Mechanical behavior of materials

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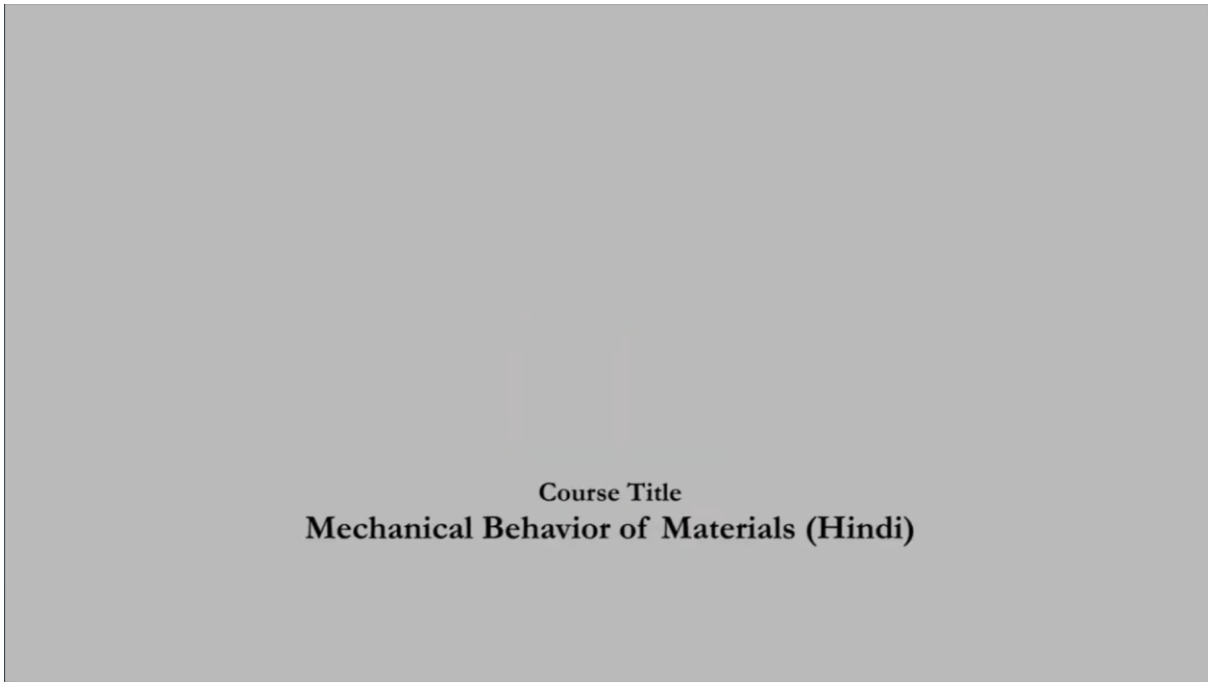
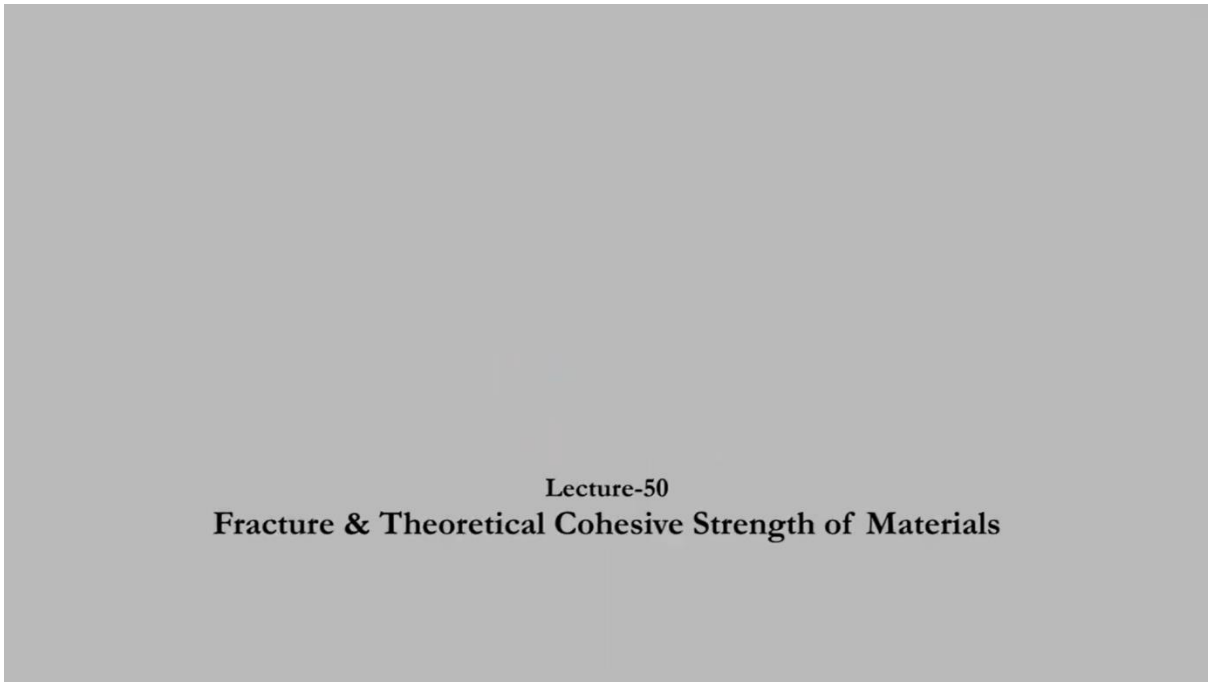
Week-10

