Mechanical behavior of materials

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Week-1

Lecture-3

Measure of Ductility, UTS and Necking

Mechanical Behavior of Materials (Hindi)

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So last part mein humne dekha ki hum engineering stress-strain curve se kaun se points nikal sakte hain jaise proportional limit, elastic limit, proof stress, aur ek aur point jo humne dekha tha UTS. Ye saare points dikhate hain ki hum elastic region se plastic region mein kaise move kar rahe hain.

Iska importance ye hai ki jab material elastic se plastic deform hota hai, to dimensions mein permanent change aa jata hai. Jab hum engineering applications dekhte hain, hume chahiye ki unke dimensions mein koi change na ho. Agar change ho gaya, to material fail ho sakta hai. Isliye hum chahte hain ki dimensions stable rahein, aur isi liye ye points important hote hain.

Uske baad hum dekhenge ki "measure of ductility" kya hota hai. Ductility ek qualitative term hai, jo batata hai ki engineering stress-strain curve ke kis hissa mein hum baat kar rahe hain. Ductility fracture tak consider ki ja sakti hai. Last class mein maine bataya tha fracture strain ek parameter ho sakta hai ductility ka, ya strain-to-fracture, ya elongation percentage.

Ek example lete hain — ek member hinge hai ek end pe, aur dusre end pe hum tensile force apply karte hain. Uska initial length L_0 hai, aur initial cross-sectional area A_0 hai. Tensile force se member elongate hota hai, aur cross-sectional area decrease hoga.

Final length L_f ho jayegi, aur elongation $e_f = (L_f - L_0) / L_0$ ho jayega. Isko hum measure of ductility mann sakte hai.

Cross-section change hone ka reason hum dekhenge, lekin yahan ek parameter define karte hain — reduction in area:
Reduction in area $q = (A_0 - A_f) / A_0$

Plastic deformation ke dauran (necking se pehle), cross-section uniform decrease hota hai aur *constancy of volume* follow hota hai. Matlab plastic deformation mein volume change nahi hota — initial volume ($A_0 \times L_0$) hamesha final volume ($A \times L$) ke equal hota hai.

i.e., $AL = A_0 L_0 = A_f L_f$

$e_0 = q/(1-q)$
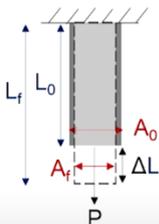
Ye relation use karke hum elongation aur reduction in area measure kar sakte hain. Jitna bada parameter, utni zyada ductility.

To yeh mera stress-strain curve hai, yeh mera linear region hai, mera plastic region hai, yeh elastic region hai, yeh mera plastic region hai. To humne dekha hai ductility hum jab baat karenge strain till fracture to strain till fracture ka matlab hota hai yahaan tak ka fracture, yahaan tak ka strain, yeh mera strain till fracture, yeh ek mera measure of ductility hai.

Strength ke parameters kaun se jo measure karte hain hum engineering stress-strain se, woh hai yield strength aur ultimate tensile strength. So yield strength ko hum is tarah se bhi dekh sakte hain ki yeh material ki ability hai jo plastic deformation ko resist karti hai. Yaani jitna yield strength zyada utna main elastic deformation kar paunga material ka aur utna hi main plastic deformation ko resist kar paunga. Isliye yield strength bhi ek important parameter hai material behavior ka jo batata hai ki material ke ability to resist plastic deformation.

Ek stiffness parameter hai, slope of stress -strain curve hai, yeh linear region mein, linear elastic region mein jo slope hai, yeh humara stiffness hai. Humne Young's modulus ko bhi dekha tha ki stress upon strain elastic region mein Young's modulus hi hota hai. To hum isko stiffness ki stiffness karte hain. Jab humein springs ya other kuch members hain jo uniform cross-section area nahi hota hai tab hum stiffness term tab v karte hai jab dusre loading conditions jaise bending, torsion. hum stiffness material ka jo batayega ki hum elastic deformation ko resist kar paate hain ki nahi.

To agar jitna zyada slope utna elastic strain kam, mujhe batane dijiye jaise mere paas do material hain aur ismein slope alag-alag hai, ismein elastic modulus zyada hai aur ismein elastic modulus kam hai, slope kam hai iska. To hum iska stiffness ki bhi jab baat karenge to stiffness ka kam rahega doosre material se. To yeh hum baat karenge to yeh elastic deformation jab hum baat karenge jo elastic strain rahega yahaan par, to doosre material mein elastic strain kam aayega. Isliye hum baat kar rahe hain isko ability to resist elastic deformation.

