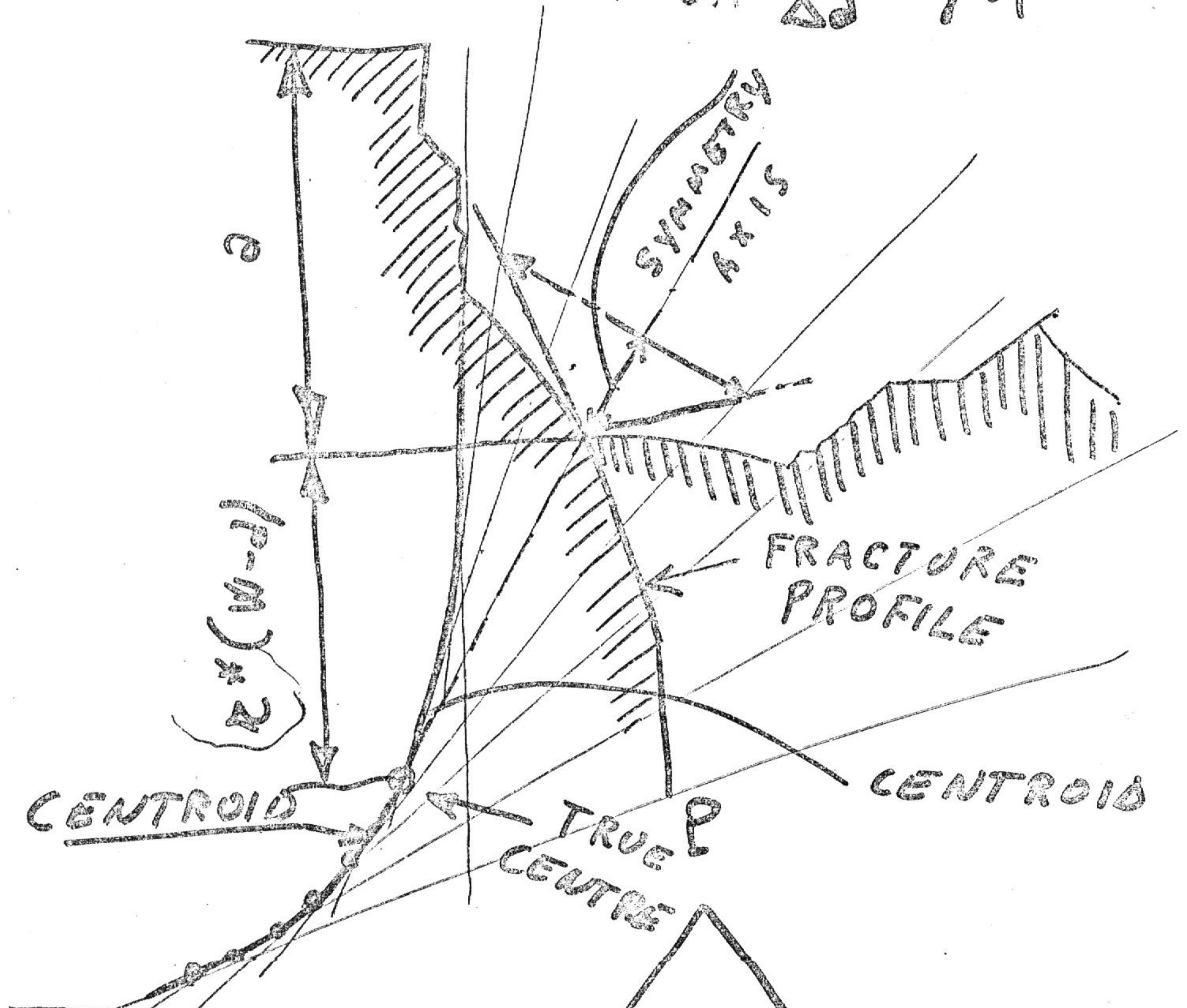
$$\frac{\partial G}{\partial a} = \frac{\partial R}{\partial a} = \frac{\partial J}{da} = \sigma_y \frac{d\delta}{da} \Longrightarrow -\sigma_y \frac{d\delta}{da}$$