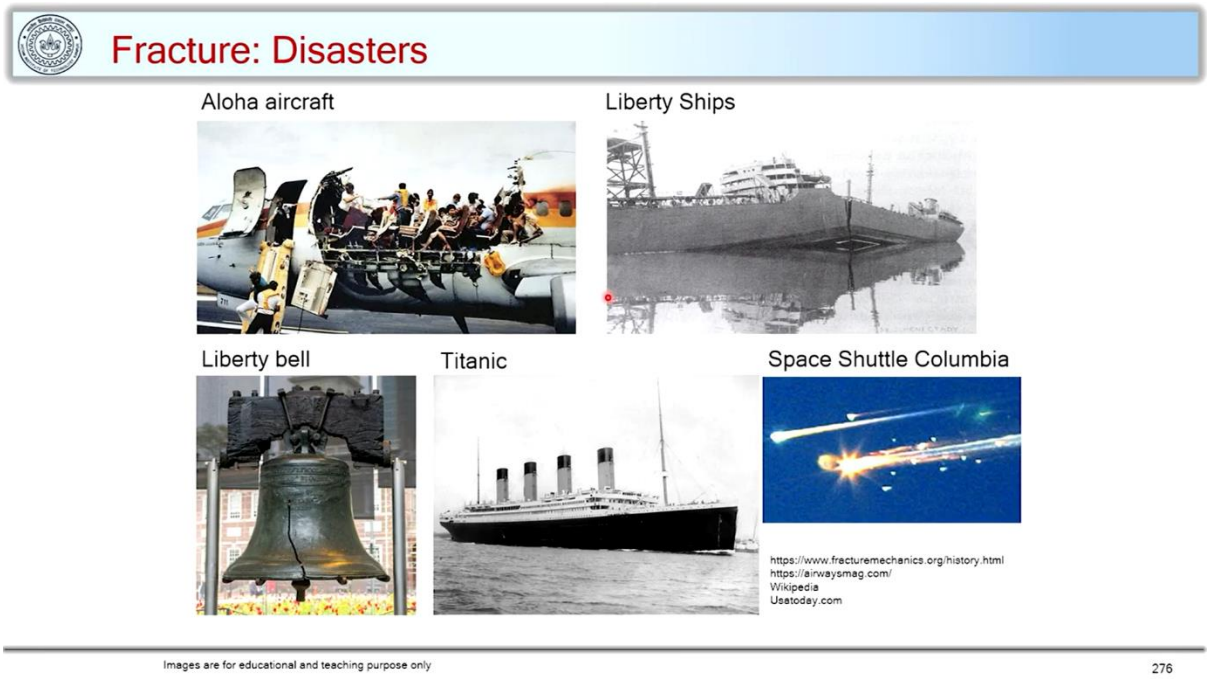
Lecture-51

Fracture & Theoretical Cohesive Strength of Materials





Namaskar fir se swagat karta hoon aapka is course mein Mechanical Behavior of Materials jo ki hum Hindi mein padhenge. Last part tak humne plastic deformation ke kuch important mechanism jaise slip aur twinning ke bare mein padha tha. Is part mein hum ek important topic ke bare mein padhenge jo ki Fracture of Materials hai. Yeh Mechanical Behavior of Materials mein ek bahut hi important topic hai. Agar mein fracture ke bare mein baat karunga toh kuch udaharan ke saath baat karna chahta hoon jaise hum jab fracture jab baat karte hain tab aapke dimaag mein aa raha hoga ki kuch accidents aur kuch disasters yahan par.

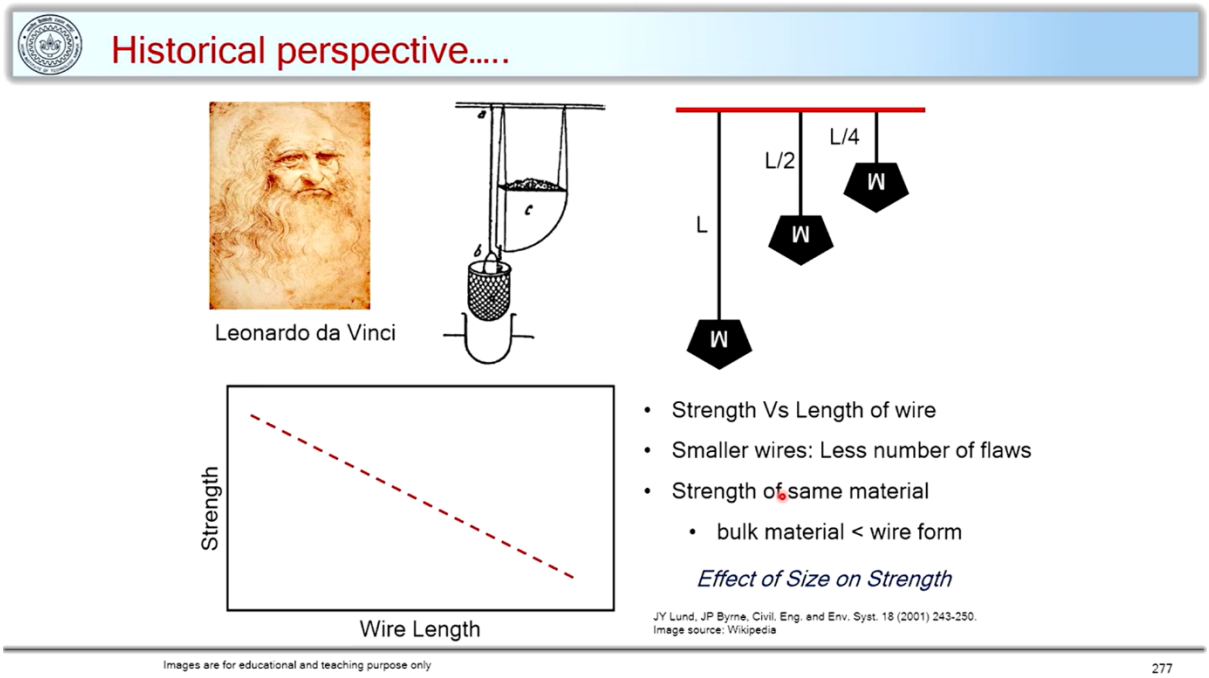


Kuch case study mein yahan par kuch present kar raha hoon jaise ki Aloha Aircraft. Yahan par aap dekh paa rahe honge ki jo aircraft ka fuselage hai yeh mid air mein hi hawa mein hi toot gaya hai, disintegrate ho gaya hai. Ek picture aap dekh sakte hain yeh yahan par fracture yahan par material ka hua hai is plane ke body ka. Doosra udaharan hai Liberty Ships. Yeh World War Two ke dauran yeh jo ships jo istemal ki gayi thi aur aap dekh paa rahe honge ki yahan par jo ship ka hull hai yahan par beech mein fracture hua hai ya yeh jo ship hai do part mein toot gayi hai. Teesra example aapne dekha hoga ki ek Liberty Bell ke bare mein aapne padha hoga. Yeh jo Liberty Bell hai yeh kuch