Toughness aapne baat suna hoga, toughness material tough hai to toughness yeh hota hai ki yeh area under this stress-strain curve, yaani isko jab hum area ki baat karenge to area under stress-strain curve hoga yeh energy absorbed per unit volume of material till fracture. To yeh jo shaded area hai yeh hum jab calculate karenge yeh material ka toughness hoga.

To toughness ka unit jab hum area nikaalte to yeh stress-strain curve hai to yeh toughness ka unit hoga stress into strain. Stress ka unit humne dekha tha Newton per meter square aur strain ka koi unit nahi hota hai. To is Newton per meter square ko hum is tarah se bhi likh sakte hain Newton meter upon meter cube. To maine meter ko upar se multiply kiya aur numerator aur denominator ko multiply kiya to mujhe mil gaya upar Newton meter upon meter cube. To Newton meter agar hum dekhenge yeh Joules hai. To hum toughness ko likh sakte hain Joules per meter cube. To yeh commonly unit hai toughness ka Joules per meter cube jo area jab hum baat karenge to yeh ho jayega humara toughness, woh Joules per meter cube mein hum isko measure karenge.

To aur ek parameter hai resilience. Resilience kya hota hai, resilience bhi energy absorbed per unit volume hota hai when deformed elastically. Yaani jab hum material ko elastic deformation karte hain, yaani yield strength tak agar hum dekhenge to yeh jo area hai yahaan ka, isko hum kehte hain resilience. Iska bhi unit kya hona chahiye, iska bhi unit hona chahiye Joules per meter cube. Yeh apply tab hoga jab hum resilience hum istemal tab karte jab hum mechanical springs wagairah ki baat karte hain.

Measuring other parameters

Parameters: from uniaxial tensile test

Ductility: strain till fracture

Strength: YS and UTS
YS: Ability of a material to resist plastic deformation

Stiffness = Slope of S-e curve in linear elastic regime
i.e. Young's modulus
Ability to resist elastic deformation

Toughness:
Energy absorbed per unit volume of material till fracture = area under stress strain curve
Toughness = stress × strain = N/m^2 = $N\,m/m^3$ = J/m^3

Resilience: Energy absorbed per unit volume when deformed elastically
Useful for applications, such as mechanical springs

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Abhi hum dekhenge UTS, tensile strength aur stress and necking kya hota hai. To yeh mera ho gaya ultimate tensile strength aur stress, yeh point yahaan par stress-strain curve par maximum stress jo mil raha hai is engineering stress-strain curve par, yeh mera ultimate tensile strength ho gaya.

Aur abhi hum dekhenge ki is yahaan tak ka progression kya hai is stress-strain curve ka mere samples ka. To yeh mere do initial gauge marks se gauge points se aur jab mera material deform ho raha hai jaise-jaise main force apply kar raha hoon badh raha hai ya strain badh raha hai material pe to yeh gauge points move honge, door jayenge ek doosre se yaani material ka elongation ho raha hai.

To yahaan par dekhenge ki humara material uniform deform ho raha hai par yahaan par is condition mein jab aayenge jaise UTS ke just turant baad yahaan par ek localized deformation chalu hoga. Yahaan par localized deformation chalu hoga jisko humne kaha tha necking. Isko constriction bhi baat karte hain kisi kisi books mein, constrict ho raha hai area, constricted yaani gala ka area jaise hota hai humara woh constricted area hai. To isko hum constriction kehte hain.

To iski wajah se kya hoga yahaan par localized deformation chalu hogi. To localized deformation jab chalu hogi to yahaan par humare kuch voids banenge, yeh voids ek doosre ke saath milenge to ek crack tayyar hogi aur phir yeh crack jab yahaan par stress badh raha hai to ek crack hogi propagate is cross-section ke through aur yeh humara material fail hoga ya fracture hoga.

To yeh humare gauge marks hain, yeh humara cross-section area uniform change ho raha tha, yeh humari initial necking hai jo yeh jo neck region hai yeh region of instability, yeh maine pehle bhi bataya tha. Instability isliye hum kehte hain kyuki iske baad yeh jo region ke baad mujhe koi extra force nahi chahiye jo material ko deform kare ya extra stress nahi chahiye jo material ko deform kare. To instability isliye kehte hain ki mujhe koi extra load ki zaroorat nahi hai material ko deform karne ki ya usmein strain develop karne ke liye.

