

**Mechanical behavior of materials**

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**Week-10**

**Lecture-53**

**Fracture & Theoretical Cohesive Strength of Materials**

Course Title

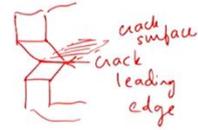
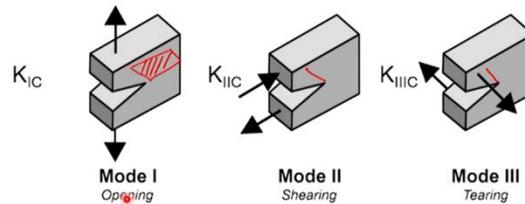
**Mechanical Behavior of Materials (Hindi)**

**Lecture-52**  
**Fracture modes and Stress Concentration**

Namaskar aapka swagat karta hoon is course mein Mechanical Behavior of Materials jo ki hum Hindi mein padhenge. Last part tak humne dekha ki fracture kis tarah se hota hai? Fracture ke kya criteria hai? Is part mein hum dekhenge ki fracture ke measurements kya hai ya fracture ke modes kya hai? Yaani kis tarah se fracture propagate hota hai material mein. To isi context mein hum fracture modes aur stress concentration ke baare mein padhenge. Jab mein fracture ki baat karta hoon to kuch terminologies yahan par clear kar dete hain. Yahan par agar mere paas kuch is tarah se crack hai. Agar mein kuch crack is tarah se consider kar raha hoon. Yeh mera sample hai. Aur kuch is tarah se ye crack mere paas available hai. Yeh meri crack hai yahan pe. Isko kehte hain leading edge. Aur yeh jo crack jis surface mein propagate hogi aur jis surface par lie karti hai usko crack surface kehte hain. Ye terminologies important hai kyunki hum kuch modes dekhenge fracture ke. To pehla jo mode hai yahan pe yahan par aap dekh pa rahe honge ki meri jo leading edge hai ya crack hai kuch is tarah se mein force apply kar raha hoon is crack ko isko kehte hain opening mode ya mode one. Agar aap dekh pa rahe honge...



## Fracture: Different Modes



- Mode I: Crack opening mode (Tensile stress normal to crack surface)
- Mode II: Forward Shear Mode (Shear stress normal to leading edge)
- Mode III: Parallel Shear Mode (Shear stress parallel to leading edge)



	$G_{IC}$ , kJ/m <sup>2</sup>	$K_{IC}$ , N m <sup>3/2</sup>	E, GPa
Alloy steels	107	150	210
Al alloys	20	37	69
Mild steel	12	50	210
Wood	0.12	0.5	2.1
Glass	0.007	0.7	70

[https://www.fracturemechanics.org/images/modes123/modes123\\_b.svg](https://www.fracturemechanics.org/images/modes123/modes123_b.svg)

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doosre jo mode hai yahan pe mein kuch is tarah se force apply kar raha hoon. Isko kehte hain mode 2 ya shearing mode. Yahan par teesre condition mein aap dekh rahe honge ki crack ko mein force kuch is tarah se apply kar raha hoon. Isko kehte hain tearing mode. Isko is tarah se samajh sakte hain ki mode one mein jo crack crack opening mode isko crack opening mode kahenge. Jo tensile stress hai yeh hota hai normal to crack surface. Agar crack surface mein maine baat ki thi. So, yeh mera crack surface hai yahan pe. Is yeh jo plane hai, ismein crack propagate hoga. Is pe yeh jo force lag raha hai yeh normal hai yaani perpendicular hai. Doosra jo mode hai...

isko kehte hain forward shear mode ya shearing mode itself. To jo shear stress hai ye normal to leading edge hai. To hum dekh pa rahe honge ki leading edge kuch is tarah se hai. To yahan pe bhi leading edge yahan pe. To ye shear stress normal hai leading edge ko. Aur teesra jo hai yahan pe jo shear stress lag raha hai wo parallel hai mere leading edge ko. Aap dekh pa rahe honge ki ye jo force lag raha hai ye parallel hai. To ye teen mode hai. Ismein hum testing karte hain aur ismein hum fracture values hai ya fracture toughness ko report karte hain. To jab jab mein fracture toughness ko report karta hoon to agar fracture toughness mein is tarah se baat kar raha hoon mode one to ya critical fracture toughness ye isko...

mein kehta hoon  $K_{IC}$ . Mode 2 agar mein experiment karke fracture toughness measure kar raha hoon to isko kahunga  $K_{IIIC}$  aur mode 3 mein agar kar raha hoon to isko mein kahunga  $K_{IIIIC}$ . To yahan pe kuch materials maine diye aur unke kuch  $G_{IC}$ ,  $K_{IC}$  aur Young's modulus yahan

