

Mechanical behavior of materials

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Week-2

Lecture-6

Stress at a point & Poisson's ratio



Mechanical Behavior of Materials (Hindi)

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References

- Mechanical Metallurgy, George E Dieter, McGraw-Hill.
- Mechanical Behavior of Materials, Marc André Meyers, Krishan Kumar Chawla, Cambridge University Press.
- Mechanical Behavior of Materials, Thomas H. Courtney, Waveland Press, Inc.
- Mechanical Behavior of Materials, William F. Hosford, Cambridge University Press.

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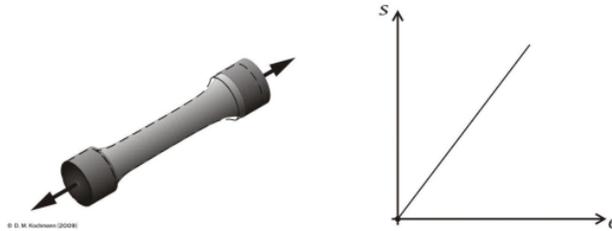
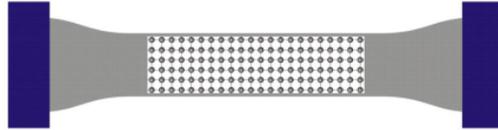
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Stress - Strain Curve till Elastic Limit



Important Note:

- There is a change in lattice parameter(s), thus change in lattice volume
- However small, there is a change in volume during elastic deformation
- What about the volume change in the plastic deformation?

Credits: Prof. Dr. Dennis Kochmann, ETH Zurich

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Namaskar main phir se swagat karta hoon aapka is course mein jo ki Mechanical Behavior of Materials jo main Hindi mein padhaunga. To humne last part mein dekha tha ki elasticity ka atomic origin kya hai. To humne yeh jaana tha, ek relation jaana tha stress ka relation jaana tha strain se, elastic modulus se, aur yeh humne relation paaya tha $\sigma = (S_0/r_0)\epsilon$, S_0/r_0 jo ki hamara elastic modulus hai. Yeh humne baat ki thi, S_0 jo hai hamara bond stiffness hai aur r_0 ek equilibrium distance hai do atoms ke beech mein.

Aur abhi is part mein hum jaanenge, jab hum elastic deformation karenge to elastic deformation mein hum dekhenge ki jaise yeh maine engineering stress aur engineering strain plot kiya hai aur material ko main strain de raha hoon to mera stress proportionally increase ho raha hai. Aur jab main usko elastic deformation aur elastic behavior mein deform karta hoon to jab main stress drop karoon to material contract hoga aur apna original shape ya dimension praapt karega.

To jab main elastic deformation kar raha hoon to yeh yahan par aap dekhenge yeh jo bonds hain yeh stretch ho rahe hain. Jab main usko force increase kar raha hoon to yeh bonds stretch ho rahe hain aur jab main force release kar raha hoon to bonds wapas ja rahe hain aur apne original position par aa rahe hain. To yahan par hum dekhenge ki jaise jaise mera stress badhta hai, jaise mera stress badh raha hai to bond stretch ho rahe hain. Mere bond stretch ho rahe hain to a_{not} ki jo value hai yeh bhi change hogi – ya increase hogi ya decrease hogi? A_{not} value change ho rahi hai? Increase ho rahi hai? Decrease ho rahi hai?

To aapko ek cheez elastic deformation mein milegi jo ki yahan par maine likha hai ki wahan par lattice parameters change honge material ke. Elastic deformation agar lattice parameters change ho rahe hain to mera lattice volume bhi change hona chahiye. To agar aapse koi pooche ki elastic

deformation mein volume change hota hai ki nahi, to aapka answer “haan” hona chahiye – haan, elastic deformation mein volume change hota hai. Yeh small volume change hota hai. Kitna bhi small ho, par thoda sa volume change wahan par hota hi hota hai.

Yahi question agar plastic deformation mein agar hum poochein – volume change hota hai ki nahi hota hai? To answer “naa” hai. Aur iska reason hum baad mein dekhenge. Elastic deformation mein volume change ho raha hai kyunki yahan pe mere bonds stretch ho rahe hain. Aur jab main force release kar raha hoon to yeh bonds apne original position pe ja rahe hain. Jab lattice parameters stretch honge to volume change hoga.