To isliye hum isko kehte hain instability region. Yeh kyun hota hai kyuki humne dekha yahaan par cross-section area decrease ho raha hai aur deformation yahaan par concentrate ho jayegi is localized region par. Isliye mujhe koi extra stress nahi chahiye, force nahi chahiye material ko further deform karne ke liye.

To yahaan par humne baat ki thi void formation ki, yahaan par yeh jo void coalescence humne baat ki thi, voids ek doosre ke saath jud jayenge isko hum kehte coalescence. To void coalescence ho jayenge aur uske baad yeh crack propagate hogi aur is crack propagation se humara material fail ho jayega, fracture ho jayega.

Humne baat ki thi is plastic region mein till UTS constancy of volume humne baat ki thi yeh valid nahi rahega UTS region mein, constancy of volume valid nahi rahegi. To yeh relation hold nahi karega.
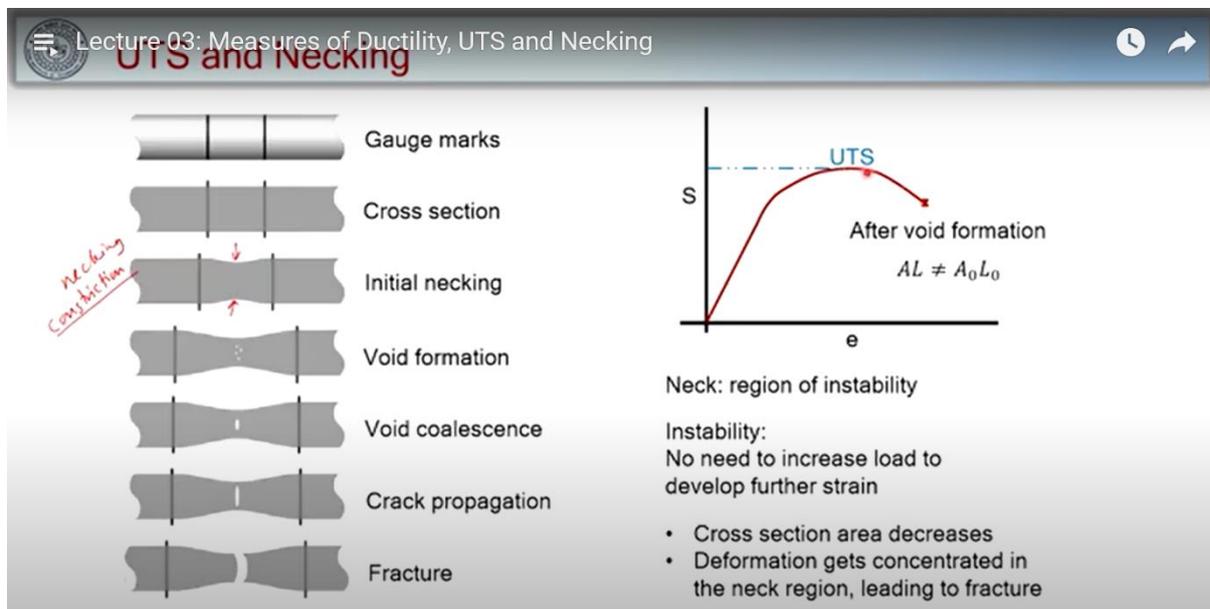
Abhi hum stress-strain curve dete hain different material ke liye. To yeh humara stress hai y-axis pe aur strain hai mera x-axis pe. To yeh jo stress-strain curve hai yeh typical stress-strain curve hai aur is stress-strain curve mein mujhe pata chal raha hai ki mera strength badh raha hai aur ductility ghat rahi hai. Ductility yaani ductility ka agar measure main yahaan par bataun to fracture strain yaani yeh yeh strain. To yeh hum isko classical mechanical textbooks mein isko strength-ductility bhi dekhte hain, isko strain-ductility trade-off kehte hain.

Trade-off isliye kehte hain kyuki agar main material ka strength badhana chahta hoon to uski ductility sacrifice ho jayegi ya kam ho jayegi. Yahaan par dekhiyega is material mein maine strength badhane ki koshish ki aur ductility decrease ho gayi hai. To isliye strength aur ductility saath-saath badhane ki hum prayas to karte hain par aisa hota nahi hai isliye isko hum kehte hain trade-off.