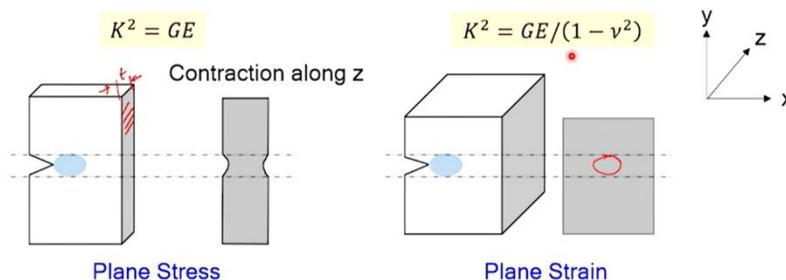
par mention kiye. To aap dekh pa rahe honge ki yahan par  $K_{IC}$  ki value maine ghatte hue order mein mention ki hai. To alloy steels mein  $K_{IC}$  ki value zyada hai aur glasses mein  $K_{IC}$  ki value kam hai. To humein pata hai ki agar mujhe koi material choose karna hai to  $K_{IC}$  ki value zyada rahegi. To jo fracture stress rahega woh bhi zyada rahega aur mein aise materials ko prefer karunga jab mein...



## Plane stress and Plane strain conditions

**Plane Stress**, when the thickness of the body is comparable to the size of the plastic zone and a free contraction of lateral surfaces occurs

**Plane strain**, when the specimen is thick enough to avoid contraction in the thickness z-direction.



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fracture resistant materials ko develop karne ki koshish karunga. To yahan pe  $K_{IC}$  yaani iska matlab hai ki yeh jo fracture toughness hai yeh measure kiya hai crack opening mode mein. Kuch is tarah se is mode mein humne isko istemal kiya hai. To mostly jab hum measure karte hain fracture toughness to hum yeh opening mode hi istemal karte hain ya mode one istemal karte hain. To jab mein fracture toughness ki baat kar raha hoon to do conditions aa sakte hain. Ek condition hai plane stress aur doosri condition hai plane strain. To plane stress condition mein jo thickness hai yaani mere material ki thickness hai body ki thickness hai yeh comparable rehti hai mere plastic zone...

ke size se aur iske wajah se kya hota hai ki ek free contraction taiyar hoga mere lateral surfaces pe. Plane strain condition mein jo specimen thickness hoti hai wo thick hoti hai yaani badi hoti hai zyada hoti hai to isse kya hoga ki lateral direction mein jo contraction hai wo avoid ho sakta hai yaani Z direction mein wahan pe koi ek contraction nahi rahega. To isko samajhte hain is do statements ko aur is do conditions ko. To mark kar lete hain hamara kuch coordinate axis is

tarah se hai aur hum pehle abhi plane stress ki baat karte hain. To mere paas kuch body is tarah se hai aur ek...