material se bana hua hai par yahan par crack yahan par aap dekh paa rahe honge is Liberty Bell mein. Yeh jo crack hai yeh bahut baar isko band karne ki koshish ki gayi par yeh crack fir bhi is material mein generate ho rahi hai. Toh uske baad yeh bell kabhi bhi istemal mein nahi layi gayi. Aur Titanic ke bare mein aapne toh padha hi hoga ki jab yeh Titanic jahaaj ek iceberg ko takrata hai tab ismein crack develop hoti hai aur uske wajah se yeh poora ka poora jahaaj paani mein doob jata hai. Uske baad recent ek example jo Space Shuttle Columbia ka yahan par aap dekh paa rahe honge ki yeh jo Columbia Space Shuttle hai yeh mid air mein hi disintegrate ho gaya, toot gaya. Iska kaaran yeh bataya jata hai ki iske upar ek jo ceramic

refractory tile thi woh toot gayi aur tootne se woh is Columbia shuttle ke jo body hai uske doosre tile par jaakar takrayi aur wahan par crack taiyar hui aur uske wajah se yeh jo Columbia aircraft ya shuttle hai yeh jab enter kar raha tha earth ke atmosphere mein uske wajah se kaafi

heat utpann hui aur uske wajah se yeh Columbia shuttle durghatna grast hua. Toh aap yahan par yeh jo examples maine diye hain yeh yahan par hum dekhte hain ki bahut saare kuch aise examples hain hamare rozmarra ke jeevan mein jahan par material apna kaam achhe se perform nahi kar paate yani application ke dauran hi woh toot jaate hain. Toh yahan pe fracture isliye important ho jata hai yahan pe



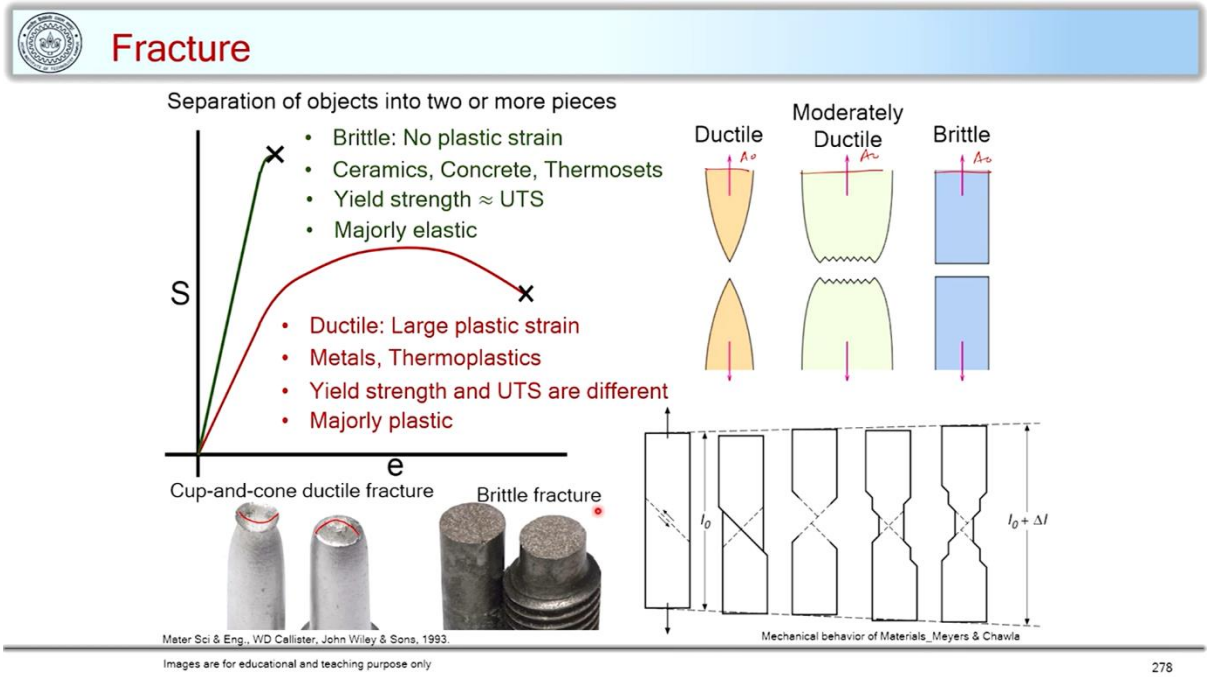
kyunki yeh kisi insaan ya kisi jeevan ki haani ho sakti hai, kshati ho sakti hai is accident ke dauran isliye fracture ek important aspect hai Mechanical Behavior of Materials ka. Toh jo mein fracture ki baat karta hoon toh hamare course ke dauran hum kuch ek historical perspective dekhte hain. Toh ek historical perspective mein Leonardo da Vinci ka ek famous experiment mein yahan prastut karta hoon. Ismein kya kiya gaya Leonardo da Vinci ne kuch wires yahan par is tarah se hang kiye gaye aur usmein alag alag tarah se weight lagaye gaye. Par unhone kya kiya jo wire ki length hai woh kuch alag rakhi hai yahan par L hai, L/2 hai aur L/4 hai yani initial length

se unhone half kar di aur weight iska same rakha. Iske baad unhone yeh dekha ki yeh jo strength hai wires ki aur wire ke length ke saath unhone uska ek relation plot kiya toh unhe ek cheez prapt hui ki jo strength of wire hai woh decrease ho rahi hai wire ki length ke dwara. Toh jaise jaise meri wire ki length badh rahi hai waise waise strength iski ghat rahi hai. Yeh teeno ek hi material se bane hue the toh yeh kyon ho raha hai toh uska unhone ek kaaran diya tha. Toh unhone kaaran diya ki jo chhote wire honge usmein flaws yani defects kam rahenge as

compared to yeh jo bade wires hain yani iski tulna mein in chhote wires mein flaws ya defects material mein kam rahenge aur