State of stress at a point

Very generic usage, stress = Force/area

Is state of stress same throughout the deforming body?

Stress is a response of material to an externally imposed strain
Rather, resistance to external strain or applied forces



Augustin Cauchy

Image courtesy: Wikipedia

A more difficult concept is the idea of forces and stresses acting *inside* a material,

“*within the interior where neither eye nor experiment can reach*” as Euler put it.

Many great minds working for centuries at the concept of stress we use today,
Augustin Cauchy, who presented a paper on the subject to the Academy of Sciences in Paris, in 1822.

To iske baad hum dekhenge state of stress at a point. Jaise maine stress ki baat ki thi initial slides mein ya previous classes mein, to humne stress ek simple generic way se define kiya tha. Stress ko humne define kiya tha: stress = (Force /Area). Ek simple terminology humne define ki thi. Par stress ka mahatva aur stress ki jo vyakhya hai, woh itni saral nahi hai. Kyunki jab hum stress dete hain kisi material ko, to pehla question humein aana chahiye ki stress – agar hum kisi force apply kar rahe hain kisi material par – to stress same hota hai throughout the body? Jo bhi deforming body hai, uske poore body mein stress same hota hai?

To kisi textbooks mein aap dekhenge ki stress ek response hai material ka, jo ki hum externally imposed strain ke liye dekhte hain. Jaise humne bhi dekha tha humare stress-strain curve se. Jaise agar main stress-strain curve nikaalta hoon, to yahan par aap dekhiye ga ki mera stress Y-axis par aur mera strain X-axis par hai. To strain jo hai woh mera independent variable hai. Jab hum kisi ko X-axis par plot karte hain to woh mera independent variable hota hai, aur stress mera dependent variable hota hai.

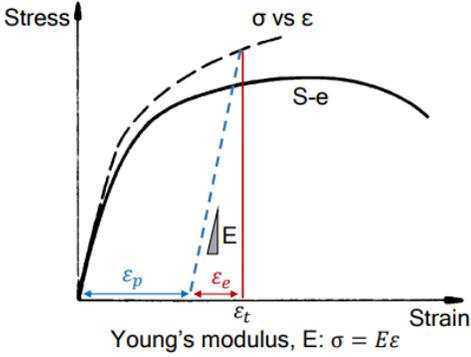
To isi ka matlab yeh hota hai ki jo mera stress hai, yeh material ka response hai, baahari jo strain main impose kar raha hoon material par uske liye, uske prati. Ya main other words mein yeh bhi keh sakta hoon ki yeh ek resistance hai external strain ke liye aur applied forces ke liye. To stress ki vyakhya karna itna saral nahi hai. Par aaj jo hum stress ki vyakhya karte hain aur is course mein hum jo stress ki vyakhya aur stress ka mahatva jaanenge woh kuch contributions se aaya hai.

To kyunki stress yeh jo concept hai, yeh jo internal resistance hai material ka, uske through aaya hai. Agar hum internal jab baat karenge to hum wahan par probe nahi kar sakte ki stress kya hai. Ya hum wahan par experiment nahi kar sakte. Na ki humari aankhein wahan par pahunch sakti hain. Jaise Euler ne point out kiya hai.

To yeh stress ki jo vyakhya aaj hum modern science mein dekhte hain, iski vyakhya Augustin Cauchy ne di thi. Uske liye centuries tak – yaani mujhe lagta hai lagbhag teen centuries – yaani teen shatabdi tak is question pe kaam ho raha tha ki stress kya hai. To aaj ki jo vyakhya hai stress ki woh Augustin Cauchy ne di thi. Aur 1822 se humne isko adopt kiya hai.



State of stress at a point: Poisson's ratio, ν



Young's modulus, $E: \sigma = E\varepsilon$

$\varepsilon_{transverse}$ is related to $\varepsilon_{longitudinal}$ by an elastic constant

Poisson's ratio, $\nu \quad \nu = -\frac{\varepsilon_{transverse}}{\varepsilon_{longitudinal}}$

Negative sign???

$\nu \sim 0 - 0.5$ for most materials

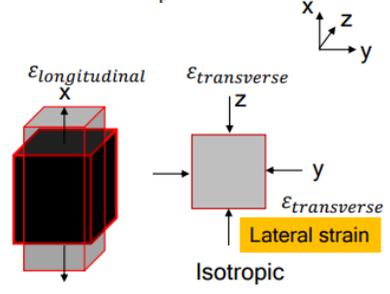
Total strain, ε_t

$\varepsilon_t = \varepsilon_e + \varepsilon_p$

Elastic Plastic

What is ε_p throughout σ vs ε

Plot, σ Vs ε_p ???