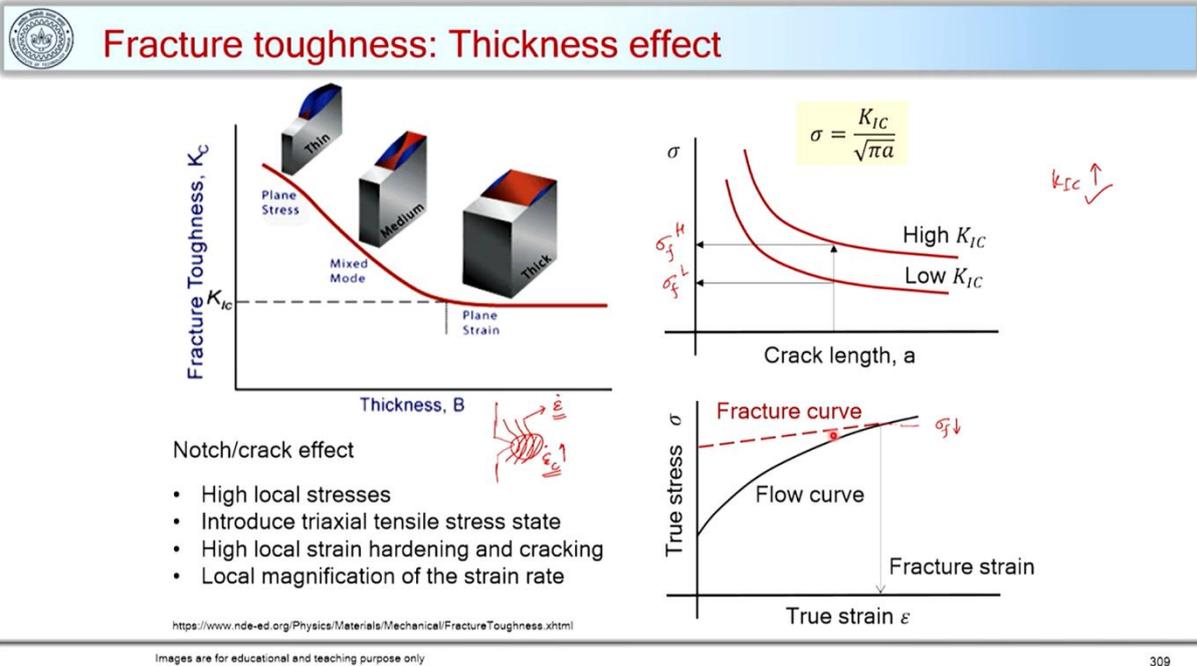
through surface crack hai is tarah se aur iski jo thickness hai wo kam hai chhoti hai. To abhi aap dekhenge ki ye agar material plastically deform karega to yahan pe kuch plastic zone taiyar hoga. Aur plane stress condition kab hoti hai? Jab material mein yeh jo plastic zone hai wah comparable rahega mere thickness ke. To agar mein isko thickness maan ke chal raha hoon. Yeh agar meri thickness hai mere sample ki, to yeh jo plastic zone hai, wo comparable rahega is thickness ke. To, iska ek view dekhte hain. Is direction mein yaani is plane ko mein consider kar raha hoon. Yeh plane jo hai, yeh kuch is direction mein mein dekh raha hoon. To humein ye plastic zone hai aur aap dekh pa...

rahe honge ki yahan pe contraction taiyar hua hai. Ye lateral surfaces mein contraction hua hai kyunki ye plastic zone kuch stress generate karega aur uske wajah se humein ye contraction milega. Agar ye plastic zone lateral surfaces pe contraction taiyar kar raha hai. Us condition ko hum kehte hain plane stress condition. Kyunki yahan par jo stresses develop honge wah Poisson's nature ki wajah se yahan par ek deformation taiyar karenge aur ye jo thickness hai yahan pe ye contract hogi kyunki ye zone hai jo plastic zone hai wo comparable hai is size se. Is condition mein hum dekhte hain ki jo  $K$  ki value hai, fracture toughness ki value...

hai, mein kuch is tarah se likh sakta hoon.  $K^2$  equals to yeh humne dekha tha  $K$  ki value is tarah se yeh hum likh sakte hain jab hamare paas plane stress condition hai. Ye hamare paas plane strain condition hai. Yahan pe aap dekh pa rahe honge ki is sentence mein humne likha tha ki thickness kaafi badi hai. Yahan pe aap dekh pa rahe honge ki ye jo thickness hai kaafi zyada hai. Kiske tulna mein? Ye plastic zone ki tulna mein. To yeh agar is direction se mein agar dekh pa raha hoon to plastic zone mera kuch is tarah se hoga. Inside hoga yeh material ke body ke aur ye kuch stresses enough nahi rahenge lateral contraction taiyar karne mein. To ye jo condition hai ye plane strain...

condition hai. To mera plastic zone sufficient nahi hai kuch lateral contraction taiyar karne mein. Jab hum fracture toughness ki baat karenge to fracture toughness is condition mein plane strain condition mein humein milta hai  $G / (1 - \mu^2)$ . Iske derivation mein hum nahi ja rahe par hamare paas do conditions hoti hai plane stress aur plane strain condition aur jo fracture toughness hai kuch is value se humein milta hai. Abhi iska mahatva jaante hain ki plane stress aur plane strain conditions ka mahatva kya hai? Jab hum fracture toughness measure kar rahe

hain. Tab yahan pe hum ek plot dikhaya hai. Jaise yahan pe fracture toughness hai y axis pe aur yahan pe thickness hai sample ka. To aap...



dekh pa rahe honge ki meri thickness is direction mein badh rahi hai. To mein plane stress se plane strain condition mein ja raha hoon. Jab mere paas plane stress condition hai to plastic zone kya hoga? Sufficient rahega is thickness ko cover karne mein. Aur mujhe extra stress ya extra energy lagegi is crack ko propagate karne mein. Kyunki yahan par material already deformed hai. To ek plastic work ko mujhe overcome karna padega. Isliye plane stress condition mein jo fracture toughness aata hai wah zyada aata hai yaani bada aata hai. Jab mein plane strain condition mein jata hoon to humne dekha tha ki plastic zone itna sufficient nahi hota hai ki lateral...

