Mechanical behavior of materials

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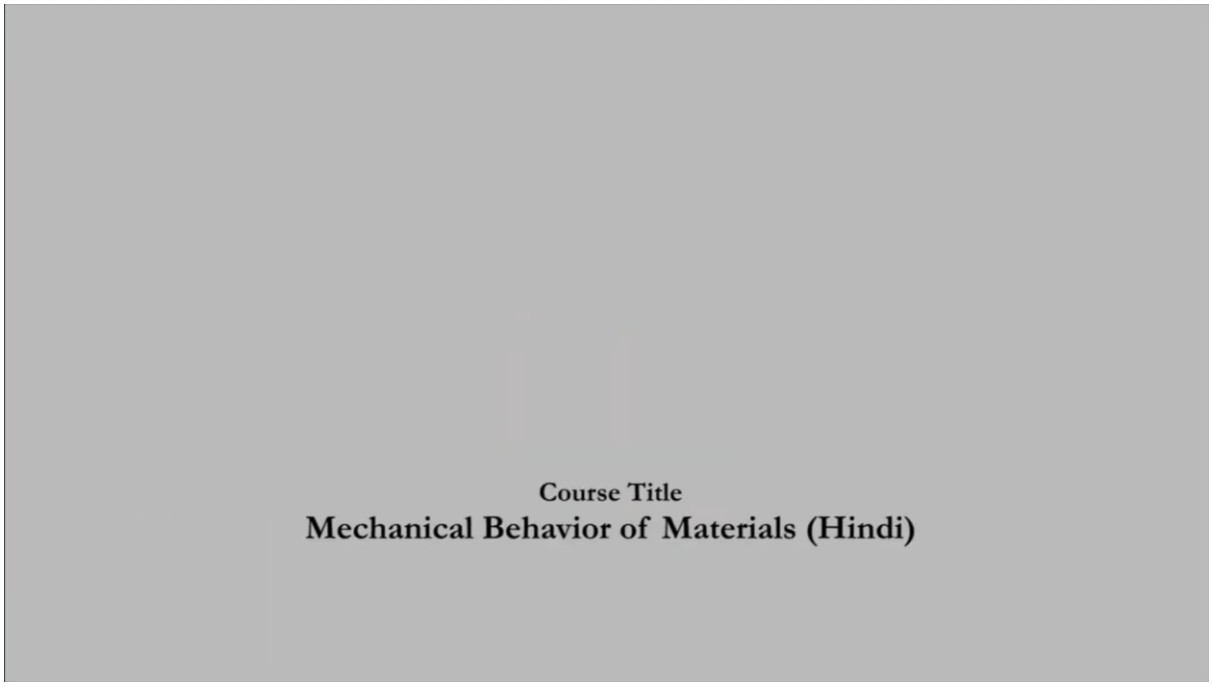
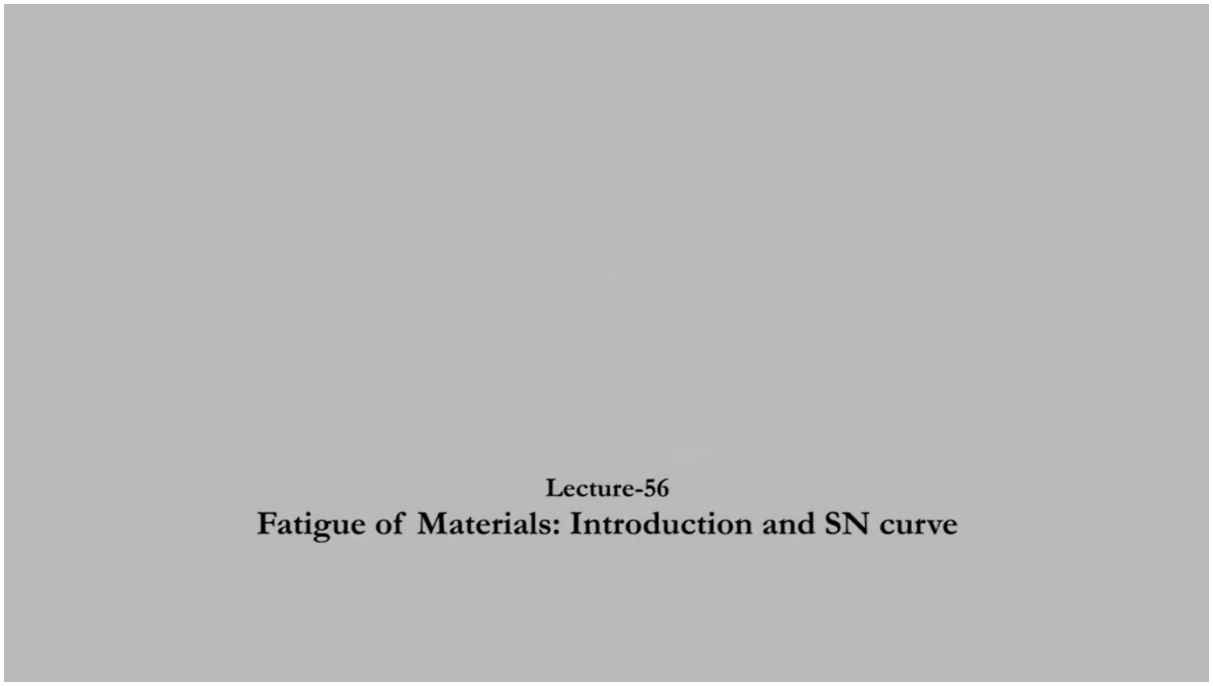
Week-11