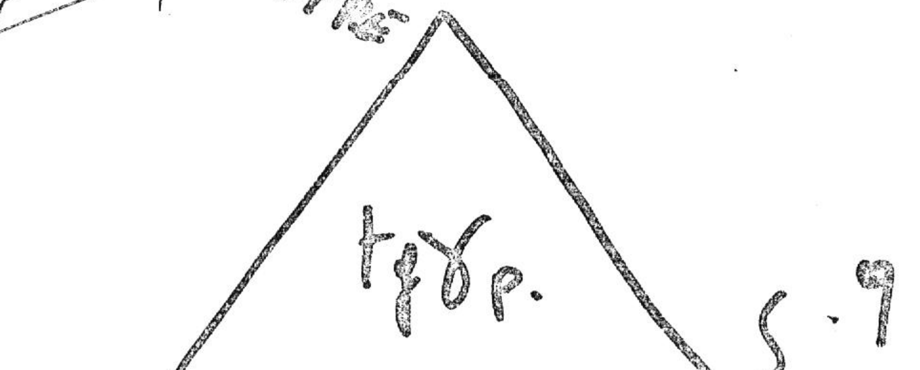
$$R \cong \frac{P}{B}\frac{d\delta}{da}$$

$$\frac{\partial R}{\partial a} \cong \frac{1}{B}\frac{\partial P}{\partial a}\cdot\frac{d\delta}{da}$$

$$\frac{d\gamma}{da} = \frac{1}{r^*(W-a)} \left(tg\,\gamma_p \right)$$

$$CTOA = \frac{\Delta\delta}{\Delta a} = tg\,\gamma_p$$





INSTABILITY

$$\frac{L}{W} \geq T_{mat}$$

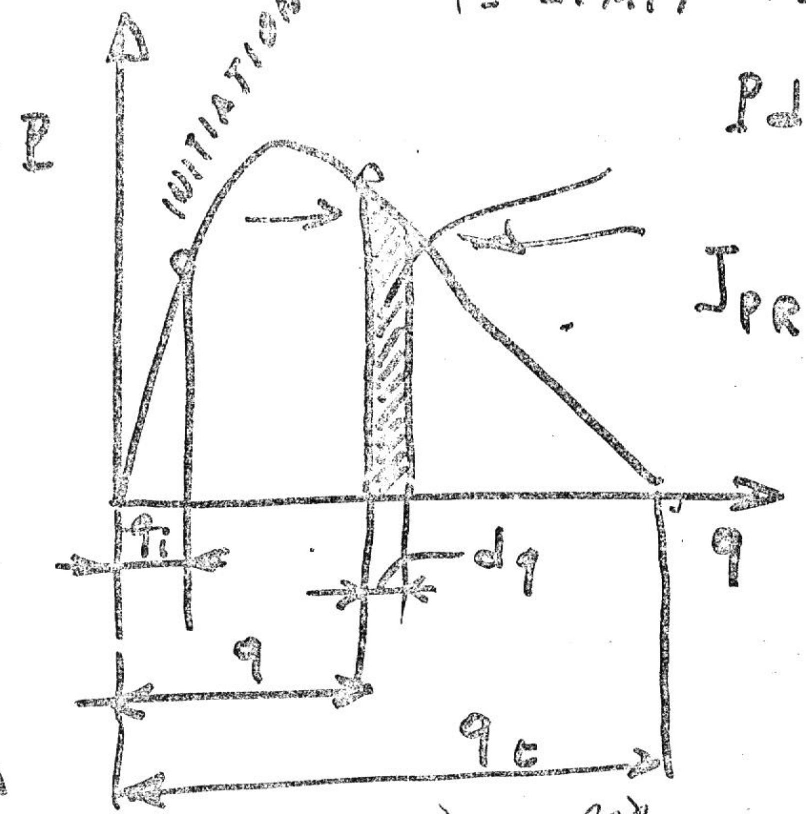
$$\boxed{\frac{dP_{LS}}{dq_{LS}} \geq \frac{dP_L}{dq}} = \left(\frac{dP}{da}\right)\left(\frac{da}{dq}\right)$$