contraction taiyar kare ya thickness yahan pe badi rehti hai aur plastic zone iske andar rehta hai. To hamare paas yeh jo plastic work ko overcome karne ke liye zyada stress ki zaroorat nahi hai. Zyada energy ki zaroorat nahi rahegi. Isliye yahan par jo fracture toughness jo milega humein wah kam value milegi aur humein agar thickness kuch in dono ke beech mein hai to humein ek mixed mode milta hai jo plane stress bhi nahi rehta hai aur plane strain bhi nahi rehta hai. To humein fracture toughness ki jo value hai somewhat in dono ke beech mein milega. Ab jaise aap dekhenge ki agar thickness agar mein badha raha hoon to yahan pe fracture toughness ki value kuch saturate ho rahi hai. Aur ye jo fracture...

toughness hum nikaal rahe hain ye  $K_{IC}$  yahan pe maine likha hai. Ye mode one mein nikaal rahe hain. Yaani crack opening mode mein hum nikaal rahe hain. To yahan pe jo value saturate hui ye kam value hai plane stress ki value se. To mostly fracture toughness mein aap report karenge values wo plane strain condition mein report karenge. Kyunki yahan par aap dekh pa rahe honge ki is condition mein hamari fracture toughness ki value kam hai. Aur design mein agar hum ye value consider karenge to hamare paas fracture hone ke chances ya humein kuch better idea rahega ki material kitna kam fracture toughness dikha sakta hai. Isliye plane strain mein hi hamesha fracture toughness ki...

value report karenge. Aur ye kam value hai yahan pe. To yeh ho gaya plane stress aur plane strain ka mahatva jab hum fracture toughness ko evaluate karte hain. Jab mein fracture toughness ki baat kar raha hoon aur crack length ki agar mein baat karunga to mere paas kuch stress hai aur us stress ko mein kuch is tarah se likh sakta hoon. Jab mere paas fracture toughness maine evaluate kiya to ye stress mein nikaal sakta hoon  $\sigma = K_{IC} / \sqrt{(\pi a)}$ . To agar mere paas do material hai jinka  $K_{IC}$  high hai aur ek ka  $K_{IC}$  low hai aur mere paas kuch crack length hai material mein maan lete hain same crack length hai kuch is tarah se same crack length hai to...

mujhe kuch fracture stress is tarah se milega to is tarah se fracture stress milega yeh high value ke liye hai aur yeh low value ke liye. To aap dekh pa rahe honge ki agar mera  $K_{IC}$  high hai to jo fracture stress hai wo high rahega aur jab  $K_{IC}$  low hai to mere paas fracture stress ki value low rahegi. Kuch is tarah se. To hamesha hum chahenge ki jis material ki value  $K_{IC}$  ki value zyada hai us material ko hum choose karenge fracture resistant material ke liye. Aur ye jo  $K_{IC}$  hai humein report karni hai plane strain conditions mein. To kyunki hum jab design karenge agar mein is stress ko le design agar kar raha hoon to mein conservative...

design taiyar karunga aur mein sure rahunga ki mein material fail na ho kisi bhi condition mein. To jab mein crack ki baat kar raha hoon to kuch notch aur crack effect ke baare mein dekh lete hain. To cracks ko notch bhi kehte hain. To is notches aur cracks ki wajah se materials mein kuch effects aate hain. Jaise ki high local stresses jaise humne dekha tha ki agar mere paas kuch crack hai is tarah se. To yahan pe kuch stress concentration humne dekha tha. Kuch is tarah se to is region mein mera stress jo concentration rahega wo zyada rahega. Isi ko hum high local

stress kahenge ki agar mein crack se door hoon to wahan par stress concentration kam hai. Par crack ke paas...