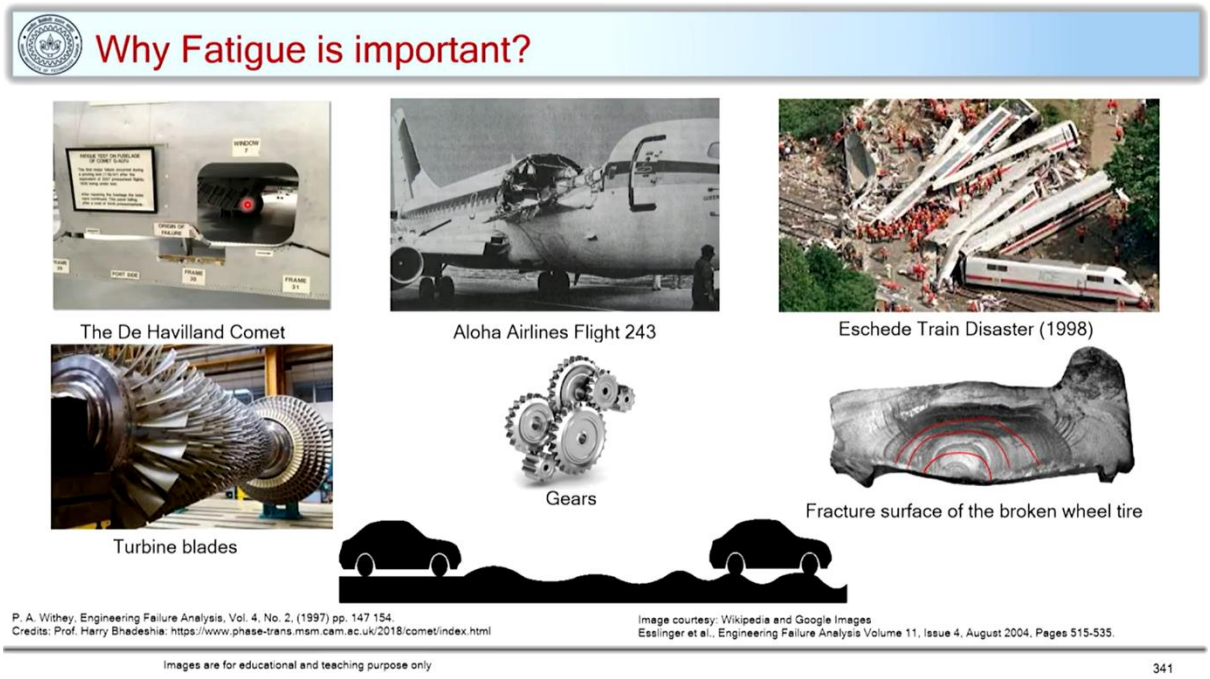
Lecture-57

Fracture & Theoretical Cohesive Strength of Materials





Namaskar aapka swagat karta hoon is course mein Mechanical Behavior of Materials jo ki hum Hindi mein padhenge. Is part mein aur is part se aage hum ek important failure mechanism padhenge jiska naam hai Fatigue of Materials. To abhi tak humne jo bhi loading dekhi thi wo static loading thi. Yani hamara load jo hai wo change nahi ho raha tha samay ke saath. Fatigue ek failure mechanism hai jahan pe hum dekhte hain ki yeh tab hota hai jab load change hota hai samay ke saath. To aaiye dekhte hain Fatigue of Materials. To sabse pehle dekhte hain ki fatigue important kyon hai? Iska mahatva kya hai? To ek example humne diya tha jab hum fracture padh rahe thay is De Havilland Comet ka. Yahan par humne dekha tha ki crack propagate ho ke is plane ko plane ke body ko fuselage ko fracture karti hai aur iske wajah se ek accident hota hai. Wahan pe kuch passengers ki mauten bhi hoti hai. To ye ek example humne dekha tha. To hum dekhte hain ki jab hum plane ki baat karte hain to plane udta hai, land hota hai tab yahan par jo stresses body pe iske body pe jo lagte hain wo change hote rehte hain samay ke saath aur uske wajah se jo crack hongi is body mein develop hoti hai aur wo crack propagate ho sakti hai samay ke saath aur material fail ho sakta hai. Waise bhi ek aur ek example humne dekha tha Aloha Airlines ka. Yahan par aap dekh sakte hain is case study...



mein yeh jo plane ki plane ka part hai yeh fuselage jo part hai wo ud gaya hai. Yani disintegrate ho gaya tha mid air mein. Yeh bhi jo example hai yeh fatigue failure ke dwara hua tha. Abhi ek aur train durghatna hui thi. Yeh sabse bhayanak durghatna keh sakte hain train ki journey mein. Yeh hui thi Germany mein Eschede train disaster isko kehte hain. Yahan par aap dekhenge ki train ki wheel jo hai wahan pe crack develop hui aur us crack develop hone ki wajah se train ka jo pahiya tha wo toot gaya. Yani jo wheel hai wo toot gaya. Uske wajah se train ye derail ho gayi. Aur yeh jo trains thi jo Germany ki jo trains thi yeh trains kam se kam 200 km/h ki...

raftaar se chalti hai. To aap samajh sakte hain ki ye durghatna jab hui ya ye jo train ka jo wheel tha jab yeh toot gaya tab train jab derail hogi to kitna bada disaster yeh create kar sakti hai. Aur ye yahan pe kuch fracture surface yahan pe humne dikhaya hai. Yeh fracture surface is wheel ka hai. To, aap dekh sakte hain ki kuch is tarah se marks yahan pe aapko dikh rahe honge. Yahan pe hum dikha dete hain. Kuch is tarah se marks aapko dikh rahe honge. Yeh jo marks hain aapke ye marks aapke fatigue failure ki wajah se aate hain. Aur aap dekhenge humne jab fracture jab padh rahe thay tab humne fracture surface ke baare mein bhi jaana tha. To ye jo surface hai ye hume dikha raha hai ki...

ye jo material hai ye brittle tareeke se fail hua hai. Yahan pe kuch dimples nahi hain. Aap dekhenge ki ye material yahan pe flat lag raha hai. Yahan pe koi dimples nahi hain jo ki signature hai ki aap is material mein koi bhi ductile failure nahi hua hai. Ye material fail hua

hai brittle tareeke se. To humne dekha ki kuch-kuch yeh jo examples hai case study mein yahan par ye jo wheel hai ya aeroplane ki body hai ye samay ke anusar iske upar stresses jo hai wo change hote rehte hain. To hum dekhte hain ki hamare rozmarra ki zindagi mein jaise gears hai ya yahan pe maine turbine blade ka example diya hai. Ye jo materials hai ye jo components hai is pe upar jo stress lagta...

hai wo samay ke anusar change hote rehta hai. Kuch simple sa example bhi dekh sakte hain. Jaise hum car chalate hain to hamare paas agar ye aise bumpy road hai to aap dekhenge ki ye jo stress ya components pe lagega ya wheel ke axles pe lagega ya wheels pe lagega wo change hoga samay ke anusar aur iske wajah se material fail ho sakta hai. Ye saare jo case studies yahan pe dikhaye hain ye jo saare case studies safety factor ko consider karke bhi liye thay. Yani yahan pe jo design criteria thay wo saare fulfill kar rahe thay saare safety design criteria. Phir bhi ye materials fail huye. To kuch important points hum likh lete hain is case studies se. To pehla...

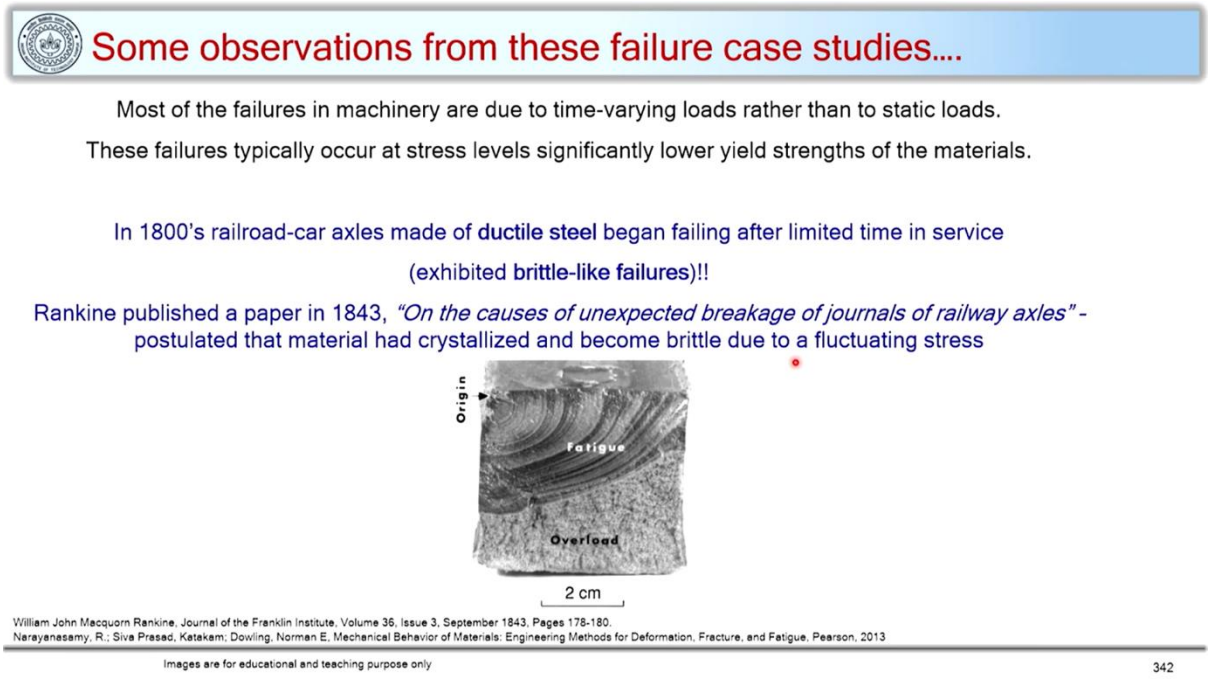
important point yahan par aap dekhenge ki yeh jo saare machineries hain, yeh ek time varying load ke saath operate karte hain. Yahan par koi static load nahi hai. Yani load sthir nahi hai. Yeh samay ke saath anusar change hota hai. Dusra agar hum dekhenge to yeh failure jo huye yeh significantly uske yield strength ke neeche huye hain. Yani saara jo failure hua hai wahan pe aap dekhenge ki stress levels thi ya loads thay wo saare yield stress se neeche hi thay. Kaafi neeche thay. To is tarah se kuch hum dekh sakte hain ki 1800 mein humne rail ki jab baat ki thi rail accident ki abhi baat ki thi to 1800 mein hum dekhte hain ki ye jo...