uske wajah se yeh defects agar zyada hain material mein toh uski strength aapko kam milegi. Toh bade wire mein defect zyada hain toh iski strength humein kam milegi. Toh aap yahan par dekh paa rahe honge ki strength meri ghat rahi hai jaise jaise meri wire ki length badh rahi hai. Toh yeh ek udaharan tha ki material mein agar defects hain toh woh jaldi toot jayega ya uski strength ghategi. Yeh pehla udaharan hum jaan sakte hain history mein bhi ki yeh effect of size hai on strength yani mein jaise length badha raha hoon yani size badh rahi hai meri waise strength ghat rahi hai. Toh hum yeh udaharan abhi dekhte hain modern science mein bhi ki size effects kya hota hai strength mein. Toh yeh ho gaya hamara

historical perspective. Pichle slide mein humne dekha ki kuch udaharan the yahan pe material apna kaam achhe se nahi kar paa rahe. Toh fracture jab hota hai tab usmein hum baat kar rahe flaws ki ya defects ki. Toh mein fracture ki jab baat karta hoon tab mein fracture ko kuch is tarah se bhi define kar sakta hoon. Fracture hota hai ek kisi bhi object ka do ya zyada pieces mein disintegration ya separation yani mera ek jo object hai woh do ya usse zyada pieces mein toot raha hai isko hum fracture kehte hain. Jab mein fracture ki baat karunga tab mein stress strain curve ki yahan pe baat karna chahta hoon jo stress strain curve humne ache



se padha hai. Yahan par maine engineering stress plot kiya hai aur yahan pe engineering strain plot kiya hai aur yeh curve humne dekha hai. Yahan par aap dekh paa rahe honge ki yeh jo curve hai yahan pe elastic region bhi hai yahan pe plastic region bhi hai aur yahan pe material fail ho raha hai ya fracture ho raha hai. Toh yeh jo curve hai isko hum kehte hain ki jo material hai yeh kuch ductility dikhayega ya large plastic strain dikhayega. Yahan par aap dekh paa rahe honge ki yeh jo plastic region hai ismein jo strain hai material ne acquire kiya hai yeh zyada hai bada hai isliye isko large plastic strain. Kuch material aise hote hain ki jis

tarah se aap dekh paa rahe honge yahan par kuch elastic region hai inki strength toh zyada hai par yahan par koi plastic behavior yeh dikha nahi rahe. Toh yahan par hum is material ko kehte hain brittle material kyunki yahan pe mujhe koi bhi plastic strain nahi mil raha hai. Toh do type ke material mein yahan pe dekhoonga ductile aur brittle material kiske upar hum yeh baat karein jab hum plastic strain ki jab baat karte hain tab yeh jo curve hai yeh mujhe milta hai metals aur thermoplastics pe aur yeh jo yeh jo stress strain curve milta hai yeh milta hai ceramics concrete aur thermosets. Abhi hum dekhenge ki yahan pe aapke paas yeh

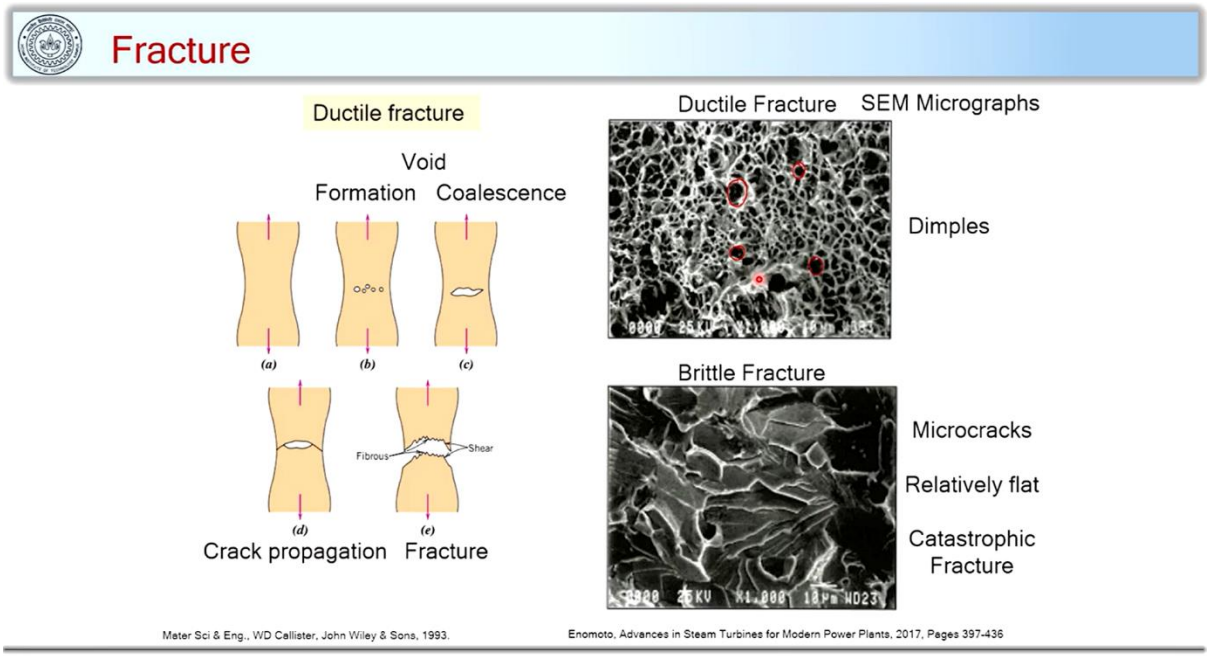
yield strength hai jo ki mere elastic to plastic behavior mein jo change hoga transition hoga woh determine karega. Toh aap dekh paa rahe honge ki yield strength aur UTS (ultimate tensile strength) jo ki yahan pe honi chahiye woh dono different hain. Mere paas ek yield strength hai aur mere paas ek ultimate tensile strength hai par is case mein aap dekh paa rahe honge ki yield strength aur ultimate tensile strength yeh dono lagbhag same hain kyunki yahan pe koi plastic behavior nahi dikha raha hai material yani jaise hi elastic behavior khatam ho jayega waise hi material plastic behavior mein jaane ki koshish karega wahin pe woh disintegrate hoga ya toot jayega ya

fracture hoga. Yeh mejarly plastic region dikhata hai aur yeh mejarly elastic behavior dikhata hai ya ismein hum ductile materials ki jab baat karenge mejarly plastic behavior dikhata hai aur yeh mejarly elastic behavior dikhata hai. Yeh aapko yahan pe isliye mention karna chahta hoon ki fracture mein hum elastic aur plastic material ke bare mein baat karenge. Jab material toot-ta hai toh agar woh elastic material hai toh kis tarah se tootega aur material agar plastic hai toh kis tarah se tootega. Toh yeh ho gaya poora hamara stress strain curve jab hum fracture ki baat kar rahe hain. Jab hum stress strain curve ki baat karte hain toh maan lete hain mein kuch tensile