Isotropic

Poisson pronounced as Posson and not Poyson

To hum “State of Stress at a Point” jaanenge – ek point pe kya hota hai. To uske pehle main ek elastic constant ko aapse introduce karwana chahta hoon jo ki Poisson's Ratio hai, aur jisko hum ‘mu’ se sambodhit karte hain.

To yeh hamara stress-strain curve hai – aap jaante hi hain. Yeh jo pehla curve hai, yeh hamara Engineering Stress-Strain curve hai. Aur yeh hamara flow curve hai jo true stress-true strain curve hai.

To agar main kisi bhi ek point – maan lijiye yeh point – par main strain nikaalne ki koshish karta hoon, to is point ke strain ko main naam de deta hoon ε_t (total strain). Yeh maan lijiye ki ε_t mera total strain hai material ka is point pe. To is strain ko main is tarah se likh sakta hoon, kyunki yahan

pe elastic deformation bhi ho raha hai, plastic deformation bhi ho raha hai. To main is strain ko likh sakta hoon ki is point pe do contribution hone chahiye – ek elastic strain ka, aur ek plastic strain ka.

To abhi main elastic strain kaise nikaalu? To mujhe yeh relation pata hai – stress ka strain ke saath – Young's modulus se, which is a material constant. To agar yeh relation pata hai, to main kya karoon – mujhe yeh agar elastic modulus pata hai, to main ek straight line draw karoon jiska slope elastic modulus hona chahiye – aur yeh jo linear region hai, isse ek parallel line draw karoon jo strain axis ko intersect karegi.

Yahan pe, us point pe maan lo yeh jo recovered strain hai, yeh mera elastic strain hai. To yahan par hum kya kar rahe hain – jaise humein is point pe nikaalna hai ki total strain kya hai – yeh hamara exercise hai. To humne ek line draw ki jo parallel hai linear region se ya jiska slope elastic modulus hai, is point se jo guzar rahi hai, aur jo strain axis ko intersect karegi. Yeh jo strain mera recover hoga, yeh mera elastic strain, aur remaining jo strain rahega, yeh mera plastic strain rahega.

To isko hum is tarah se bhi jaan sakte hain – jaise yeh mera material hai, yahan tak maine deform kiya hai, is strain tak ϵ_t tak, aur maine yahan se stress release kar diya. To mera recovered strain yeh hoga elastic strain – itna amount. Aur yeh jo rahega – yeh jo rahega – yeh mera plastic strain rahega. Yaani main keh sakta hoon ki mera stress yahan pe zero bhi aa gaya, to bhi material mein ek permanent deformation hai. Aur yeh permanent deformation ka measure jo hai, yeh mera plastic strain hai.

To ek exercise main aapko dena chahta hoon – ki aapko ek plastic strain nikaalna hai yeh poore stress-strain curve ke liye, yaani flow curve. Aap maan lijiye is flow curve ke liye aapko ek plastic strain nikaalna hai, aur aapko ek plot karna hai – stress versus plastic strain. Yahan pe humne stress versus strain plot kiya, yeh total strain hai material ka. Par agar hum yahan pe plot karenge – main likh deta hoon yahan par – agar main stress versus plastic strain plot karta hoon to mujhe kis tarah se plot milna chahiye yeh aapka exercise hai to abhi hum ek aur ek elastic constant ko define karenge Poisson's ratio to usko define karne ke liye maan lete hain ye ek member hai mere paas theek hai aur iske coordinate axis main kar leta hoon is tarah se x, y aur z. Aur maan lete ki is x direction mein main ek force apply kar raha hoon ek tensile force apply kar raha hoon to usse kya hoga ki material elongate hoga jaise is tarah se elongate ho gaya. To maan lijiye mera cross section area hai main upar se agar dekh raha hoon is direction se to yeh mera ek cross section area hai. To yeh material elongate ho gaya to yahan par mujhe ek strain milega x-direction mein. Aur yeh jo cross section hai aap dekhenge yeh decrease ho gaya jaise material elongate ho raha hai humne dekha ki uska cross section area decrease hoga to hum dekhenge ki z-direction aur y-direction se yeh material contract hoga aur yeh jo cross section area hoga yeh decrease hoga.