LOADING SYSTEM SPECIMEN

$\downarrow$

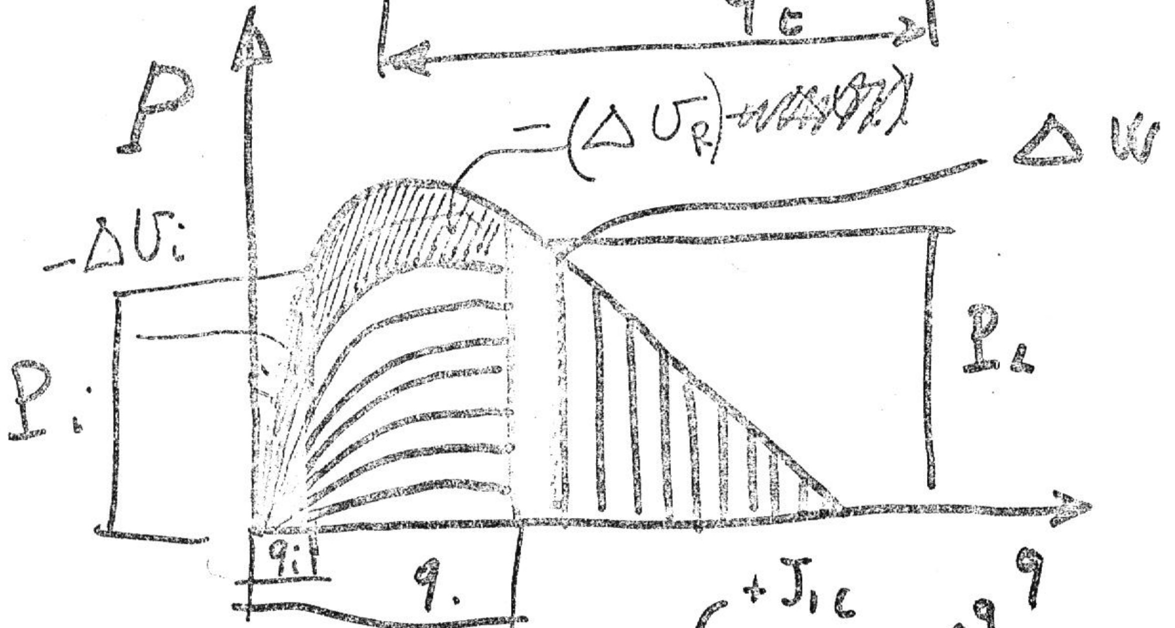
$$-\frac{1}{C_{LS}} \geq \frac{dP}{da} \cdot \frac{dq}{da}$$