deformation kar raha hoon kuch is tarah se aur yahan pe material elongate ho raha hai. Yeh mera initial length tha aur yeh ΔL mera elongation tha. Toh yahan par hum dekhenge jab maine stress apply kiya tensile stress yahan par toh yahan par mujhe maximum shear milta hai aur yahan par material ki cross section area ghatna chalu hogi. Yahan par aap dekh paa rahe honge ki material ki cross section area is direction mein ghat rahi hai aur yahan par mujhe geometric softening milegi. Yeh humne dekha tha necking hogi geometric softening hogi aur material ki jo strength carry karne ki ability hai woh ghategi aur material ultimately yahan par fracture hoga.

jaise jaise iska cross section area ghatega. Jab mein yeh baat kar raha hoon aur maine ductile material aur brittle material ki baat ki hai tab mein kuch aapko yeh jo fracture surface yahan par yani humne baat ki hai ki material separate hoga do pieces mein. Toh humne jab tensile deformation kiya yahan par material mere do pieces mein separate ho raha hai ya toot raha hai. Toh is case mein aap dekhenge ki yahan par cross section area bahut zyada change ho gaya yani yeh mera agar mein initial cross section area is tarah se maan loon yeh mera initial A_0 hai teeno ke case mein toh aap dekhenge ki yahan pe yahan pe jo cross section area bahut zyada change hua hai A_0

naught ki tulna mein. Is case mein aap dekhenge ki cross section area jo A_0 tha almost equal hai jab fracture hua hai material ka. Is case mein halka sa change hua hai yani yahan pe aap dekhenge ki kuch is tarah se humein deformation mila hai. Toh agar mein fracture surface agar dekhoonga agar mein tensile test karne ke baad toh mein bata paoonga ki mera material brittle tha ya ductile tha agar just mein fracture surface ki baat kar raha hoon toh. Toh yeh jo behavior hai jahan par mujhe cross section area bahut zyada change mila hai woh ductile material yeh behavior show karte hain aur brittle material yahan par aap dekhenge ki cross section area change hi nahi hua hai aur almost same hai. Yeh brittle materials



demonstrate karte hain mera yeh fracture surface aur in dono ke beech mein mujhe milta hai moderate ductile kuch is tarah se fracture surface mujhe milega. Toh jab mein fracture surface ki baat kar raha hoon tab ek practical udaharan aapko dena chahta hoon jaise aluminum ke case mein jo ductile material hain unke case mein mujhe cup and cone brittle fracture milenge. Toh cup aur cone ki jab mein baat karunga tab yeh yahan par mujhe kuch cup is tarah se mil raha hai aur yeh is tarah se mujhe kuch cone mil raha hai. Toh yeh cup and cone fracture jo milta hai yeh mujhe ductile material mein milta hai aur brittle material mein aap dekhenge ki jo

fracture surface hai yeh almost flat hai aur yahan par koi cross section area yahan par zyada change nahi milega. Toh is tarah ka agar humein fracture surface mil raha hai toh yeh humein brittle material mein milta hai. Toh jab hum fracture ki baat kar rahe hain jab hum aage badhenge tab yeh fracture surface is tarah se kyon hote hain. Toh mein ductile fracture ki jab baat karunga toh lete hain jab maine tensile deformation kiya toh hamara cross section kuch is tarah se change hua aur humein pata hai ki hum yahan par ductile material mein hum UTS achieve karenge uske baad necking hogi aur necking yani cross section area yahan par locally change hoga aur locally change hone ki wajah se cross section area yahan par stress concentration yahan par badhega is area mein aur uske wajah se

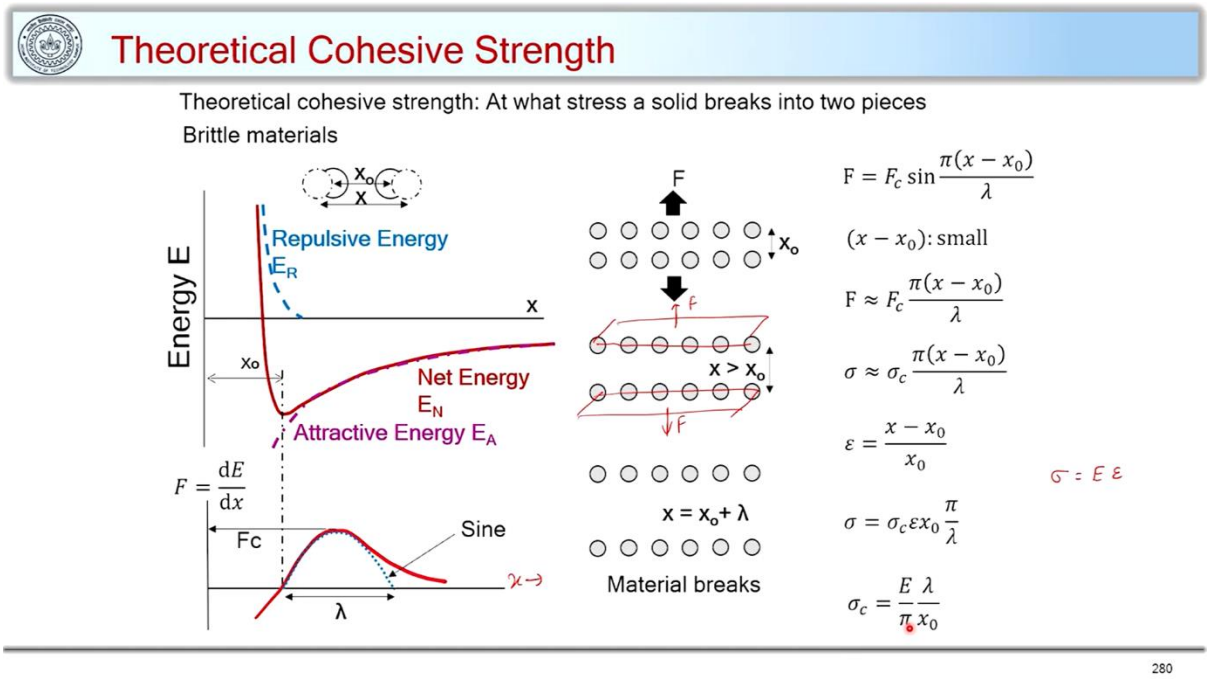
humein kuch void formation honge aur yeh void yahan par form hone ke baad yeh void jaise jaise cross section area ya mein stress badhate ja raha hoon yeh cross section area ghatega aur yeh void coalesce ho jayenge ya jud jayenge ek doosre ke saath aur yeh taiyar karenge kuch