train ke wheels thay wo ductile steel se banaye jaate thay. Phir bhi jab wo fail hote thay tab aap dekhenge ki usmein ek brittle like failures hume dikhte thay. Jahan ke is micrograph mein humne dikhaya. Yahan par aap dekh sakte hain ki kuch is tarah se marks yahan par aap dekh rahe hain. To aur yahan par material ye jo micrograph hai wo dikha raha hai ki material brittle way se fail hua hai. Yeh hum jaanenge ki ye marks kya hote hain. Jaise-jaise hum is course mein aage badhenge. To kehne ki baat yeh hai ki yahan pe ye jo material hai ductile material bhi ye brittle way se fail hui hai. Jab mere loads samay ke anusar badal rahe hain ya change ho rahe hain. To jab ye case studies jab consider kar...

rahe thay jab 1800 mein tab Rankine ne ek paper publish kiya tha wheels ke upar, railway wheels ke upar, axles ke upar aur unhone ek theory di thi ye brittle failure ke liye. Unhone kaha tha ki crystallization hota hai is area mein varying time varying loads ki wajah se isiliye ye

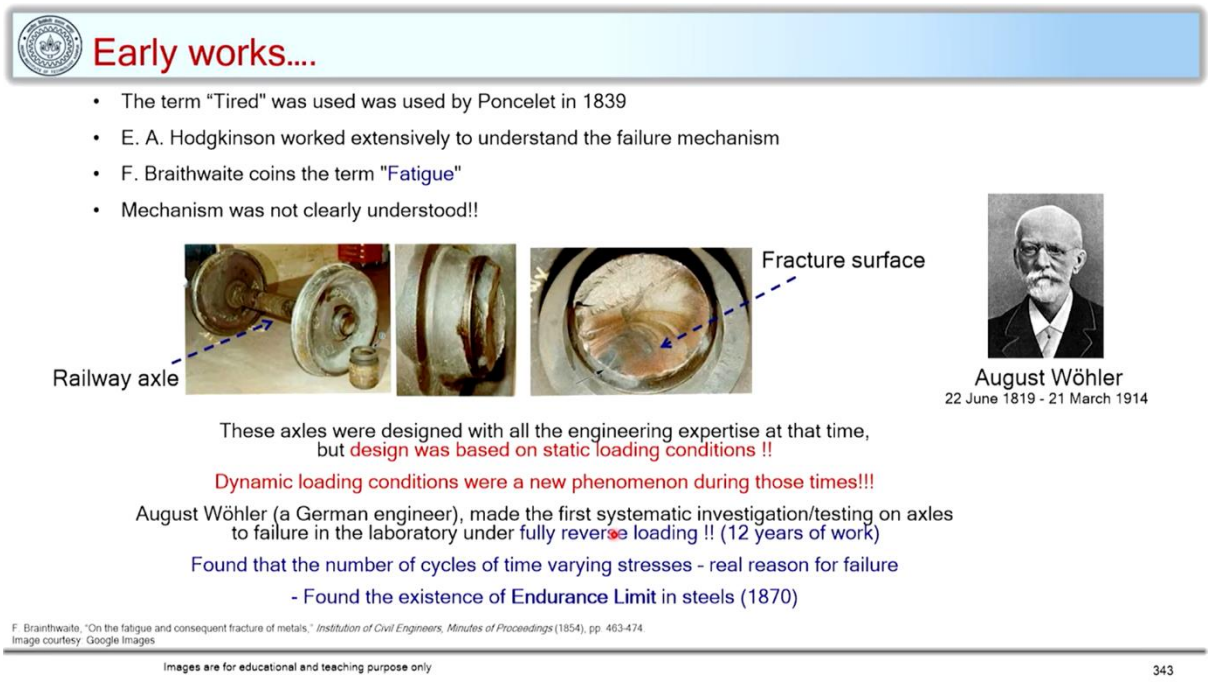
material fail hote hain. Halanki ye theory abhi paryapt nahi hai yani ye valid nahi hai theory. To abhi hum jaanenge ki yeh jo failure hua tha yeh fluctuating stresses ke wajah se ho raha hai. To tab hum dekhte hain ki jab 1800 ismein fluctuating stresses pe jab kaam chalu kiya tha to sabse pehle word ek istemal kiya tha Poncelet ne. Usko kaha tha humne ki ye failure jo ho raha...

hai yeh material ke tiring ki wajah se ho raha hai. Yani material thak raha hai. Tiring ka matlab thakna hota hai. To yeh word unhone istemal kiya tha. Uske baad Hodgkinson ne kaafi kaam kiya hai is failure mechanism ko samajhne mein aur sabse pehle jo fatigue word ka istemal kiya tha wo Braithwaite ne kiya tha apne kaam ke dwara. Phir bhi us samay ke anusar yeh mechanism jo hai wo clearly understood nahi thay. To phir hum dekhte hain jab yeh railway axle hai yeh jab rotate hoti hai ya yahan pe jo loads yahan pe dekhenge ye cyclic loading yahan pe hum dekhenge aur yahan pe jab ye axle toot-ta hai to is tarah se kuch brittle failure hume yahan pe mil...



raha hai. Ye iska fracture surface hai. To iski systematic study ki thi sabse pehle August Wöhler ne. To ye jo axles yahan pe hum baat kar rahe hain yeh design kiye thay static loading conditions ke dwara. Yahan pe dynamic loading jo condition hai wo tab ek naya phenomena tha us samay ke anusar. To, yeh jo design kiye thay axles ye static loading yani maan ke chale thay ki load yahan pe vary nahi ho raha hai application ke dauran. August Wöhler ne ek

systematic study thi ki thi apne laboratories mein. Unhone ek setup bhi develop kiya tha. Uske baare mein bhi hum padhenge. Jaise-jaise hum aage badhenge aur...

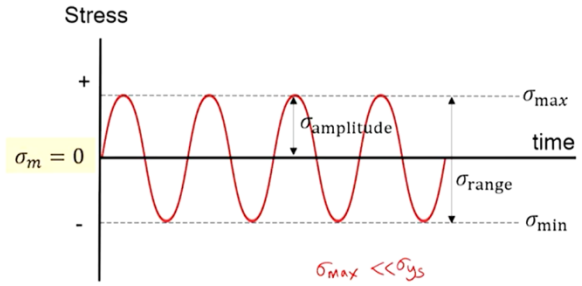


unhone ek fully reversed loading ke dwara dikhaya ki yeh jo change ho raha hai load ka yehi culprit hai failure ke liye aur unko lagbhag 12 se 15 saal lage is kaam ko samajhne mein aur is mechanisms ko samajhne mein. To unka bahut bada yogdaan hai fatigue ko samajhne mein, fatigue of materials ko samajhne mein. To unhone bataya ki number of cycles jo hai wo varying stresses ki hai aur uske wajah se hamara material fail ho raha hai jo ki hamare yield strength ke bahut neeche hai aur unhone ek endurance limit di thi. Iske baare mein bhi aaj is part mein hum padhenge steels ke liye aur jaanenge ki material kis tarah se fail hota hai. To August...