To yeh jo mera material hai usko main kahunga material A jo low strength aur high ductility material hai aur yeh mera material B hai jisko hum kahenge high strength aur low ductility material. To mera material A jo hai jo typical material hai aluminum, copper yeh jo material hai yeh humare ductile material mein aate hain aur yeh jo B material hai yeh mere high strength steel ya spring steels ismein aate hain. To yeh jo material hai high strength steel yeh is tarah ka stress-strain behavior dikhate hain.

Yeh typical stress-strain curve hai jo aap dekhenge aur isko hum padhenge abhi detail mein is course mein. Yeh jo material hai yeh humein de raha hai two yield points yahaan par material yield ho raha hai pehla yielding yahaan par ho raha hai doosra yielding yahaan par ho raha hai. To yeh jo typical behavior hai stress-strain behavior hai yeh low carbon steels dikhate hain jismein humein do yield points milte hain.

Yeh jo pehla wala yield point hai hum usko kehte hain upper yield point kyuki upar hai aur yeh jo doosra wala yield point hai usko hum kehte hain lower yield point. To yeh humara upper yield point ho gaya, yeh humara lower yield point ho gaya. To low carbon steel hum jab baat karenge tab main baat kar raha hoon 0.3 weight percent se neeche wale jo carbon content hai steel mein, un steels ki baat kar raha hoon.

Yeh aur ek material hai isko maine naam diya D yeh mujhe brittle behavior de raha hai aur ismein main bataunga ki ismein no plastic strain yaani ismein plastic strain nahi, jaise hi elastic limit cross ho gayi ya yield strength aa gaya material fail ho jata hai. To yeh jo is type ka behavior jo milta hai woh humein ceramics ya intermetallics ya ordered material mein milta hai. Mujhe likhne dijiye isko bhi yaani ceramics ya intermetallics ordered material ismein bhi humein yeh behavior dikhta hai.

To hum kis tarah se baat karenge ki kaun sa material high strength hai low ductility hai to uske liye ek parameter hai humne baat ki thi strain to fracture jo maine bola hai strain to fracture ek mera parameter hai jisse main bataunga ki kaun sa material ductile hai kaun sa material mera brittle hai.

Strain-to-fracture:
$e_f \leq 0.1\% \rightarrow$ brittle
$e_f \approx 10\% \rightarrow$ ductile
$e_f \geq 1000\% \rightarrow$ superplastic

To agar strain to fracture mera less than and equal to 1% hai usko main kahunga brittle material. To is case mein dekhenge ki jaise yeh jo strain hai woh bahut kam strain hai woh less than and equal to0. 1% hai to main usko brittle materials kahunga. Agar woh 10% hai strain to fracture yaani yeh yahaan tak yeh jo agar 10% hai to usko main kahunga ductile material aur agar kuch material aise hote hain ki jo strain to fracture jiska greater than 1000% hota hai usko hum superplastic material kehte hain.