flaw mere material mein aur yahan par aap dekhenge ki jab yeh void coalesce ho jayenge jud jayenge tab yeh yahan par ek stress concentration taiyar karega ek high stress concentration region taiyar karega agar mein usko aur deform karne ki koshish karunga toh yeh flaw jo ki crack ban jayega abhi woh propagate karega aur mera material fail hoga ya fracture hoga. Toh aap dekh paa rahe honge ki mere paas kuch aise fibrous fracture humein ductile material mein milte hain par brittle material mein is tarah ka koi humein void formation ya coalescence nahi milega. Wahin pe

material fail hoga catastrophic. Yeh hum jaanenge hamare part mein. Yeh yahan par sirf mein yahan par aapko sirf iska introduction de raha hoon. Toh yeh ductile fracture mein humein kuch is tarah se void formation aur coalescence ke dwara failure milta hai. Agar mein SEM micrographs dekhoonga toh SEM micrographs mujhe ductile fracture kuch is tarah se dikhega aur brittle fracture kuch is tarah se dikhenge. Toh aap dekh paa rahe honge ki mein SEM mein agar dekh raha hoon scanning electron microscopy karke toh mujhe kuch is tarah se dimples mil rahe hain yani material mein yahan pe yeh jo regions hain yahan

pe yeh kuch isko hum kehte hain dimples jo gaalon pe dimples hote hain usi usi ke analogy ke anusar isko hum kehte hain dimples par agar brittle fracture ki mein baat kar raha hoon toh aap dekh paa rahe honge ki yeh jo surface hai yani fracture surface hai ismein humein relatively yeh jo surface hai flat hai yeh yahan par kuch micro cracks form honge aur yahan par aap dekh rahe honge ki yahan par koi dimples ya cup and cone fracture nahi mil raha hai yahan par ek humein flat surface mil raha hai ek particular crystallographic plane par yeh fracture propagate hota hai. Yeh relatively flat rehta hai aur iske wajah se koi humein cross section area change nahi

milega material mein ya samples mein aur yeh catastrophic failure hota hai. Toh humein brittle failure jo hai woh avoid karna hai aur yeh ductile fracture humein kuch indication deta hai fracture hone se pehle. Toh yeh jo ductile aur brittle fracture hai yeh material ke kuch conditions ke dwara prabhavit hota hai jaise temperature, strain rate, corrosion, corrosive atmosphere ya state of stress uske dwara mera ductile aur brittle fracture material mein ho sakta hai. Toh humein yeh conditions bhi samajhni padegi ki mera fracture kis tarah se affect hoga mere environment ke saath ya deformation conditions ke saath. Toh jab mein fracture ki baat karunga tab



yahan par hum jaante hain ki material mein jo strength hoti hai toh kis strength ke baad material do pieces mein disintegrate hota hai usko hum kehte hain theoretical cohesive strength. Isko samajhne ki koshish karenge kuch model ke dwara. Toh jab mein theoretical cohesive strength ki baat karunga yeh jo strength hai isko mein kahunga ki ek particular stress hai uske baad material ya solid breaks into two pieces yani jo solid hai yeh do se zyada pieces mein tootega ya disintegrate hoga isi ko hum kehte hain theoretical cohesive strength. Toh jab hum theoretical cohesive strength ki baat rahe hain tab hum yahan par yeh development karenge brittle material ke liye.

Brittle materials mein humne dekha ki mostly elastic behavior dikhata hai jaise ki yani material elastic behavior se plastic behavior mein transition karne ki koshish karega toh material fail ho jayega. Toh yeh hum yahan pe theoretical cohesive strength brittle material ke liye study karenge. Toh uske pehle hum dekhte hain ki jab hum iski baat kar rahe hain toh yeh energy versus distance ki baat ki thi Lennard-Jones potential Lennard-Jones potential ke dwara. Toh yahan pe hum dekhenge ki agar mere paas kuch do atom hain kuch is tarah se aur unka ek equilibrium separation hai x_o. Yahan par jo equilibrium separation hai yahan par yeh mark kiya hai x_o is tarah se agar hum material

ko do pieces mein todne ki koshish karte hain toh iska matlab hum kya kar rahe is atoms ko separate kar rahe ya pull kar rahe ek doosre se. Toh jab hum isko pull karenge tab mujhe kuch is tarah se separation milega yani in dono ke beech ka distance badhega aur usko maan leta

hoon mein x aur yeh jo x hai yahan par maine is tarah se plot kiya hai. Toh yahan par initial mere paas ek equilibrium separation distance aur jab mein force lagakar isko separate karne ki koshish karunga pull karne ki koshish karunga toh iska distance x ho jayega x. Ab jab hum yeh energy versus x ki plot karte hain toh hamare paas kuch yeh jo red curve mein mark kiya hai is tarah se kuch energy variation milta hai aur is energy variation se

hum ek force bhi nikal sakte hain ki mujhe force kya chahiye aur agar mein iska derivative leta hoon x se toh yeh humein force milega aur force mujhe kuch is tarah se milega mein iska derivative leta hoon toh humein kuch force is tarah se milega. Toh x_0 par force hamara shunya rahega aur agar jaise mein iska distance badha raha hoon toh yeh force is tarah se vary karega is tarah se change hoga x direction mein. Jab hum yeh force variation baat kar rahe x ke dwara yani x direction mein ya jaise jaise mein isko pull kar raha hoon atoms ko unke beech ka separation badhane ki koshish kar raha hoon toh mujhe is tarah se force lagega yeh yahan pe darshaya hai. Abhi is jab yeh