P = LIMIT LOAD



$P\,dq$

$$J_{PR} = \frac{P}{B}\left(\frac{dq}{da}\right)$$

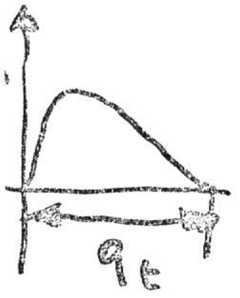


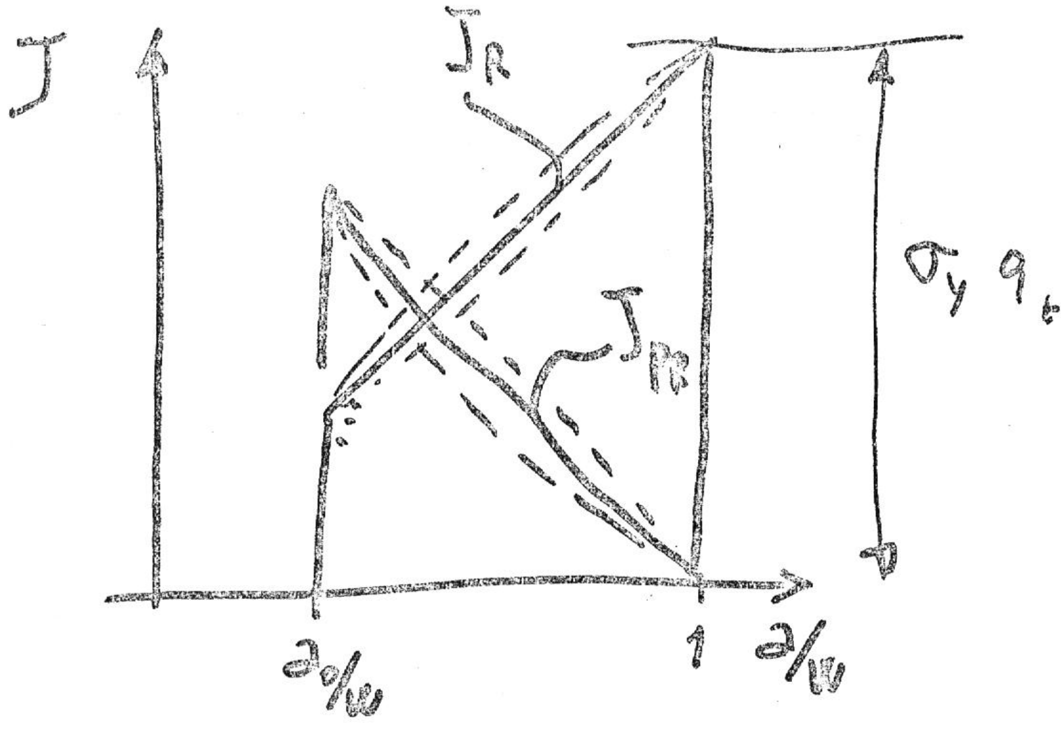
$$J_R = \lim_{\Delta a \to 0} \frac{-\Delta U_R}{B\,\Delta a} = -\frac{1}{B}\int_{q_i}^{q} \left.\frac{dP}{da}\right|_q dq + J_{IC}$$

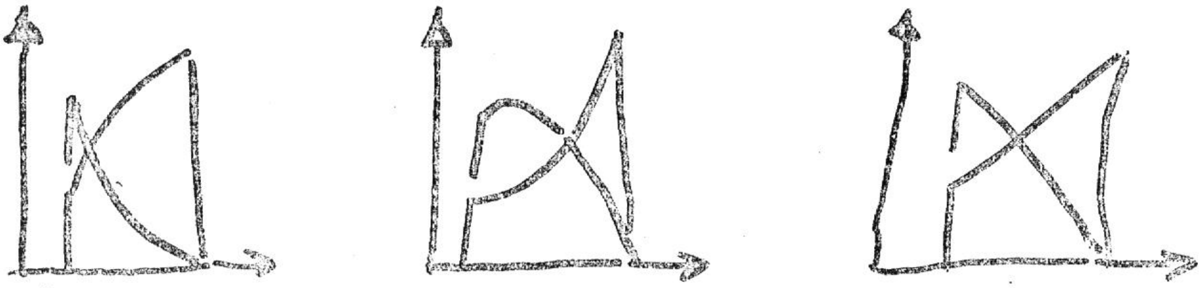
$$J_{PR} = \lim_{\Delta a \to 0} \frac{\Delta W}{B\,\Delta a} = \frac{1}{B}\int_0^{P} \left.\left(\frac{dq}{da}\right)\right|_P dP$$

$$\frac{dJ_R}{da} = -\frac{dJ_{PR}}{da}$$

$$J_R + J_{PR} = \text{const} = \sigma_y\, q_c$$







NO STRAIN HARDENING
$\frac{dq}{da} = f(a)$

STRAIN HARDENING
CTOA = const

NO STRAIN HARDENING
$\frac{dq}{da}$ = const. = CTOA

$$J_R = \begin{cases} \sigma_L (a - a_0) \frac{dq}{da} \\ \sigma_L\, q \\ \frac{(P_i - P)}{B} \frac{dq}{da} \end{cases} \qquad J_{PR} = \begin{cases} \sigma_L (W - a) \frac{dq}{da} \\ \sigma_L\, (q_r - q) \\ \frac{P}{B} \frac{dq}{da} \end{cases}$$