To in saare material ke baare mein hum is course mein jaanne ki koshish karenge. Humare typical stress-strain curves hain jo main aapko introduce karana chahta tha.
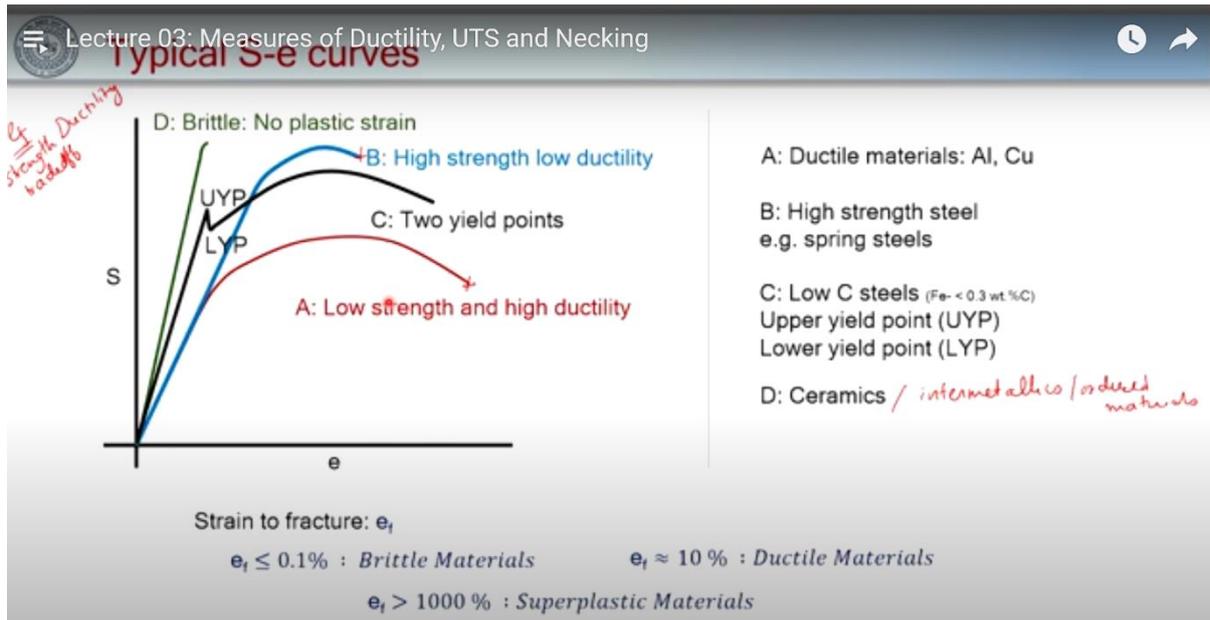
Abhi humne dekha hai ki jaise stress-strain ki baat kar rahe the to jaise jaise mera material deform hota hai to uska cross-section area decrease hota hai. Agar cross-section area decrease ho raha hai to stress jo material experience kar raha hai woh badhega. Agar woh badh raha hai to mujhe ek parameter ki zaroorat hai jo yeh instantaneous yaani us moment par kya cross-section area hai ya us moment par kya strain hai yeh measurement ki mujhe zaroorat padegi.

Mujhe usko thoda sa explain karne dijiye jaise maine stress ko define kiya tha yeh mera engineering stress, strain engineering stress hai jo usko maine force upon initial cross-section area aise define kiya tha aur maine strain ko engineering strain ko define kiya tha change in length upon original length par. Yeh jo original length hai jab main material deform kar raha hoon tab yeh constant nahi hai yeh change ho rahi hai.

$S = F/A_o$

$e = \Delta L/L_O$

Jaise maine initial liya tha L_O aur cross-section mera A_O hai jaise badhega to yeh A_O nahi rahega yeh A ho jayega aur yeh length change ho jayega. To jaise jaise cross-section area

gatega waise waise mera stress experience badhega. Mujhe kuch clear idea nahi mil raha hai jab mera material deform ho raha hai jaise elastic to plastic deform ho raha hai kisi bhi strain par mujhe ek idea nahi aata hai engineering stress se isliye mujhe true stress aur true strain ki baat karni padegi jo mujhe batayega ki instantaneous instantaneous yaane us moment par us time par mera stress kya hai material par aur strain kya hai material par.

To isko hum define karte hain $\Delta\varepsilon$ is is parameter se yeh yahi mera symbol rahega epsilon true strain ke liye. To yeh mera instantaneous change in length jisko main dL ke ba ya differential hai upon instantaneous length. Yeh mera instantaneous at that moment jo length hai mere sample ka us hisaab se main baat kar raha hoon.

$d\varepsilon = dL/L$

To true strain agar main baat karun yaani jaise mera material deform ho gaya initial length to final length to yeh mera main usko integrate kar raha hoon is mera small strain hai jo develop hua material par at any given instant kisi bhi moment par jo diya hai us moment par jo mera strain hai yeh maine define kiya.

$$d\varepsilon = \frac{dL}{L}$$

$$True\ strain = \varepsilon = \int_{L_0}^{L} \frac{dL}{L} = ln\frac{L}{L_0} = ln\frac{L_0 + \Delta L}{L_0}$$

$$\varepsilon = ln(1 + e) \qquad \qquad \because e = \frac{\Delta L}{L_0}$$

To yeh engineering strain agar maine isko replace kar diya is equation mein to mujhe milega true strain equal to $ln(1 + e)$ yeh bahut important relation hai true strain kisi bhi uske true uske engineering strain ke saath. To ek kisi bhi given moment par main true strain agar mujhe pata hai to main uska engineering strain us moment par nikaal sakta hoon ya mujhe engineering strain pata hai us moment ka to main us moment par mera true strain nikaal sakta hoon.