Wöhler ne ek systematic study ki thi fatigue ke dwara jo is fatigue of materials ka foundation bani. To abhi hum baat kar rahe hain ki load kaise vary hote hain? To usko hum kehte hain cyclic loading. Cyclic loading ko samajhte hain. Jab mein baat kar raha hoon failures ki cyclic loading ke dwara isko hi hum kehte hain fatigue failures. Aur is cyclic loading ko hum kabhi-kabhi dynamic loading bhi kehte hain. Kyunki material change kar yani material pe jo load pad raha hai wo change ho raha hai samay ke anusar. Isliye hum isko dynamic loading bhi kehte hain. To, jab mein cyclic loading ki baat karunga, to kuch simple way se samajhte hain...

Cyclic loading

Failures occurring under conditions of dynamic loading are called fatigue failures



$$\sigma_{range} = \sigma_{max} - \sigma_{min}$$

$$\sigma_{mean} = \sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_{amplitude} = \sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{\sigma_{range}}{2}$$

$$Stress\ Ratio, R = \frac{\sigma_{min}}{\sigma_{max}}$$

$$\text{Amplitude ratio, } A = \frac{\sigma_{amplitude}}{\sigma_{mean}} = \frac{\sigma_a}{\sigma_m}$$

σ_{max} comparison with σ_{ys}

$\sigma_{amplitude}$ is also called as an alternating stress

All the stresses are engineering stresses and not true stresses

Since most fatigue failures occur with minimal gross plastic deformation during service, the difference between the original and instantaneous cross-sectional areas is negligible. As a result, the engineering stress (S) and the true stress (σ) remain nearly identical.

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isko. Yahan par maine stress plot kiya hai mere y-axis pe aur x-axis pe ye time hai aur samay ke anusar ye stress change hoga. To kuch is tarah se simple hum samajhte hain sinusoidal way se ye stress is tarah se change ho raha hai. Yani hum jaanenge ki jaise-jaise is time ke saath hum dekhen rahe hain ki load kis tarah se change ho raha hai. To pehle ye tensile tha isliye positive likha hai yahan pe aur yeh compression ke liye humne negative likha hai. To pehle material tensile stress experience karega samay ke anusar. Phir wo compression mein jayega. Phir tensile stress experience karega. Phir compression mein jayega. Kuch is tarah se hamara stress vary ho raha hai hamare material ke upar. To...

ye hamara load static nahi hai yani constant nahi hai. Ye vary ho raha hai time ke anusar. Isko kehte hain hum cyclic loading. To maan lete hain kuch is tarah se material kuch ek maximum stress experience kar raha hai σ_{max} aur ek minimum stress experience kar raha hai σ_{min}. To abhi mein kuch stresses ko introduce karunga. Kuch parameters ko introduce karunga jo ki hume fatigue of material samajhne mein aasani karenge. Yeh jo range hai meri maximum aur minimum stress ki isko mein kehta hoon stress range σ_{range} aur is σ_{range} ko mein kuch is tarah se likh sakta hoon $\sigma_{range} = \sigma_{max} - \sigma_{min}$ in dono ka...

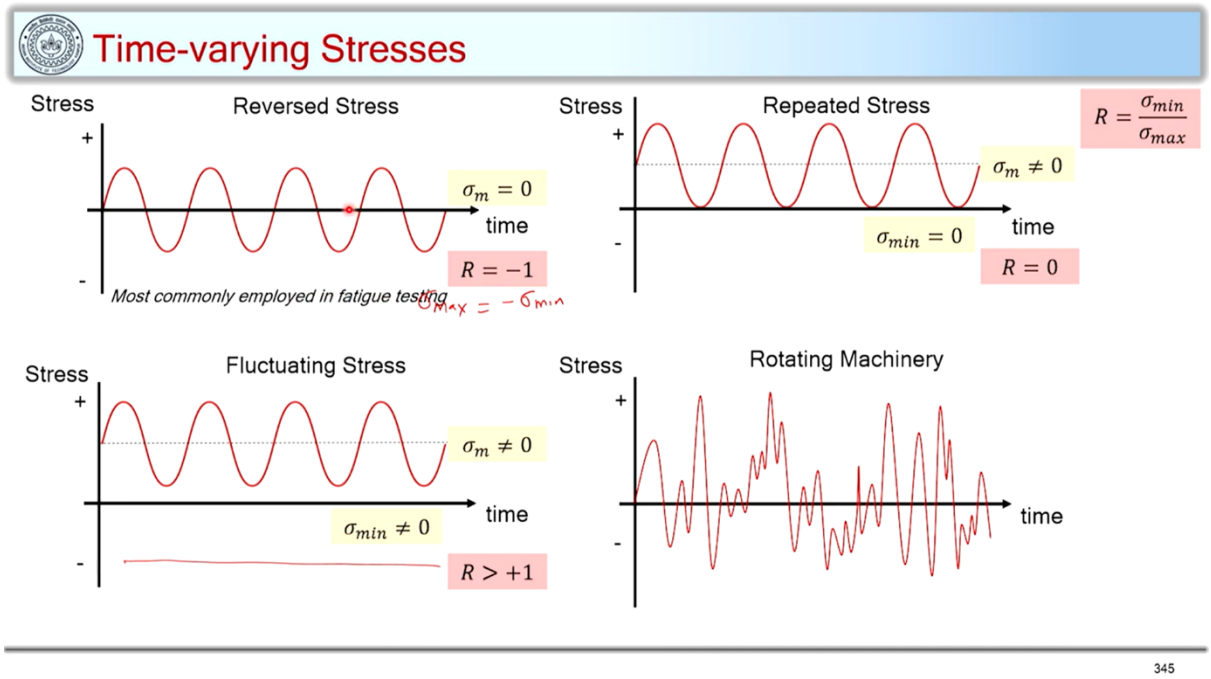
maximum stress ka aur minimum stress ka ek difference hai. Sigma mean define karte hain. Sigma mean kya hota hai? Sigma mean ko mein kuch is tarah se likhunga. σ_m aur ye hoga in dono ka average. So $\sigma_m = (\sigma_{max} + \sigma_{min}) / 2$. To yahan pe agar σ_{max} aur σ_{min} mein agar consider karunga aur σ_{max} aur σ_{min} equal hai agar ye tension mein hai aur ye compression mein hai aur

dono ka magnitude same hai to is case mein sigma mean yahan pe shunya rahega zero rahega. Ek aur term introduce karte hain. Isko kehte hain hum sigma amplitude. Kuch is tarah se aur sigma amplitude ko hum...

likhte hain σ_a ke dwara. Aur sigma amplitude kya hai? $\sigma_a = (\sigma_{max} - \sigma_{min}) / 2$. To isko mein kuch is tarah se bhi likh sakta hoon. Yahan pe aap dekh rahe honge ki ye sigma range hai $\sigma_{max} - \sigma_{min}$ to mein isko $\sigma_{range} / 2$ likh sakta hoon. Aur ek do terms yahan pe introduce karte hain. Ek stress ratio jo ki kaafi important hai. Iska hum baar-baar istemal karenge hamare analysis mein. To stress ratio hai. Isko likhte hain $R = \sigma_{min} / \sigma_{max}$. Ye ek ratio hai minimum stress ka aur maximum stress jo material experience kar raha hai. Amplitude ratio hum define karenge...