$$J_R + J_{PR} = \sigma_y\, q_t \qquad \frac{dJ_R}{da} = - \frac{dJ_P}{da}$$

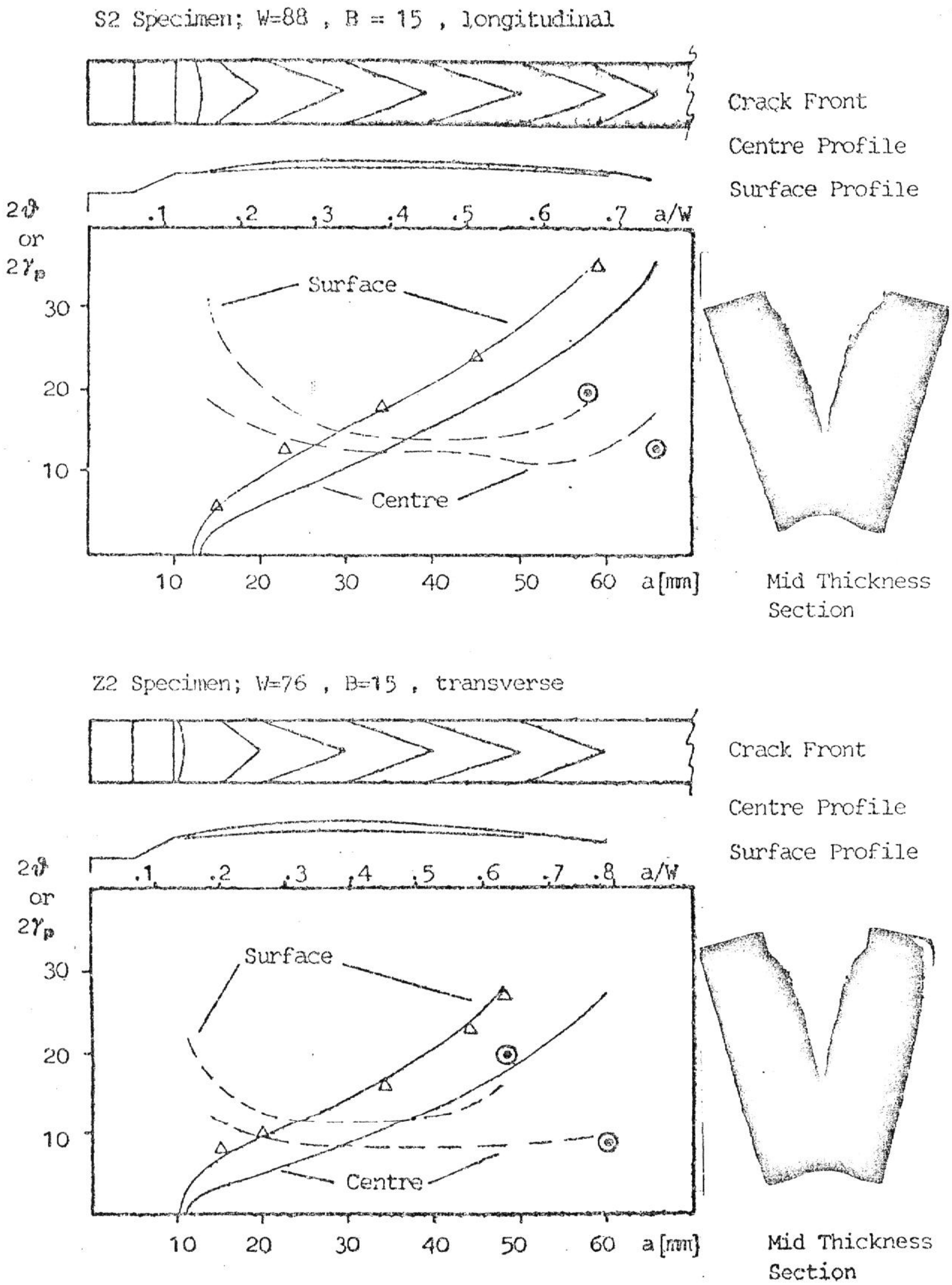
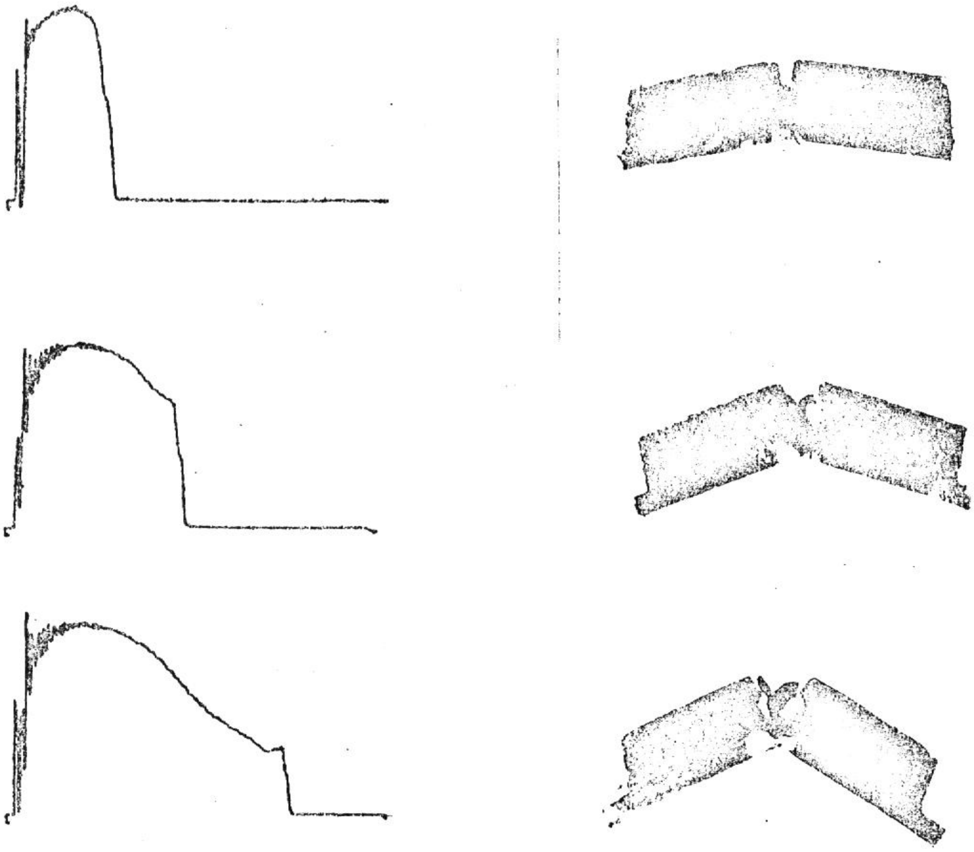