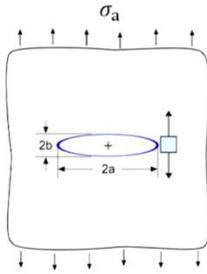
stress concentration zyada hai. Iske wajah se jo stress concentration ke wajah se kabhi-kabhi material mein tri-axial tensile stress state bhi develop hota hai. Aur iske wajah se material jaldi fracture hota hai. Humne dekha agar material plastically deformed hai to yahan pe ek plastic zone bhi taiyar hoga. Aur yeh plastic zone taiyar hoga to yahan par material strain harden ho sakta hai aur wah crack mein lead kar sakta hai ya crack taiyar ho sakti hai. Ek aur cheez dekh sakte hain ki jab mein yahan pe mere paas stress concentration badh gaya hai to ye kya karta hai? Local magnification of strain rate. Yaani mein...

material ko constant strain rate par agar deform kar raha hoon to yahan par jo strain rate experience karega crack ke door aur yahan pe jo strain rate experience karenge crack ke nazdeek wo zyada rahega. To yahan pe dekh sakte hain ki crack ke paas jo strain rate hoga wo magnify hoga ya badh jayega. Aur isse crack catastrophically propagate ho sakti hai aur material fail ho sakta hai. Jab hum failure ki baat karte hain tab dekhte hain ki true stress aur true strain se hum kis tarah se samajh sakte hain materials ki failure ko. Yahan pe true stress plot kiya. Yahan pe true strain plot kiya hai. To agar mein...

## Stress concentration



Notch



$\sigma_a$

Inglis (1913), stress concentration factor around an elliptical hole

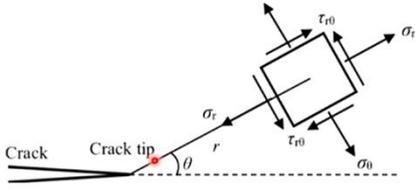
$$\sigma_{max} = \sigma_a \left( 1 + \frac{2a}{b} \right)$$

For circular hole,  $a = b$

$$\sigma_{max} = 3\sigma_a$$

For infinitely sharp crack,  $b \rightarrow 0$

$$\sigma_{max} \rightarrow \infty \quad K = \sigma\sqrt{\pi a}$$



Crack tip

$\sigma_{xx} = \frac{K_I}{\sqrt{2\pi r}} \cos\left(\frac{\theta}{2}\right) \left[ 1 - \sin\left(\frac{\theta}{2}\right) \sin\left(\frac{3\theta}{2}\right) \right]$

$\sigma_{yy} = \frac{K_I}{\sqrt{2\pi r}} \cos\left(\frac{\theta}{2}\right) \left[ 1 + \sin\left(\frac{\theta}{2}\right) \sin\left(\frac{3\theta}{2}\right) \right]$

$\sigma_{xy} = \frac{K_I}{\sqrt{2\pi r}} \cos\left(\frac{\theta}{2}\right) \sin\left(\frac{\theta}{2}\right) \cos\left(\frac{3\theta}{2}\right)$

$\sigma \propto \frac{1}{\sqrt{r}}$

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flow curve dekhta hoon material ka kuch is tarah se. Aur mein fracture stress ki baat karunga. To fracture stress mein kuch is tarah se fracture curve mujhe kuch is tarah se milega. To

material kab fail hoga? Jab ye flow curve mera intersect karega fracture curve ko. To yahan pe aap dekh pa rahe honge ki yahan pe jo ye jo stress hai iske corresponding jo stress hoga jahan pe intersect ho raha hai isko kehte hain fracture stress. Aur ye jo point hai ye jo strain hai isko kahenge fracture strain. To yaani aap dekh pa rahe honge ki yeh stress ke baad ye point ke baad yeh fracture curve is tarah se cross karega cross over karega to fracture stress ki...

value ye kam rahegi mere is stress ke flow curve flow stress se to ye value agar kam hai to material yahan pe fracture hoga aur ye value agar flow stress se zyada hai to yahan pe material plastically deform karega ya material fail nahi hoga ya fracture nahi hoga. To abhi jab mein cracks ki ya notches ki baat kar raha hoon tab humne bataya tha ki yahan pe stress concentration hota hai ya high local stresses hote hain. To ye hum rozmarra ki zindagi mein bhi dekhte hain kyunki jaise hum yahan pe kuch wrappers hain plastic wrappers aur yahan pe kuch notches hum dekhte hain. Yeh notches isliye di jati hain ki...

yahan par agar hum isko todne ki koshish karenge. Ya yahan par agar stress apply karenge to crack yahan se propagate hogi aasani se aur yeh wrapper ko hum acche se tod payenge. Jaise hum dekh pa rahe honge ki kuch wrappers mein kuch is tarah se notches bane hue hote hain. Agar hum yahan pe agar stress apply karte hain, to aasani se hum is wrapper ko is direction mein tod sakte hain. Agar yahan pe agar koi notches nahi hain, maan lete hum is direction mein faadne ki koshish karenge, to yeh wrapper tootega nahi. Aur yeh kyun hota hai? Jab kyunki yeh notches ya cracks material mein ek higher stress concentration taiyar karte hain. To ye yahan pe notches ke dwara hum...