$A = \sigma_a / \sigma_m$. To ye kuch is tarah se hum likh sakta hoon. Ye σ_a / σ_m. Jab hum yeh stresses ki baat kar rahe hain to yeh sigma amplitude ko hum alternating stress bhi kehte hain. Kaafi books mein aap dekhenge ki ye word bhi istemal kiya hai alternating stress. Abhi hum dekhte hain ki yeh jo σ_{max} hai yahan par yeh jo maximum stress jo material experience kar raha hai yeh yield strength ki tulna mein kaafi kam hai. To ye aap dekhenge ki kabhi-kabhi application mein ye jo maximum stress yahan pe apply kar rahe hain ye kaafi kam hota hai mere material ke yield strength ke hisab...

se. Aur yeh jo stresses hain, yeh saare engineering stresses hai. Yeh true stresses nahi hai yahan pe. Yahan par jo bhi likhe iska ek kaaran hai kyunki agar hum dekhenge ki fatigue failure mein jo plastic strain hai wo kaafi minute hai. Yani jo plastic strain hai ye kam rehta hai. To hum keh sakte hain ki jo original aur instantaneous cross section area hai ye usmein jo change hai wo negligible hai. Aur isi ke liye hum keh sakte hain ki jo engineering stress aur true stress wo nearly identical rehta hai. To yeh ho gaya kuch introduction stresses ke upar jab mein cyclic loading ki baat kar raha hoon. Abhi hum dekhte hain ki kuch cyclic loading kis...



tarah se hoti hai. To mein kuch time varying stresses cycles aapko bataunga. To simple stress cycle mein aapko yahan pe dikha raha hoon. Jahan pe aap dekhenge ki ek maximum value aur minimum value of stress ek tension mein hai, ek compression mein. Yahan pe yeh dono same hai. Yahan pe σ_m yeh shunya aayegi. Agar yeh σ_{max} aur σ_{min} same hai. Aur ye tension mein hai aur compression mein hai. Yani inka magnitude same hai. Par ek inka nature alag-alag hai. To aapko σ_m yahan pe shunya milega. Isko kehte hain hum reversed stress cycle. Aur ek cycle yahan par dekhte hain. Yahan par hum dekhenge ki yeh jo cycle hai kuch is tarah...

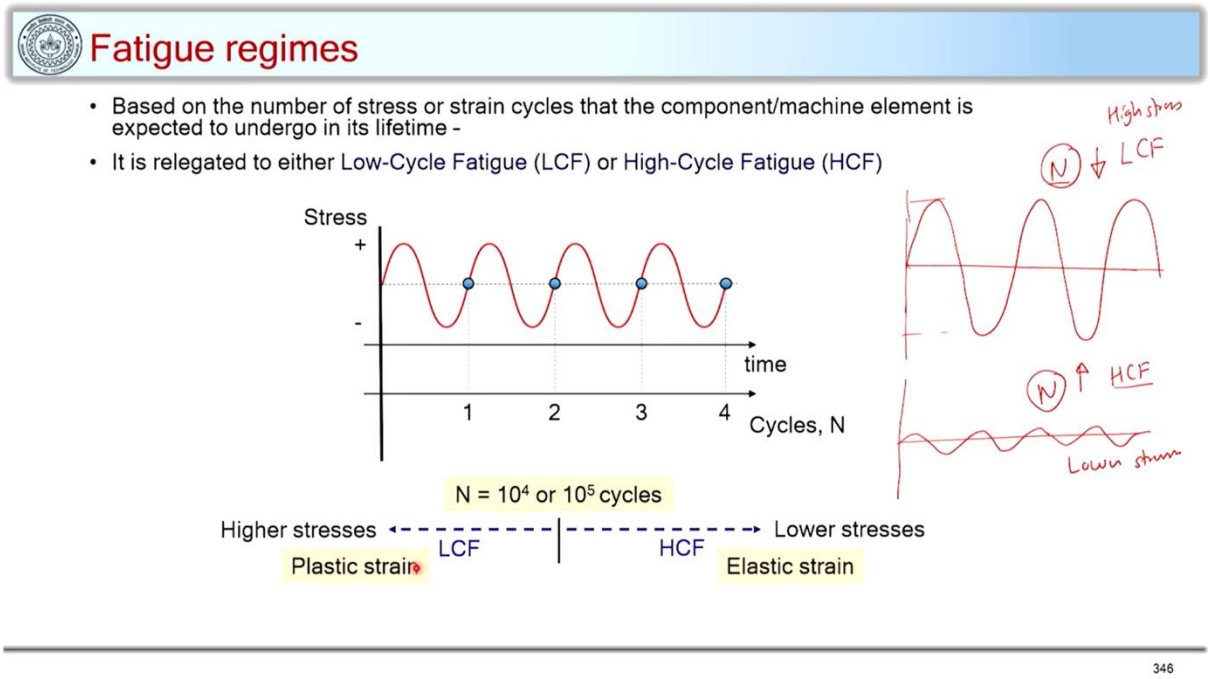
se vary ho rahi hai. To aap dekhenge ki yahan par σ_m yahan par shunya hai aur ye ek σ_{max} yahan pe tension mein positive hai. Aur yahan pe aap dekhenge ki σ_m jo hai yeh value jo hai yeh non zero hai. Yeh minimum value of stress yeh shunya hai. Yahan pe isko hum kehte hain repeated stress. Abhi hum dekhenge aur ek cycle. Yahan par aap dekhenge ki yahan par sigma mean minimum jo hai wo shunya nahi hai. σ_m jo hai wo non zero hai aur positive hai. Yahan pe aap dekhenge dono yahan pe yani σ_{max} aur σ_{min} ye ye positive hai yani tension mein hai. Isko hum kehte hain fluctuating stress cycle. Par janrally jab...

yeh cycles mein aapko yahan pe dikha raha hoon to aap dekhenge ki jab mein rotatory machinery ki baat karunga to jo stress vary hota hai kuch is tarah se vary hota hai. Wo kuch is tarah se periodic nahi rehta hai. Wo random variation hote hain. Kuch is tarah se par jab hum experiment karte hain tab hum ek kuch ye cycles hum istemal karte hain. σ_m yahan pe yeh jo mean value hai yahan pe yeh non zero hai. Positive hai. Tension mein hai. Ye compression

mein bhi ho sakti hai. Par hum compression yahan pe itna isko emphasize nahi kar rahe kyunki hume pata hai ki jab humne introduction ki baat ki thi ki crack propagation ke wajah se fatigue hota hai. Ye hum mechanisms ke dwara jaanenge abhi. To jab...

hum compressive stresses ki baat karenge agar mere paas stresses kuch is tarah se compressive hai. Maan lete hain yahan par σ_m ye jo non zero hai but ye compressive hai. Tab ye jo stresses hai ye aapki crack ko open karne mein madad nahi karte hain. Rather ye crack ko close karne mein madad karte hain. Isliye isko itna importance nahi diya hai. Isliye hum ye teeno cycle hi yahan pe consider karte hain. Par σ_m jo value hai wo compression ho sakti hai ya < 0 ho sakti hai. To ye teen cycles hum yahan pe dekhenge to janrally fatigue failure mein hum ne ye parameter define kiya tha $R = \sigma_{min} / \sigma_{max}$. Agar ye R ki value hum yahan pe dekhein is cycle ke...

dwara to hamare paas cycles mein kuch is tarah se values hain. Uh ye R yahan pe -1 hai kyunki hum dekhenge ki $\sigma_{max} = -\sigma_{min}$ kuch is tarah se milega. Ek tension mein hai to ek compression mein hai. In dono ka magnitude same hai. Yahan pe aap dekhenge ki dono ye sigma minimum yahan pe zero hai. To R ki value yahan pe shunya hai. Aur yahan pe aap dekhenge ki dono σ_{max} aur σ_{min} positive hai. To R ki value > 0 aur greater than $+1$ aayegi. To kuch is tarah se aapko ye values yahan pe milegi. To jab mein baat karunga is stress cycles ki to yeh jo stress cycle hai yeh mostly...



mostly commonly employ hogi hamare fatigue testing materials mein. To hum isko istemal karenge reversed stress ko jahan pe meri σ_m ki jo value hai wo shunya hai. Yani mera material ek maximum stress experience karega tension mein aur ek minimum stress experience karega compression mein aur dono ka magnitude same rahega. To yeh commonly employed hai stress cycle fatigue testing. To abhi jab mein fatigue ki baat kar raha hoon to do regimes yahan pe hum dekhte hain. Yani mere material jo component varying load ke saath deform hota hai ya fail hota hai wo do tarah ke se deform ho sakta hai. Yani do life ke...