Fig.(2)- Static tests: crack fronts, fracture profiles, theoretical 2θ(—), $2\gamma_p$(---) curves and experimental 2θ(Δ), $2\gamma_p$(⊙) values.



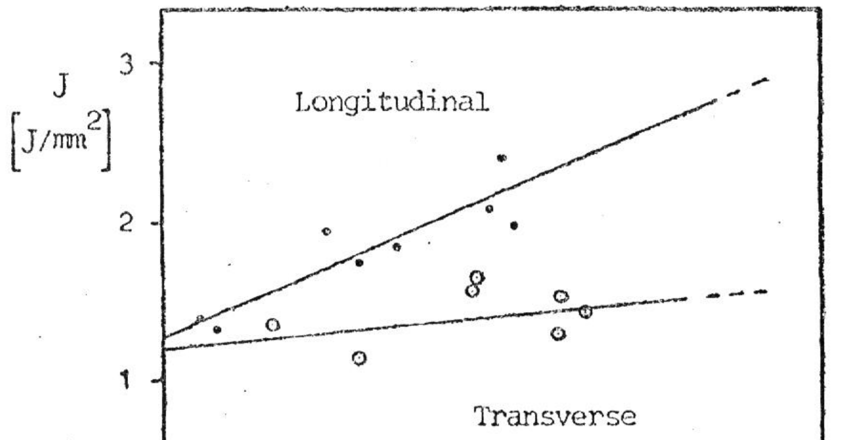


Fig.(4) - J_R curve by multispecimen technique.