isko todne ki koshish karte hain. To jab hum stress concentration ki baat karte hain to maan lete hain mere paas kuch aisa material hai aur ek elliptical crack hai kuch is tarah se aur ek tensile stress maine apply kiya  $\sigma_a$  aur yeh internal crack hai. Tab Inglis ne ek criteria diya hai stress concentration factor ka elliptical crack ke around ya elliptical hole ke around. Usmein aap dekh pa rahe honge ki stress concentration yaani ye jo elliptical hole hai iske around jo stress rahega kuch is tarah se rahega. Yahan pe hum  $\sigma_a$  apply kar rahe hain. Par yahan pe jo stress material experience karega kuch is tarah se rahega.  $\sigma_{max} = \sigma_a (1 + 2a / b)$  aap dekh...

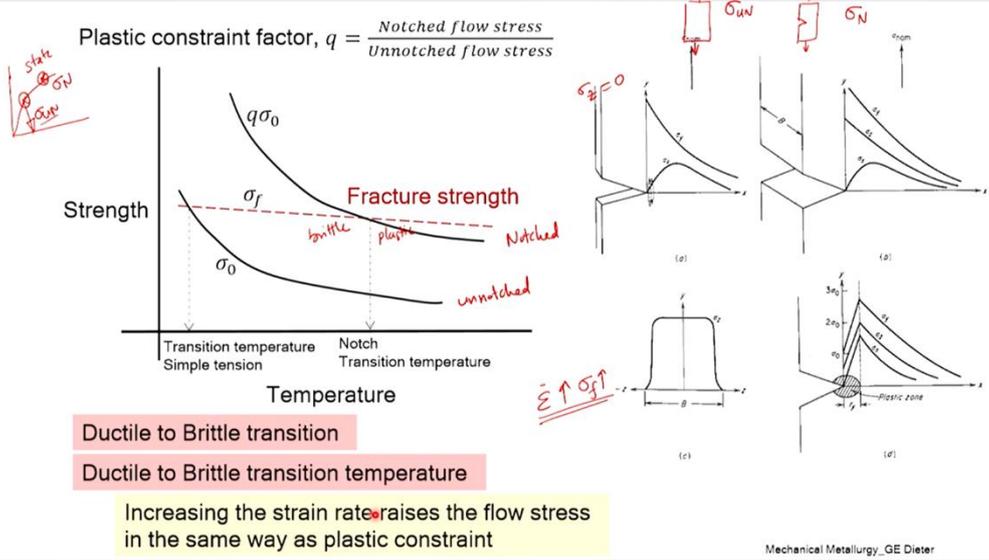
pa rahe honge ki ye jo term hai ye positive hai to aap dekh pa rahe honge ki ye  $\sigma_{max}$  hamesha  $\sigma_a$  se bada rahega applied stress se bada rahega isi ko hum kehte hain stress concentration. Agar ye elliptical hole hai aur agar isko hum circular hole agar hum consider karenge to  $a = b$  ho jayega aur hum dekh pa rahe honge ki jo maximum stress circular hole mein experienced hoga

wah three times  $\sigma_a$  yaani agar hum yahan pe  $\sigma_a$  apply kar rahe hain to yahan is crack ke around ya is hole ke around humein jo stress milega jo material stress experience karega wah teen guna zyada hoga applied stress se. Agar hum dekhenge ki agar ye sharp crack hai material mein to hum ye keh sakte hain ki b...

tends to zero ye b zero ki taraf jayega. To hum yahan pe is agar ye equation consider karte hain to agar  $b \rightarrow 0$  ho jayega to  $\sigma_{max} \rightarrow \infty$ . To hum dekh pa rahe honge ki sharp crack agar hai material mein to local jo stress hai experience karega material wah bahut zyada hoga isko hum formulate bhi kar sakte hain. Isko hum calculate bhi kar sakte hain. Jaise meri ek crack tip hai aur yeh mera crack surface hai. Kuch is tarah se yeh 2D mein humne dikhaya aur kuch element is tarah se hai aur yahan pe yeh jo element hai kuch angle bana raha hai  $\theta$  to is location pe jo r distance ka part hai mere crack tip se mein ek...

stress element yahan pe find out kar sakta hoon aur uska kuch relation mujhe kuch is tarah se milega yaani ya is element pe jo stress experience hoga material ko wah kuch is tarah se hum find out kar sakte hain. Yahan pe aap dekh pa rahe honge ki  $\sigma_x$ ,  $\sigma_y$  aur  $\tau_{xy}$  ye teeno jo hai ye humne is coordinates mein likhe hain. To  $\sigma_x$  hum ya  $\sigma_y$  jo bhi hai jo stress hai to ismein sigma ye hum likh sakte hain ki ye is tarah se vary ho raha hai radius ke saath. Radius kehne distance from crack tip. To jaise-jaise mein meri radius badh rahi hai ya distance badh raha hai crack tip se waise-waise stress ghatega. Aur ye jo  $K_I$  yahan pe ye  $K_I$ ...