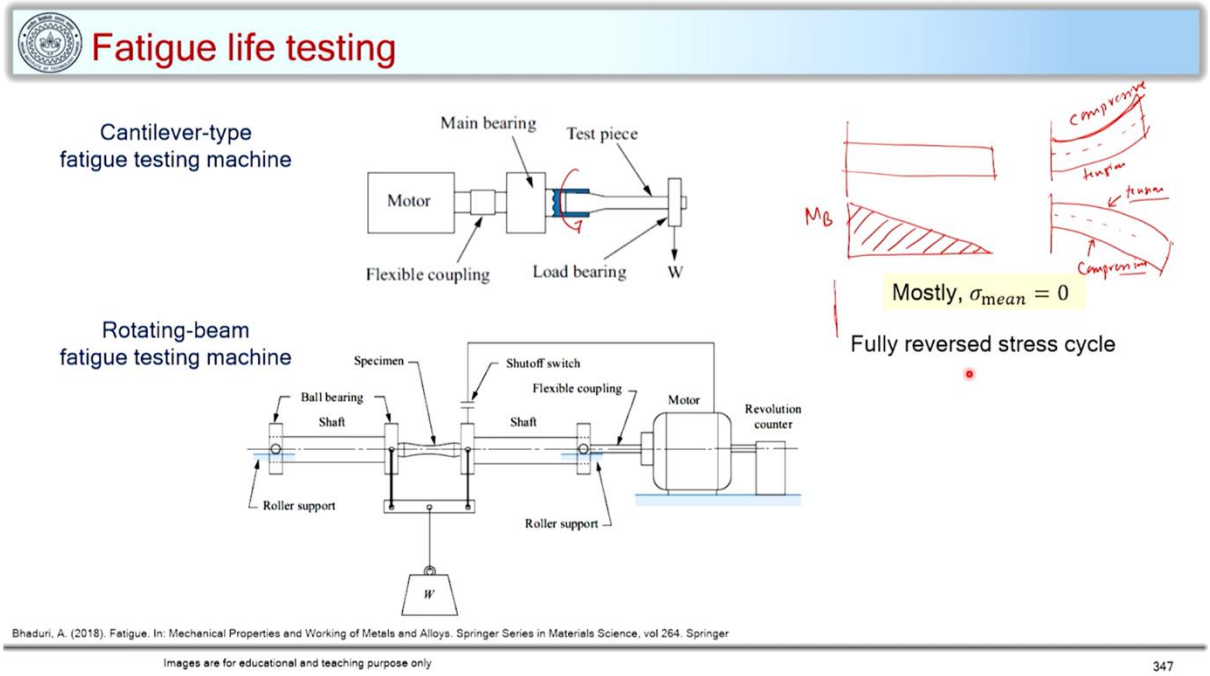
dwara ja sakta hai. Wo hai low cycle fatigue aur high cycle fatigue. To inko jaante hain ki mein low cycle fatigue aur high cycle fatigue kya hoti hai. To yeh hamari stress cycle hai. Stress is tarah se vary ho raha hai time ke anusar. Agar mein cycle ki baat karunga to agar aap dekhenge ki ye complete meri ek cycle hogi. Ye tension se gaya. Phir compression mein aaya. Phir tension mein enter kar raha hai. To ek ye complete ek cycle hogi. Usi tarah se yeh jo ek cycle hai ye do cycle hogi. Aur is yeh third cycle aur yeh fourth cycle. Is tarah se material stress experience karega. To mein maan ke chal raha hoon ki material mera N number of cycles experience karega. To mein...

cycles jab baat karunga fatigue stress cycles ki to mein usko N se yahan pe denote kar raha hoon. To jab mein low cycle aur high cycle fatigue ki baat kar raha hoon to hum dekhte hain ki ek number yahan par define kiya gaya hai ki 10^4 aur 10^5 cycles agar material ki life agar mein consider kar raha hoon to iske neeche jo rahega material experience karega aur materials

iske neeche agar fail ho raha hai to usko hum kehte hain low cycle fatigue aur iske zyada agar cycles material sustain kar raha hai stress cycle agar sustain kar raha hai to isko hum kehte hain high cycle fatigue iske baare mein hum aage padhenge. To ye sirf introduction ke liye...

yahan pe hum samajh rahe hain. To yeh jo low cycle fatigue hai yeh higher stresses pe hum dekhte hain. Aur high cycle fatigue hai ye lower stresses pe hum dekhte hain. Kuch is tarah se samajhte hain. Agar meri ye cycle hai aur agar stress mera zyada hai kuch is tarah se to material jo hai wo less number of cycles mein hi fail ho jayega. To ye number of cycles decrease ho jayegi. Agar mera stress zyada hai kuch is tarah se to isko hum kehte hain low cycle fatigue. Ye hume milti hai high stresses pe. Agar hum dekhte hain ki stress agar kam hai kuch is tarah se vary ho raha hai. To hum dekhenge ki ye material ki cycles jo hai wo sustain kitna number of...

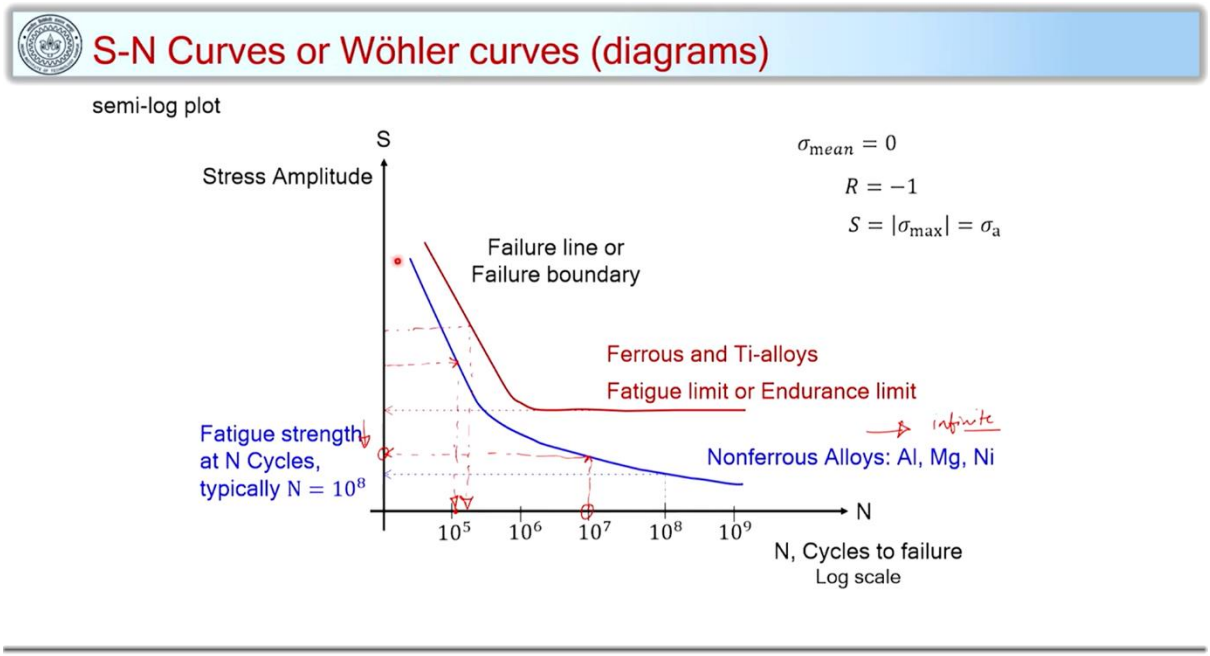
cycles wo sustain zyada kar payega. Isko isliye hum kehte hain high cycle fatigue. Yeh hume milti hai lower stresses par. To, yeh ho gaya hamara demarcation low cycle fatigue aur high cycle fatigue ka. Aur low cycle fatigue mein hum dekhte hain ki jab material deform ho raha hai, to plastic strain dominate karta hai aur high cycle fatigue mein elastic strain dominate karta hai. Yeh aap yahan ke liye samajh lijiye. Yeh demarcation ke liye hum iske baare mein aur aage padhenge. Jaise-jaise hum fatigue ke baare mein jaanenge. To fatigue life testing ke baare mein abhi dekhte hain ki fatigue life testing kis tarah se ki jati hai. To do methods hain. To...