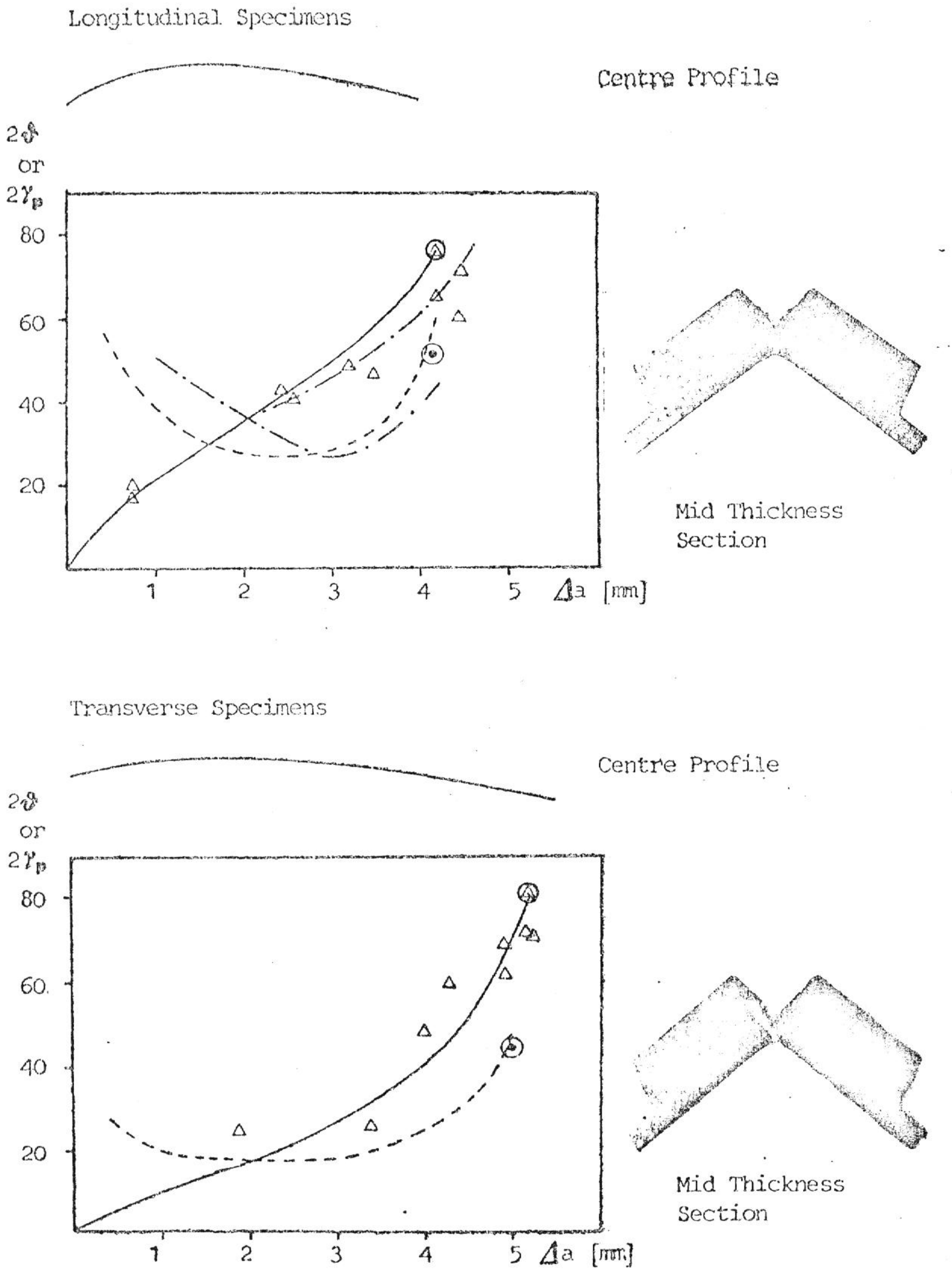
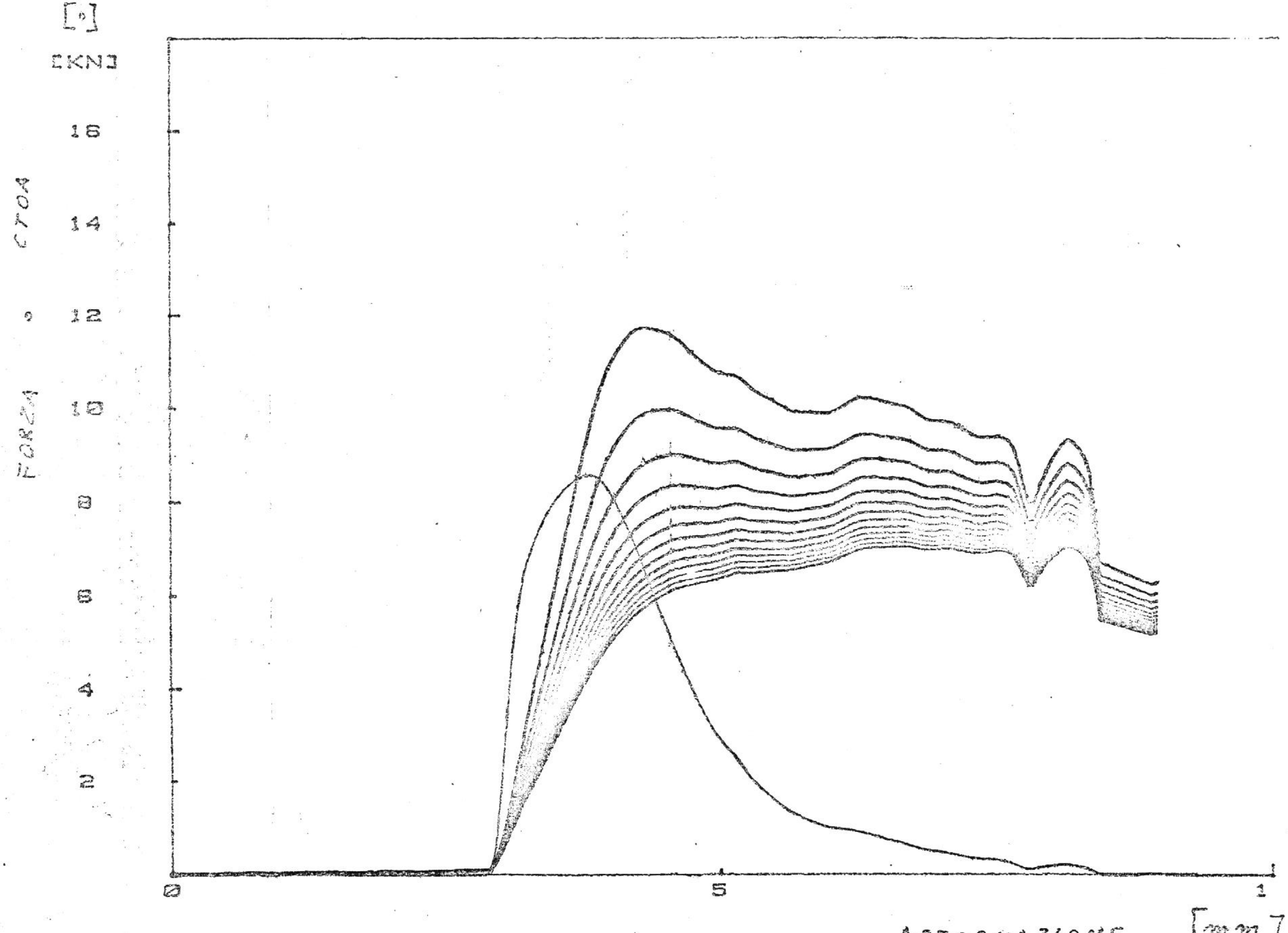


Fig.(3)- Interrupted Charpy dynamic tests: centre fracture profiles, theoretical 2θ(——), $2\gamma_p$(---) curves derived from the profiles, experimental $2\theta(\Delta)$ and $2\gamma_p$(o) values and theoretical 2θ and $2\gamma_p$ curves (-·-) optimized on all 2θ values of longitudinal specimens.



[°]
[KN]
FORZA , CTOA
16
14
12
10
8
6
4
2
0
5
1
DEFORMAZIONE [mm]