**Notch effect and triaxial state stress**



nothing but mera  $\sigma \sqrt{(\pi a)}$  hai. To hum is tarah se is  $K_1$  ko nikaal sakte hain. Ye aapko yaad karne ki zaroorat nahi hai. Ye aapke just information ke liye hai. Ye ek standard textbook mein aapko iske derivations bhi mil jayenge. Yeh isiliye tha ki aap yeh samajh paaye ki jaise-jaise mein crack se door ja raha hoon waise-waise stress jo experience hoga wah ghatega aur jaise-jaise crack ke nazdeek aa raha hoon waise-waise jo stress concentration hai wah yahan pe badhega. To jab hum crack ki baat kar rahe hain to ek parameter hamesha introduce kiya jata hai jo ki plastic constant factor hai.  $q$  isko hum kehte hain  $q$ . Yeh jab material...

plastically deform ho raha hai, ek factor hum introduce kar sakte hain jo ki diya jayega ratio hai wah ek notch flow stress aur unnotch flow stress ka. Yaani agar mein flow stress ki jab baat kar raha tha jaise agar mere paas kuch aise material hai jismein koi crack nahi hai to ek flow stress milega mujhe aur isko hum kehte hain unnotched aur agar mere material mein kuch crack hai is tarah se aur mein usko deform karne ki koshish karunga jo mujhe flow stress milega wah rahega notch flow stress. To agar inka ratio agar mein lunga notch flow stress ka aur unnotch flow stress ka wah rahega mera plastic constant factor. To aap dekh pa rahe honge ki ye jo...

jab mein strength aur temperature ki baat karunga tab agar mein jab unnotched material hai usmein ek flow stress rahega. Wah kuch is tarah se ye  $\sigma_0$  is tarah se mein baat karunga. Ye is tarah se vary hota hai temperature ke saath. Yaani mera strength jo hai material ka wah ghatega temperature ke saath. Agar mein notch flow stress ki baat karunga to ye jo factor hai ye hamesha jo notch flow stress hoga wah higher hoga. Ye is tarah se hum samajh sakte hain. Jaise agar mein stress strain curve ki baat kar raha hoon. To agar material high stress hai ya hum isko ek is tarah se consider kar sakte hain ki material deformed hai notch ke aage to ye state of stress is...

tarah se rahegi plastic deformation mein aur unnotched hai to elastic behavior dikhayega to aap dekh pa rahe honge ki notch mein mujhe hamesha higher stress milega unnotch stress se. Yeh ek analogy hum consider kar sakte hain. To ek  $Q$  factor hum nikaal sakte hain hamesha. Experiment se aur yeh higher hoga. Yeh jo notched hai stress hamesha higher hoga aur yeh temperature ke saath kuch is tarah se vary hoga. Isko likh lete hain. Ye notched hai aur ye unnotched hai. Abhi hum dekhenge ki fracture stress kis tarah se vary ho raha hai. Agar mein fracture strength ki baat

karunga to fracture strength  $\sigma_f$  agar mein nikaalunga wah temperature ke saath kuch is tarah se vary...

hota hai. Aap dekh pa rahe honge ki  $\sigma_f$  jo hai jab mera material unnotched hai to yahan pe intersect ho raha hai. Aur jab mera material notched hai to kuch is tarah se intersect ho raha hai. Abhi hum dekhenge iska implication kya hai? Jaise is case mein jab material unnotched hai. Yahan par aap dekh pa rahe honge ki yeh jo temperature hai is temperature ke above mera material deform hoga plastically. Par is temperature ke neeche  $\sigma_f$  lower hai mere  $\sigma_0$  se. To aap dekh pa rahe honge ki is temperature ke neeche mera material fracture hoga. Similarly agar mein yeh curve ki baat karunga jahan par notch hai mere material mein to  $\sigma_f$  yahan par intersect ho raha hai aur aap dekh pa rahe honge ki ye temperature ke baad...