To yeh ho gaya mera true strain. True stress kya hota hai true stress bhi hum is tarah se define karte yeh mera symbol hai sigma true stress ko main isi symbol se denote karunga is course mein. Yeh mera force hai jo maine force apply kiya member par aur yeh kisi bhi given moment par jo cross area hai woh mera at that instant jo cross-section area us area ko main maanoonga aur us area se main nikaalu true stress.

Jaise jaise ki is condition mein is condition mein mera cross-section area A tha to is condition mein mera true stress ho jayega sigma = P / A agar mera cross-section area doosre movement

par ghatta hai kam hota hai main usko loonga A1 to yeh jo true stress hoga mera force applied upon the area at that cross-section at that instant so yeh ho jayega mera true stress.

To true stress ko hum is tarah se bhi likh sakte hain P / A to main usko A not aur A not se divide aur multiply kar raha hoon to P / A not yeh kya ho gaya mera yeh ho gaya mera engineering stress aur yeh jab main istemal kar raha hoon to yeh isliye kar sakta hoon kyuki main constancy of volume mein constancy of volume valid hai to yeh ho jayega mera

$$True\ stress = \sigma = \frac{P}{A}$$

$$\sigma = \frac{P}{A_0}\frac{A_0}{A} \qquad \because AL = A_0 L_0$$

To yeh term jo maine replace kiya L / L$_o$ to isko main likh sakta hoon A$_o$ / A ko main likh sakta   1 + e to yeh jo term hai yahi yahi term hai L / L$_o$ ko main 1 + e likh sakta hoon yeh jo term hai. To mere paas do relations aa gaye ek true strain aur engineering true stress jo main engineering strain aur engineering stress aur engineering strain se likh sakta hoon.

$$\sigma = S(1 + e)$$

To hum iska implication dekhenge ki true stress true strain curve pe yeh mera stress-strain curve hai to jo mera pehla jo solid line curve hai yeh mera stress-strain curve hai engineering stress-strain curve hai aur yeh jo mera curve hai dotted wala yeh jo hai mera true stress true strain curve hai.

To agar main dekhunga to maine true stress true strain curve yahaan tak hi draw kiya hai is point tak hi draw kiya hai. To yeh jo mera point hai yeh mera point hoga hamesha UTS tak kyuki yeh curve main agar yahaan tak hi draw kar sakta hoon kyuki constancy of volume jo maine istemal kiya yeh yahaan tak hi valid hai iske beyond yeh valid nahi hoga.

To kyuki humne yeh relation ismein istemal kiya hai to isliye hum true stress true strain curve yahaan tak hi nikaalna valid hai unless aap koi parameters istemal nahi karte hum dekhenge advanced courses mein but abhi ke liye hum true stress agar true strain agar aapko nikaalna hai to aapko UTS beyond constancy of volume applicable nahi rahegi to aapko kuch modifications karne padenge is equation mein agar aapko true stress true strain nikaalna hai beyond UTS.

To yeh jo nikaala hai yeh maine tensile test ke liye nikaala hai to aapko dekhna hai ki yeh jo true stress true strain curve hai jaise yeh value hai to meri koi bhi stress rahega to jaise true strain mein agar kisi bhi moment par nikaalne ki koshish kar raha hoon to yeh mera engineering stress hai aur engineering strain yeh agar tensile strain hai to yeh positive rahega to yeh jo value aayegi yeh isse zyada hi aayegi hamesha to isliye yeh curve aap dekhiyega yeh upar move hua hai as compared to engineering stress-strain curve. True stress-strain curve mera upar move hua hai as compared to engineering stress-strain ka yeh mera tensile deformation mein aur thoda left shift hua hai is side shift hua hai.

To yeh mera ho gaya engineering stress-strain ka aur true stress-strain ka. To iski utility hum next class mein dekhenge. Humne isliye define kiya true stress aur true strain main phir se dohrana chahta hoon kyuki jaise jaise mera deformation badh raha hai material par is tarah se hi dekhte hain jaise jaise mera deformation badh raha hai mera cross-section area change ho raha hai cross-section area change ho raha hai length bhi change ho raha hai mera to jo stress jo experience kar raha hai material woh bhi change hona chahiye aur jo strain jo hai material ka woh bhi instantaneous woh bhi change hona hi chahiye.

To isliye humein true stress aur true strain ki zaroorat hoti hai definition mein kuch understanding karne ke liye jo ki hum next part mein dekhenge. Aaj abhi yahi rukta hoon. Dhanyavaad.