To is strain ko jab hum calculate karte jo x-direction ke strain ko hum kehte isko kehte longitudinal strain aur agar material isotropic hai hum yeh maan ke chalte hain agar isotropic hai to x-direction aur y-direction jo strain milega wo samaan hona chahiye to is strain ko hum kahenge transverse strain kyunki transverse isliye kahenge ki wo tensile axis ke perpendicular hai.

To transverse strain yaani yeh jo cross section hai yeh jo humara tensile axis hai yeh is area ko perpendicular hai isliye is strain ko hum kahenge transverse strain aur jo tensile axis ke along jo hai usko hum kahenge longitudinal strain isko lateral strain bhi kaha jaata hai. To ek constant hum define karte hain jo ki in dono strains ko relate karte hain jaise transverse strain ko longitudinal strain se hum relate karte hain aur usko kehte hain hum Poisson's ratio.

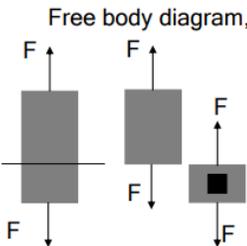
To Poisson's ratio is tarah se define hota hai $\nu = -\epsilon_t/\epsilon_l$ negative of transverse strain ka ratio longitudinal strain se. Yani jo mera transverse strain hai uska longitudinal strain se kya ratio hai us ratio ko hum kehte hain Poisson's ratio. Aur ek aur ek elastic constant hai iska mahatva hum jaanenge jaise jaise hum is course mein badhenge. To negative sign isliye hai kyunki yeh jo strain hai yeh jab hum tensile deformation karte hain to length to increase ho raha hai aur cross section area jo decrease ho raha hai to hum dekhenge ki yahan par contract hoga to yeh strain negative aayega aur longitudinal strain humara positive aayega tensile deformation mein.

To yeh ratio hum positive chahte hain metals aur glass ke liye isliye hum yeh negative sign yahan par istemaal karte hain. To yeh Poisson's ratio bahut saare material ke liye mostly metals alloys ceramics ke liye 0 se 0.5 ke beech mein vary karta hai. To yeh constant ho hamara elastic constant isko bahut saare log mis-pronounce karte hain jaise 'Poissons' kehte hain par actual pronunciation iska hai 'Poisson'. Aapse anurodh hai ki aap jab bhi yeh elastic constant ke baare mein baat karenge jo ki transverse strain to longitudinal strain ka ratio hai usko hum Poisson hi kahenge.



State of stress at a point

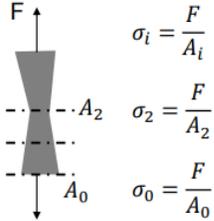
Free body diagram, FBD



State of stress at a point

$$\sigma = \frac{\Delta F}{\Delta A}$$

$$\sigma = \lim_{\Delta A \rightarrow 0} \frac{\Delta F}{\Delta A}$$

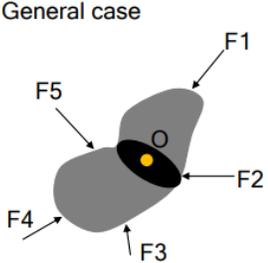


$$\sigma_i = \frac{F}{A_i}$$

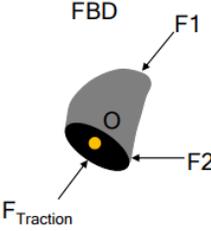
$$\sigma_2 = \frac{F}{A_2}$$

$$\sigma_0 = \frac{F}{A_0}$$

General case



FBD



Change in shape or cross section
Change in state of stress

Force/traction implies body is in Static Equilibrium

$$\sum F = 0 \quad \text{No acceleration}$$

$$\sum M = 0 \quad \text{No rotation}$$

$$\sigma = \frac{\Delta F}{\Delta A}$$

To abhi chalte hain state of stress at a point. Wahan se humne shuruat ki thi ki point pe state of stress kya hona chahiye. To iske liye maan lete hain ek humare paas ek member hai aur jisko maine tensile force apply kiya hai aur ek equilibrium mein hai static equilibrium mein hai. Ismein koi deformation nahin ho raha hai bas ek force apply kiya hai. To hum maan lete hain is body ko hum do bhaag mein divide kar dete hain kaat dete is plane se to hum iska ek free body diagram nikaal sakte hain.