mera material plastically deform hoga aur is temperature ke neeche  $\sigma_f$  lower hai  $\sigma_0$  se to ye material brittle failure dikhayega ya fracture hoga to hum dekh pa rahe hain ki agar mera material notched hai aur ya unnotched to material ka ductile brittle transition hum study kar sakte hain. Yaani hum yahan pe likh sakte hain ki material plastically deform hoga. Yaani material ductility dikhayega aur yahan pe brittle way se fail hoga. To mein ductile aur brittle transition ki baat kar raha hoon. Jab mere material mein notched aur unnotched conditions hai. To jo ductile aur brittle transition temperature hai wah shift ho raha hai. Jaise agar is case mein koi notch nahi hai ye shift ho...

raha hai lower temperature se higher temperature. Yaani aap dekh pa rahe honge agar mere material mein flaws hain, cracks hai to material high temperature pe bhi brittle failure dikhayega. Jab mein state of stress ki baat kar raha hoon. Yaani agar mein dekhunga yahan par is case mein kuch stress state plot kiye gaye hain in front of crack tip. To is case mein aap dekh pa rahe honge ki ye jo thickness hai sample ki chhoti hai. To iske wajah se yahan pe jo stress hai ye plane stress condition hoga. Yaani  $\sigma_z$  yahan pe shoony (zero) hai. Aur jo stress variation hai  $\sigma_x$  kuch is tarah se vary ho raha hai. Jaise-jaise mein crack ke door ja raha hoon ya  $\sigma_y$  kuch is tarah se reduce ho raha hai. Yahan pe humein higher...

values of  $\sigma_y$  mil rahi hai. Jaise meri thickness badhegi to yahan pe aap dekh pa rahe honge ki  $\sigma_x$  is tarah se vary ho raha hai. Aur hum mere paas  $\sigma_y$  aur  $\sigma_z$  dono dono bhi present hain yahan

pe. Ye ek tri-axial state of stress hai in front of crack tip ye jab mera material elastically deform kar raha hai ya elastic behavior dikha raha hai. Jab material plastically deform hoga yaani yahan pe plastic zone rahega in front of crack tip to mere paas kuch is tarah se stress state rahega.  $\sigma_x$  is tarah se vary hoga aur  $\sigma_y$  is tarah se vary hoga.  $\sigma_z$  is tarah se vary hoga. To aap dekh pa rahe honge ki ye jo agar material plastically deformed hai to...

meri jo crack propagate hogi yahan pe jo stress concentration hai wah zyada nahi rahega high nahi rahega as compared to jab mera material elastic behavior dikhata hai. Yaani aap dekh pa rahe honge ki yahan pe jo stress concentration hai wah crack tip ke aage bahut zyada hai. As compared to jab material yahan pe plastically yield karta hai ya plastic zone rehta hai crack tip ke aage. Yeh jo conditions hai abhi hum is tarah se bhi samajh sakte hain ki yeh stress concentration mere strain rate ko bhi affect karte hain. Yaani agar mein is tarah se keh sakta hoon ki agar mera strain rate badhta hai to...

yeh affect karega mere flow stress ko just mere plastic constraint ke dwara. Yaani aap dekh pa rahe honge ki agar mere paas kuch extra stresses available hain. Yeh act karega jaise ki maine material high strain rate pe deform kar raha hoon. To flow stress par jaise humne dekha ki strain rate agar badh raha hai to mera flow stress badhta hai. Ye same condition mujhe mil sakti hai jab mere paas notch present hai mere material mein. Yaani agar mein keh sakta hoon ki agar mere paas notch present hai to mere paas kuch ek plastic ka constant factor rahega. To similar behavior agar mein ye low...

strain rate pe deform kar raha hoon aur high strain rate pe deform kar raha hoon to mujhe kuch is tarah se transition milega aur ya mein keh sakta hoon agar material low strain rate pe deform ho raha hai to transition temperature kam rahega aur high strain rate pe agar mein deform kar raha hoon to transition temperature zyada rahega. Iska yeh meaning hai. To aap yeh keh sakte hain ki notch jo effect hai ya plastic constraint jo effect hai wah same way se effect karega. Jis wajah se strain rate affect karta hai mere flow stress ko. To abhi humne is part mein do cheezein dekhi ki hum fracture toughness hamesha measure karenge plane strain condition mein aur humne stress...

concentration ke baare mein padha aur humne dekha ki tri-axial stress state kis tarah se affect kar sakta hai mere ductile aur brittle transition temperature ko bhi. Abhi ke liye yahan par rukta hoon. Agle part mein aur jaanenge fracture ke baare mein. Dhanyavaad.