pehla method hai ek cantilever type fatigue testing machine. To yahan pe aapko ek specimen dikh raha hai. Kuch is tarah se test piece aur iske ek end pe aapne ek load yahan pe lagaya hai aur ek end pe yeh fixed hai aur yahan pe material ko is tarah se rotate karenge. To material ek stress experience karega jo varying load hoga. To kuch is tarah se hum samajh sakte hain. To agar mera ek cantilever beam hai kuch is tarah se aur hum isko rotate kar rahe hain to ye jo beam hai kuch is tarah se position lega. Kuch is tarah se position lega. To aap dekh payenge ki yahan par material abhi compressive stress experience karega is is surface pe aur yahan pe material tension...

mein experience karega. Dusre moment pe yeh agar yahan pe kuch is tarah se bend hoga to aap dekh pa rahe honge ki yeh jo surface hai yeh abhi tension experience karega aur yeh jo surface hai yeh compression experience karega. To is tarah se material mera yani samay ke anusar yeh jo stress state hai is element pe ya surface par yeh change hogi is material ke dauran. To aur material yeh stress cycle experience karega. To yehi ek concept hai yahan pe is cantilever type mein. To aap dekhenge ki agar mein is tarah se cantilever ko load karta hoon to ek bending moment aap nikal sakte ho iske upar. To yeh bending moment kuch is tarah se aapko milega. To bending moment is tarah se...

vary hota hai is sample ke upar. To ye material aap dekhenge ki yahan pe fail hota hai. To ye ek type hai fatigue testing ka. Ye Wöhler ne develop kiya tha. Dusra hai rotating beam type ka. To yahan par aap dekhenge ki yeh jo hamara specimen hai aur load kuch is tarah se lagaya gaya hai. To yahan par sirf hum dekhenge ki ye jo bending moment hai kuch is tarah se vary hota hai sample ke upar. Kuch is tarah se mein bending moment ko nikal sakte hoon. Mera bending moment hai. To kuch is tarah se change hota hai mera bending moment. To aap dekhenge ki is region par yeh bending moment constant hai. To ye hai mera specimen aur ye mera bending...



moment hai. To yehi difference hai. Yahan par increase ho raha hai kuch is tarah se aur yahan par aap dekhenge ki bending moment maximum hai kuch sample ke beech mein. To material kuch yahan pe fail hoga. To ye do techniques hai jisse hum fatigue life measure kar sakte hain. To abhi hum dekhte hain ki ye jo fatigue life hum measure karte hain mostly hum consider karte hain jab σ_m ki value shunya hai. Yani fully reversed stress cycle hi hum yahan pe employ karte hain. Abhi hum yeh jo fatigue life test karne ke baad hume kuch values milengi stress ki aur cycles ki. Isko hum kehte hain Wöhler curves ya Wöhler diagrams also. Kyunki...

ye jo methodology develop ki thi ye Wöhler ne develop ki thi. To Stress S-N curve ke liye hum kya karte hain? Ye stress amplitude jo hai wo y-axis pe plot karte hain aur number of cycles hum yahan pe x-axis pe plot karte hain. Ye kabhi semi-log plot hota hai ya log-log plot bhi ho sakta hai. Yahan pe semi-log plot mein consider kar raha hoon. To yahan pe stress amplitude mein plot kar raha hoon. To number of cycles kuch is tarah se 10^5, 10^6 is tarah se number of cycles hum x-axis pe rakhenge. Aur yeh jo test hum yahan par S-N curve janrally obtain kiya jata hai. Yeh σ_m jo hai mean value jo hai yahan pe shunya rehti hai...

Yani R ki value yahan pe −1 rahegi. Ye fully reversed stress cycle hai aur S jo hai ye stress amplitude hai. Jisko hum σ_a likha tha humne. Iski value hum likh sakte hain. Ye σ_{max} ke barabar hogi. Agar aap wo peeche ja ke mathematical relations dekhenge jo humne padhe thay. Wo agar find out karenge to S ki value ye σ_{max} yahan pe hum likhenge. But yahan pe ye S ki value janrally ye stress amplitude hai. To hume jab hum test karte hain to hume kuch is tarah se jo

ye stress amplitude change hota hai number of cycles ke anusar ye kuch is tarah se hum plot kar sakte hain. Iske baare mein bhi samajhenge hum. Yeh jo nature milta hai, yeh hume ferrous aur...

titanium alloys ke liye milta hai. Aur yeh jo abhi hum isko samajhne ki is tarah se koshish karenge. Yahan pe hum dekhenge ki agar mein 10^5 cycles apply kar raha hoon aur mein is stress pe aaunga tab mera material fail hoga. Agar mein is stress ko cross kar raha hoon to mera material yani fail hoga. Ye stress amplitude ko cross karunga to. Agar mein 10^6 pe hoon to kuch is tarah se is stress ko cross karunga to material fail hoga. Kuch alag dusre way se bhi hum dekh sakte hain. Agar mein material pe mere application mein kuch is tarah se maine stress apply kiya hai. To mein material pe material mera is number of cycles ke...

baad fail hoga. To ye jo curve hum yahan pe draw kar rahe hain ye hume dikhata hai ki failure boundary kya hai? Aur ye jo typical nature hai yahan pe ye hume ferrous aur titanium alloys ke liye milta hai. Yahan pe hum dekh paa rahe hain ki agar stress mera high hai to number of cycles kuch is tarah se change ho rahi hai. Par hume ek knee yahan pe milti hai. Isko hum kehte hain fatigue limit ya endurance limit. Iska matlab kya hai? Ki agar mein is stress ke agar neeche hoon to mera material infinite number of cycles le sakta hai without failure. To agar mein is stress ke agar neeche hoon to ya mera material infinite number of cycles le sakta hai. Isko hum kehte hain fatigue limit ya...