nature ki baat karunga toh isko mein ek sine curve mein fit kar raha hoon yahan pe. Yeh hamare model ke understanding ke liye ek achha approximation hai. Mein isko ek is tarah se sine nature mein yeh jo variation hai force ka isko mein sine nature mein isko consider kar raha hoon. Abhi aap dekh paa rahe honge ki yahan pe mujhe maximum force agar mujhe apply karna hai material mein toh yeh jo hai yeh jo value hai yeh maximum force rahegi aur is distance ko mein abhi maan ke chal raha hoon ki yeh distance hai λ (lambda) aur yeh jo force hai f_c yeh critical force ho jayega yeh maximum force hai isko mein consider kar raha hoon f_c. Toh mein yeh jo force variation hai agar mein

usko sine consider kar raha hoon toh mein kuch is tarah se likh paoonga. Toh ab isko samajhte hain jaise mere paas ek equilibrium separation tha do atomic planes yahan pe aur yahan par inke beech ka jo distance tha woh x_0 mein maan ke chal raha hoon aur ek mein force apply kar raha hoon jab yeh force apply karunga toh inke beech mein ek separation hoga yeh planes yahan pe kheenche jayenge aur yeh jo x hai yeh greater than x_0 hoga aur jab mein $x = x_0 + \lambda$ pahunch jaoonga tab mera material break ho jaoonga break ho jayega. Toh yeh yahan pe yeh force mein apply kar raha hoon aur uske wajah se inke beech ka separation badh raha hai aur ek value aa jayegi critical value uske baad material

break ho jayega yeh yahan pe mein maan ke chal raha hoon is model mein. Toh mere paas yeh jo separation hai agar mein maan ke chal raha hoon yeh x_0 hai yahan pe aur yeh λ hai toh yeh

jo separation aa jayega x ki value $x_0 + \lambda$ ho jayegi tab material mera break ho jayega disintegrate ho jayega tab yeh force variation yahan par mein kuch is tarah se likh paoonga mere paas f hai maximum value yahan pe $f_c \cdot \sin$ aa jayegi aur hum mein sine variation consider kar raha hoon toh mein sine yahan pe rakhunga aur yeh jo value hai yahan agar mein shunya maan ke chal raha hoon toh yeh π ho jayegi toh yahan pe π/λ aa jayega aur kyunki yeh yahan pe distance x jo maan raha hoon yeh mein λ

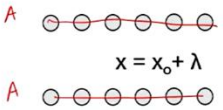
maan ke chal raha hoon aur yeh jo variation hai mein kuch is tarah se likh paoonga $x - x_0$. Toh mein is force ko is force variation ko is tarah se likh paoonga $\pi(x - x_0) / \lambda$. Agar mein isko simplify karunga kyunki yeh jo separation hai $x - x_0$ agar mein small separation ke liye baat karunga toh $x - x_0$ ek bahut chhota separation hai toh yeh value mein simplify karunga kuch is tarah se sine ko mein $\sin(\pi(x - x_0) / \lambda)$ ko mein sirf $\pi(x - x_0) / \lambda$ likh sakta hoon. Toh mere paas ek force ka variation kuch is tarah se aayega. Agar mein force ki baat kar raha hoon toh mein simple approximation consider karunga stress ke bare mein. Toh yahan pe is tarah se

samajhiye kyunki mere paas ek area hai yahan pe yeh kuch is tarah se area hai aur ispe mein force apply kar raha hoon aur yeh area agar mein constant maan ke chal raha hoon toh ek kuch ek achha approximation yahan pe kar sakta hoon $\sigma = \sigma_c \cdot \sin(\pi(x - x_0) / \lambda)$. Agar mein dono side ko area se divide karunga toh mere paas ek stress ki value aa jayegi toh ek simple approximation yahan pe hai toh ek mere paas stress ki value aa jayegi. Toh is stress ki value ko agar aap dekhenge toh yeh jo term hai isko hum strain mein abhi likhenge. Strain mein kuch is tarah se likhenge agar mere paas initial distance x_0 hai agar mein usko elongate kar raha hoon x se

toh strain ko mein is tarah se likh sakta hoon $(x - x_0) / x_0$. Toh yeh meri strain ki value ho jayegi aur is term ko $x - x_0$ ko mein strain ke hisab se likh sakta hoon kuch is tarah se. Toh maine $x - x_0$ ko $\varepsilon \cdot x_0$ se replace kar diya. Abhi mein is stress ko bhi strain ke dwara likh sakta hoon elastic modulus dwara. Toh mein jab mein is stress upon strain mein is tarah launga yahan par toh mere paas kuch elastic jaise stress ko mein is tarah se likh sakta hoon. Toh yeh agar relation mein istemal karunga toh mein σ_c ek critical stress jo yahan pe mujhe chahiye material ko disintegrate karne ya

Theoretical Cohesive Strength

$$\sigma_c = \frac{E}{\pi}\frac{\lambda}{x_0}$$



Two new surfaces created at fracture

Surface energy/area: γ

$2A\gamma = work\ done \quad \Rightarrow 2A\gamma = \int_{x_0}^{x_0+\lambda} F\,dx = F_c \int_{x_0}^{x_0+\lambda} \sin\frac{\pi(x-x_0)}{\lambda}\,dx$

$$2A\gamma = 2F_c\frac{\lambda}{\pi}$$

$$2A\gamma = 2F_c\frac{\lambda}{\pi} \quad \Rightarrow \gamma = \frac{\sigma_c\lambda}{\pi} \quad \Rightarrow \lambda = \frac{\pi\gamma}{\sigma_c}$$

$$\Rightarrow \sigma_c = \frac{E}{\pi}\frac{1}{x_0}\frac{\pi\gamma}{\sigma_c} \quad \Rightarrow \sigma_c^2 = \frac{E\gamma}{x_0} \quad \Rightarrow \sigma_c = \sqrt{\frac{E\gamma}{x_0}}$$

Cohesive strength of a material

Silica
$E = 95\ GPa$
$\gamma = 1\ J/m^2$
$x_0 = 0.16\ nm$
$\Rightarrow \sigma_c = 24.4\ GPa$

2 to 4 orders of magnitude higher than the experimental values

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fracture karne ke liye maximum stress mujhe chahiye jo material ko disintegrate karega woh kuch is tarah se aayega σ_c = E / π · (λ / x₀). Jo x₀ hai yani equilibrium separation hai yeh mein kisi XRD techniques ke dwara istemal karke nikal sakta hoon. E mein ya elastic modulus mein kisi mechanical testing ke dwara nikal sakta hoon par yahan par jo λ hai yeh determine karna bahut mushkil hai ya difficult hai most of the materials ke liye. Toh is λ ko humein kisi aur term se ya kisi aur parameter se humein replace karna padega. Toh aap dekhiye yeh humne ek equation mila hai σ_c = E / π · (λ / x₀) isko hum istemal karenge aur modify karenge.