Free body diagram hum agar upar wale part ka hum nikaalenge to yahan par yeh jo force hai yeh balance karna chahiye is force se kyunki humne kaha ki body equilibrium mein hai yani ismein koi deformation nahin ho raha hai bas humne force apply kiya hai. To doosra part jo hai yahan par is part mein bhi is direction mein force apply hona chahiye. To maan lijiye jaise humne ek plane consider kiya hai yeh wala plane humne consider kiya hai to yahan par force lagega is direction mein aur yahan par force lagega is direction mein.

To yeh hum maan sakte kyunki jab hum equilibrium ki baat karte hain to body mein jo forces hain woh ek doosre ko poorn karne chahiye tabhi agar yeh imbalance hai forces to material mein deformation hoga material equilibrium mein nahin rahega. Maan lijiye yahan par to humne stress kaise define kiya tha pehle? To ek point par hum stress kaise define karenge? Hum stress ko define karenge stress $(\sigma) = \Delta F / \Delta A$. To isko maan lete hain ek chhota sa point yahan par is body par iska cross section area hai main likh leta hoon iska cross section area hai mera ΔA aur yeh cross section area par jo force change agar experience kar raha hai mera material to ek delta F hai to yahan ka stress = delta F upon delta A. Simple definition se humne jaana.

Isko hum thoda aur accurate kar sakte hain. State of stress at a point hum baat kar rahe hain to hum bolenge ki area is tending to zero to yani area ghat raha hai chhota chhota ho raha hai yani yeh area jaake milega ek point pe. To hum is tarah se stress ko abhi define kar rahe hain. To ek ho gaya hamara thoda aur rigorous mathematical definition stress ka ek kisi bhi point pe.

Aur yeh to uniform body thi. Agar humare paas aisi body hai to kya hoga? Jaise maine isko force apply kiya aur yahan par mera cross section area change ho raha hai to is yahan par mera cross section area A_0 hai, yahan par A_1 hoga, yahan pe A_2 hoga. Aur main dekh raha hoon ki is geometry se ki A_0 mera area bada hai A_2 ki tulna mein. To stress yahan pe A_0 pe kya experience hoga material ka? To yahan par main σ_0 define karunga $\sigma_0 = F/A_0$. σ_2 pe hoga Force upon cross section area A_2 . To yeh hoga $\sigma_2 = F/A_2$. To main general case aise likh sakta hoon ki koi bhi cross section area jab main is body mein loonga to yeh is tarah se define hoga Force upon body ka cross section area. To main jaan sakta hoon ki yeh body jiska cross section area uniform nahin hai jiska shape uniform nahin hai to usmein mera overall stress vary ho raha hai har point par.

Jahan par mera cross section area change ho raha hai wahan par mera stress alag hoga. To is tarah se hum jaan lete hain ki jaise mera area agar kam hai to stress experience zyada rahega.

To isiliye aap jaanenge ki humne tensile test jab kiya tha tab maine baat ki thi ki humara tensile specimen shape dog-bone shape hai to maine bola tha ki gauge points mein stress zyada hona chahiye aur yeh jo cross section area hai yeh uniform hona chahiye kyunki main nahin chahta ki in dono points ke beech mein stress ka koi variation ho. Stress change na ho is point par.

To isiliye hum cross section area ek uniform rakhte hain aur sabse kam cross section area is gauge length mein hi rahta hai. To yahi reason tha ki state of stress hamara change ho sakta hai agar hamara shape ya cross section area change ho raha hai.

To ek general case lete hain abhi. Yeh to humne define kiya ki humare paas do simple cases hain. Agar general case hai ek body hai arbitrary shape ki aur uske upar forces lag rahe hain different

directions mein body hamari equilibrium mein hai F1, F2, F3, F4, F5 yeh forces lag rahe hain different directions mein aur in wajah se yeh body equilibrium mein hai.

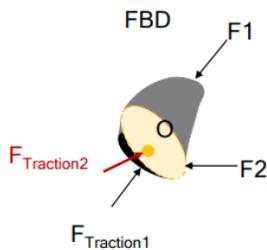
To ek maan lete hain ek point O hai mera is body pe aur ek plane main draw kar leta hoon is point O se jaane wala. To main agar is body ka FBD nikaalta hoon upper part ka agar FBD nikaalta hoon to mujhe main is tarah se kuch likh paonga. Aur main kya karta hoon agar mujhe FBD nikaalna hai to main in forces ka F3, F4, F5 inka ek resultant force jo main apply karoon us force ko main kehta hoon traction force jo is surface area par act ho raha hai aur is point ke through ja raha hai.

To yeh body mera equilibrium mein hai. To yeh traction force isliye mujhe zaroori hai kyunki mera body ka equilibrium maintain hona chahiye. To main agar FBD nikaal raha hoon upar ke part ka to mujhe yeh forces ko replace karna padega ek resultant force se jo meri is body ko equilibrium mein maintain rakhe. To equilibrium jab main baat karta hoon to yeh do conditions main apply karta hoon: $\sum F = 0$ aur $\sum M = 0$. Yani do saare forces ka summation shunya hona chahiye aur saare moments ka summation shunya hona chahiye.

To jab main FBD draw karta hoon to maan lijiye yahan par agar main stress ko define kar raha hoon abhi to yeh force yani equilibrium kyon maintain hona chahiye kyunki body hamara accelerate nahin hona chahiye aur hamara body rotate nahin hona chahiye. To agar hum stress ko define kar rahe abhi is condition mein jab jo mera body static equilibrium mein hai to hum isko is tarah se define karenge $\sigma = \Delta F / \Delta A$.

 **State of stress at a point**

Stress changes with orientation of the cutting plane



Stress changes with orientation or change in reference coordinate axis

For convenience, we don't define stress at some arbitrary angle

Stress defined on perpendicular to the cut surface and parallel to the cut surface

To agar hum firse dekhenge is FBD ko to yeh ek mera plane maine draw kiya tha is point O se ja raha hai aur agar maan loon ek doosra plane is point se ja raha hai to agar is body ko equilibrium mein maintain rakhna hai to mujhe ek resultant traction ($F_{Traction}$) force firse find out karna padega jo in dono forces ko balance kar sake jo main traction ke through aapko yahan pe likh raha hoon.

To main jaan sakta hoon ki mera state of stress change ho raha hai Hai to agar is main F traction ke liye agar stress nikal loonga to to mujhe σ jo maine likha tha ΔF upon ΔA okay aur yahan par bhi main limit likh sakta hoon ΔA tends to 0 to yahan par mera traction force is case mein change ho raha hai delta F ho raha hai aur yeh bhi change ho raha hai to mera state of stress jo plane mein interested plane jo hoon uske wajah se change ho raha hai.

To ek point se to infinite number of plane ja sakte hain to main state of stress ek kisi bhi point mein kaise define karunga. Ya doosri cheez ho sakti hai ki agar maine coordinate axis pehle aise likh liye aur coordinate axis maine change kiye to mera state of stress usmein bhi change ho sakta hai. To stress change hota hai mera reference coordinate axis ke wajah se ya mere plane ke orientation ki wajah se. To hum aise hi kisi yaane state of stress aise hi define nahin karte kisi bhi arbitrary plane par. Force jab act kar rahe us plane ko hum usko decompose karte hain do components mein. To hum jaanenge jaise mera ek plane hai is yahan par ek plane hai aur ek mera force act ho raha hai yahan par. Kisi bhi agar yeh mera surface ka normal hai to aur yeh force angle alpha bana raha hai to hum is tarah se usko define nahin karte is traction ko. Hum chahte hain ki is force ko resolve karein do cases mein ek along the direction of normal aur is force ko hum resolve karenge is plane mein. Hamare paas do component honge ek normal component hoga is force ka aur ek component hoga jo is plane mein rahega in-plane component. In dono component ko hum resolve kar sakte hain. To stress ko hum do tarah se define karenge ek perpendicular to the cut surface aur ek parallel to the cut surface. To isko hum jaanenge aur is slide mein state of stress hum kaise define karte hain.