Abhi hamare paas ek relation hai abhi hum dekhenge jab mein material ko break karne ki koshish karunga kuch is condition mein jab x ki value x₀ + λ ho jayegi tab yeh material disintegrate ho jayega. Disintegrate hoga yani kya hoga yahan par mere paas do surface banenge. Jab humne baat ki thi yeh area hai aur ek area hai toh yeh pehle jude hue the aur yeh jab separate ho jayenge tab mere paas do area yahan par taiyar honge yani jab fracture hoga tab do naye surface yahan pe banenge. Agar surface hamare paas hain toh us surface ki kuch surface energy hoti hai aur us surface energy ko mein γ (gamma) se represent kar raha hoon aur jo surface energy hai surface energy per unit area isko mein

γ se represent kar raha hoon. Abhi mere paas do surface hain toh total surface energy mere paas kuch is tarah se aayegi 2A · γ yeh mere paas do surface hain so yeh mere paas 2Aγ yeh total surface energy aayegi aur yeh total surface energy mein isko consider kar sakta

hoon work done. Work done yani isliye kyunki mere paas yeh energy yahan par aayi hai aur yeh aayi hai kyunki jab mein material ko force apply kar raha hoon aur yeh jab material fracture ho jayega toh isi ko mein consider kar sakta hoon work done aur yeh work done mein consider kar raha hoon toh mein work done ko kuch is tarah se likh sakta hoon yani $2A\gamma = \int F\, dx$ aur isko mein agar integrate

karunga initial condition se x_0 se $x_0 + \lambda$ tak toh mujhe total work done mil jayega. Yeh total work done aur yeh ho jayegi meri total surface energy jab do surface taiyar hote hain. Agar mein isko solve karunga yani yeh f ko mein is tarah se f aur yeh initial sine ke k ismein likhunga toh agar mein is integral ko solve karunga mere paas kuch is tarah se final answer aayega $2A\gamma = f_c \cdot \lambda / \pi$ aur isko mein aur simplify karunga toh yahan par yeh mere paas ek relation hai aur yahan par mein γ ki value kuch is tarah se likh paoonga $\gamma = \sigma_c \cdot \lambda / \pi$. Yeh surface energy mere paas aa gayi. Is λ ko mein mein surface energy ke terms mein

likh sakta hoon $\lambda = \pi \cdot \gamma / \sigma_c$ aur yeh λ ki value hai mein is relation mein plug in karunga mere paas kuch σ_c ki value is tarah se aayega $E / \pi \cdot 1 / x_0 \cdot \pi \cdot \gamma / \sigma_c$ aur mein isko solve karunga toh σ_c^2 is tarah se aayega $\sigma_c^2 = E \cdot \gamma / x_0$. Toh yahan pe σ_c ki value kuch is tarah se aayegi $\sigma_c = \sqrt{(E \cdot \gamma / x_0)}$. Abhi hum dekhenge yeh jo relation humein mil raha hai yeh jo maximum stress humein chahiye jo material ko disintegrate kar sakta hai isko hum kehte hain theoretical cohesive strength of material aur yeh kis par dependent hai yeh dependent hai mera elastic modulus surface energy aur equilibrium

separation between initial atoms aur planes yahan pe. Toh yeh σ_c yahan par yeh ho gayi meri cohesive strength of material. Toh yahan par humne dekha humne ek formulation kiya tha aur yahan par humne jo λ hai isko replace karke kuch simplified way se ek maximum value of stress ki nikali hai jisko hum kehte hain cohesive strength of a material. Abhi hum dekhte hain yeh jo value hai yeh valid hai hamare brittle material ke liye kyunki hamara initial assumption tha brittle material ke liye. Toh abhi hum kuch values dekhte hain silica ke liye. Toh silica ke liye value hai kyunki silica ek brittle material hai aur iski value hai elastic modulus maan ke chalte hain 95 GPa hai γ

maan ke chalte hain 1 J/m² aur x_0 yeh maan ke chalte hain 0.166 nm. Toh yeh teeno value hai yeh experimentally hum determine kar sakte hain. Surface energy bhi hum bahut saare

experimental technique se determine kar sakte hain. Toh yeh agar values hum yahan par rakhenge toh humein ek maximum value of stress मिलेगा aur usko hi hum cohesive strength of material kahenge. Toh σ_c ki value kuch is tarah se aayegi 24.4 GPa agar yeh values yahan pe rakhenge toh aapko yeh value milegi aur yeh value agar aap dekhenge aur practical value agar aap measure karenge yani yeh jo value nikali hai humne theoretically aur practically nikalenge ismein hum dekhenge ki

silica break hota hai yeh much much lower values pe break hota hai ya disintegrate hota hai ya fracture hota hai yeh almost two to four orders of magnitude lower hai ye jo value humein mili hai ye theoretical value experimental values se. Toh yahan par ek discrepancy hai discrepancy kya hai mere paas ek theoretical cohesive strength maine nikali brittle material ke liye aur experimentally observed value jo hai woh much much lower hai mere theoretical cohesive strength ke dwara. Toh yeh jo discrepancy hai yeh hum next part mein dekhenge. Is part mein humne jaana ki humne ek material mein cohesive strength theoretical cohesive strength kya hoti hai jo material mein koi flaw nahi hai aur hum

material ko disintegrate karna chahte hain do parts mein jo maximum value of stress hum jo nikalenge isko hum theoretical cohesive strength kehte hain aur humne silica ke dwara dekha ki jo theoretical cohesive strength hai woh do se chaar order badi hai experimental value se aur yeh jo discrepancy hai yeh hum jaanenge next part mein. Abhi ke liye yahin rukta hoon fracture ko hum padhenge flaws ke dwara ya cracks ke dwara ya koi defect ke dwara agle part mein. Dhanyawad.