State of stress at a point: Normal and shear stress

σ_{\perp} is called as a Normal Stress
Compression or extension

$$\sigma_{\perp} = \lim_{\Delta A \rightarrow 0} \frac{\Delta F \cos \theta}{\Delta A}$$

$$\sigma_{\parallel y} = \lim_{\Delta A \rightarrow 0} \frac{\Delta F \sin \theta \cos \phi}{\Delta A}$$

$$\sigma_{\parallel x} = \lim_{\Delta A \rightarrow 0} \frac{\Delta F \sin \theta \sin \phi}{\Delta A}$$

σ_{\parallel} is called as Shear Stresses
Distortion of shape σ_{\parallel} represented by τ

Normal or shear stresses changes with surface orientation or change in reference coordinate axis

Maan lijiye mera ek area hai ΔA aur ek point O hai aur yahan par maine mere coordinate axis mark kar liye x, y aur z. To sahajta ke liye main z jo manoonga yeh jo surface normal hai is surface ka usi direction mein mera z-axis hai aur x aur y plane hai yeh mere is surface mein hai. Aur ek force act kar raha hai is surface par ΔF aur mujhe agar angle pata hai direction ka aur is ΔF ka to is force ko main decompose kar sakta hoon do components mein ek is plane ke perpendicular component

mein aur ek is plane ke parallel component mein ya is plane mein jo act ho raha hai. To yeh jo component hai yeh milega mujhe $\Delta F \cos \theta$ aur yeh jo component hai jo is plane mein aa raha hai yeh mera ho jaayega $\Delta F \sin \theta$. To agar mujhe yeh angle bhi pata to agar main perpendicular component nikaaloon stress ka is agar hum stress ka definition nikaalein to ek perpendicular component mera aayega limit ΔA tends to zero $\Delta F \cos \theta / \Delta A$.

Yeh jo ho gaya mera perpendicular stress is surface ko perpendicular. Agar mujhe angle ϕ pata hai y-axis se jo make kar raha hai to is stress component ko ya force component ko main aur divide karoon x aur y direction mein is tarah se aur yeh jo component aayenge mera $\Delta F \sin \theta \sin \phi$ aur $\Delta F \sin \theta \cos \phi$. To mere paas do stress aane chahiye aur yeh do stress aayenge jo ki is surface ko parallel hain. Abhi agar yeh dekhenge do components yeh forces ke component parallel hain is surface ko ya is surface mein hi hain. To yeh jo pehla component hai jo parallel to y-axis hai isko main likh sakta hoon limit ΔA tends to zero $\Delta F \sin \theta \cos \phi / \Delta A$.

Aur yeh jo doosra component hai jo x-axis ko parallel hai usko main likhoonga stress = limit ΔA tends to zero $\Delta F \sin \theta \sin \phi / \Delta A$. To mere paas do component honge jo perpendicular hain is surface ko aur ek component hai jo parallel surface ko. Jo parallel hai usmein mere paas do component x-axis ko parallel aur y-axis ko parallel hai. To jo perpendicular component hai isko main kehta hoon normal stress kyunki yeh normal hai is surface area ko. Aur jo parallel components hain unko main kehta hoon shear stresses. To main ek force se agar ek force ya traction jo bhi act kar raha hai mere surface par usse mujhe teen stresses mil rahe hain: ek normal stress hai aur do shear stresses hain.

To shear stresses abhi aapko pata honge ki shear stresses parallel to surface rahte hain aur normal stress perpendicular to surface rahte hain. To normal stresses hum jaanenge yeh hamare material ko compress ya extend karte hain aur shear stresses hamare material ko distort karte hain. To distortion kya hota hai jaise ek mera yeh surface ek component hai aur yahan par mere shear stresses hain. Yeh shear stresses ke symbol hai hum dekhte hain isko aur jaankari lenge par yeh jab distort karenge to yeh material ko is tarah se distort karenge to mera material is tarah se yaani pehle square tha abhi ek aise rhombus ho gaya hai. To hamare paas abhi normal stresses hain aur shear stresses hain. Humne jaana is video mein ki normal stresses yaani koi bhi force ko main resolve kar sakta hoon koi bhi surface hai usko us tarah se resolve kar sakta hoon ek normal stress mein aur do shear stresses.

To abhi bhi hum state of stress isko achchhe se define nahin kar paa rahe kyunki yeh jo delta A hai agar mera change ho raha hai yaani mera orientation plane ka change ho raha hai to phir mera state of stress change hoga. Aur ya maine ek mera coordinate axis change kar liya to mera state of stress firse change hoga. To hum next video mein dekhenge ki state of stress doosre point ya kisi point par define karne ke liye aur kya cheezen aur kya cheezon ki aavashyakta hai hum dekhenge next part mein.

Thank you.