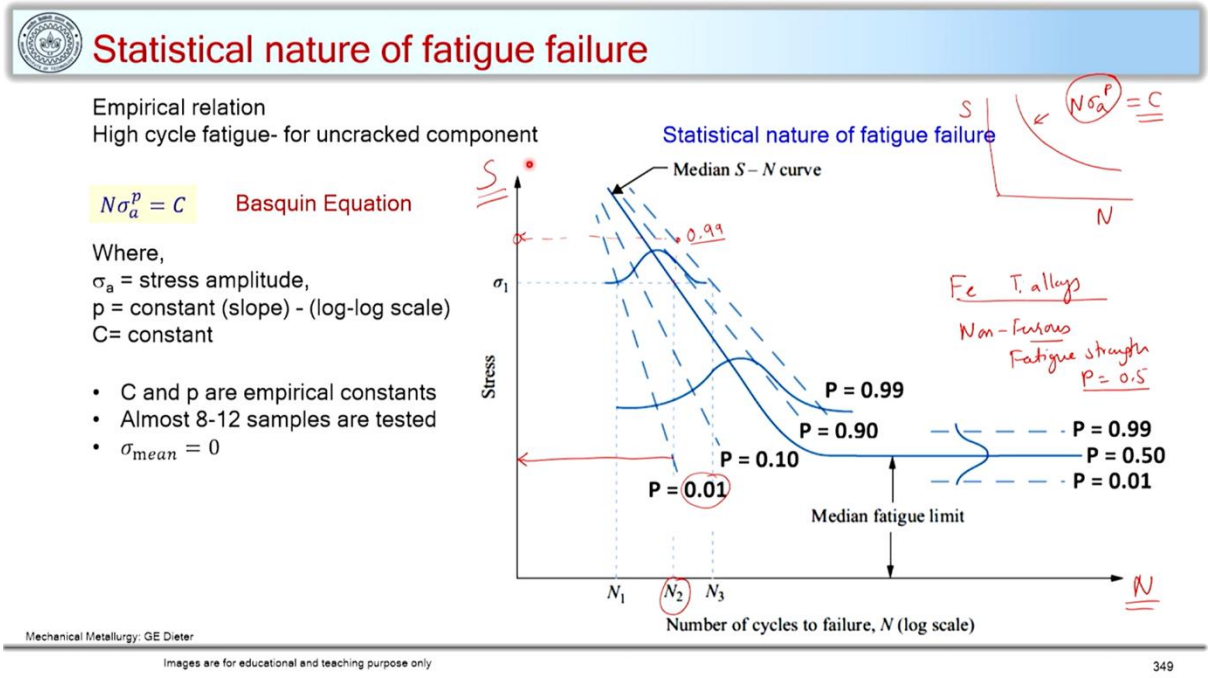
endurance limit. Yeh hume milta hai sirf ferrous aur titanium alloys ke liye. Non ferrous materials ke liye hume kuch is tarah se behavior milta hai. Hume yeh knee yani sharp change yahan pe nahi milta hai. To hum dekh sakte hain ki fatigue jo behavior hai kuch is tarah se hume milta hai non ferrous alloys jaise ki aluminum, magnesium aur nickel. To hum is tarah se samajh sakte hain ki agar mera material pe jaise mere paas non ferrous material hai aur maine stress kuch is tarah se apply kiya material pe to ye kuch is tarah se hi kuch is tarah se hi maximum value of number of cycles ye sustain kar payega. Agar mera stress kuch is tarah se hai. Yahan pe...

hai to yahan pe mera maximum number of cycles le payega. Ferrous materials mein hume endurance limit aur fatigue limit milti hai. Non ferrous mein kuch is tarah se nahi milti hai. To ferrous material ke liye hum hamesha fatigue limit aur endurance limit define karte hain. Hum bata sakte hain ki ye stress hai mera fatigue limit. To hum yeh samajh payenge ki iske neeche agar hum operate kar rahe hain to material fail nahi hoga. Yani infinite number of cycles le

payega ferrous aur titanium alloys ke liye. But non ferrous ke liye hume kuch define karna padega. Aur wo definition kuch is tarah se jati hai. Jaise mein ek particular cycle pe ek strength...

define karunga. Jaise typically hum dekhte hain ki 10^8 number of cycles pe mein ek strength define karunga. Yahan pe ek 10^8 cycles hai kuch is tarah se aur mein ek strength define karunga aur isko mein kehta hoon fatigue strength. To fatigue strength jab hum define karte hain kisi bhi non ferrous materials ke liye to hume number of cycles wahan pe likhni padegi. To hum is tarah se likh sakte hain ki fatigue strength mera is number of cycles pe hai. Ya aap is tarah se bhi likh sakte hain ki 10^7 pe aap consider kar rahe ho to aap isko keh sakte ho ki ye meri fatigue strength hai is cycle pe 10^7 cycles pe. To ye is tarah se aapko fatigue...

strength define karni padegi non ferrous alloys ke liye. Abhi hum dekhte hain ki yeh jo boundary hai, yeh boundary meri dikha rahi hai failure line aur failure boundary. Yani iska matlab kya hai? Agar mein stress amplitude kuch is tarah se aur number of cycle kuch is tarah se agar mein is boundary ke is side hoon to material fail nahi hoga. Material mein safely operate kar sakta hoon. Agar is boundary cross karunga to material mera fail hoga. To ek, ek failure boundary aur failure line mujhe dikha rahi hai ki kis kaun si operating conditions mere material ke liye ho sakti hai. Ye hume fatigue testing ke dwara milti hai. Aur ye jo methodology thi ye develop ki...



thi hamare August Wöhler ne aur isko hum kehte hain Wöhler curves aur Wöhler diagrams. To abhi hum S-N curve ke baare mein jaan chuke hain. To kuch cheezein aur dekhte hain S-N curve ke baare mein. To ek dekhte hain ki ek relation hum high cycle fatigue ke liye hum dekh sakte hain for unnotched components. To ek equation hum yahan par jaan sakte hain ki agar humne dekha tha ye jo equation hai Basquin ne diya tha ye hai $N \cdot \sigma_a^p = C$ jo ki constant hai to ye jo product hai ye constant hai. To yahan pe p jo milega ye hume milega slope se aur ye C ek constant se. To agar mein is stress aur number of...

cycles S-N curve yahan par mein dekhunga to mein kuch is tarah se nature dekh sakta hoon. Aap dekh paa rahe honge ki ye nature kuch is tarah se vary ho raha hai. To yani agar mein ye normal curve dekhunga to mujhe variation kuch is tarah se milega. To ye jo equation hai aap dekh paa rahe honge ki ye simply ek empirical equation hai. To aap ye product to constant maan ke chal sakte hain. Aur yehi Basquin equation hai. Abhi hum dekhenge jab mein S-N curve ki baat kar raha hoon. To aap dekhenge ki agar mein σ_1 apply kar raha hoon stress yahan par aur number of cycles mein yahan par dekhunga aur mein different samples agar yahan pe test karunga...

to aap dekhenge ki ye stress pe agar mein N_1 cycles apply karunga to mera probability failure yahan pe aap dekhenge ye P jo hai ye probability of failure hai. To ye probability hai 0.01. Agar mein ye cycles apply karunga N_3 cycles agar apply kar raha hoon to probability failure yahan pe close to 1 ho jayegi. 0.99 yahan pe hai. To is tarah se aap dekhenge ki mein different agar aur kuch ulta samajh sakte hain. Jaise mein agar mein N number of cycles yahan pe apply kar raha hoon. Ya yeh consider karte hain. N_2 agar cycles apply kar raha hoon aur mein is stress pe agar operate karunga jaise kuch is tarah se to material ki failure probability meri...

0.01 hogi. Agar mein is stress pe ja ke yahan pe agar operate karunga to meri material ki probability yani is stress pe agar mein operate kar raha hoon is cycles pe to meri material ki probability 0.99 hogi. To hum dekh sakte hain ki ye jo stress strain curve jo hai wo sample ke anusar change hoga. Yani meri jo fatigue limit hai ya fatigue life hai mere material ki wo sample ke anusar change hogi. To ye jo nature hai ye statistical nature hai. Yani aapko bahut saare samples test karne honge. Tab ja ke aap ek fatigue life ya fatigue limit ko aap define kar paoge. To aap bahut saare samples is tarah se test karte hain aur phir jo ye jo line hai yahan par probability 0.5 hai failure...

ki us line ko hum kehte hain ek median fatigue limit ko hum yahan pe define karte hain hamare application ke liye. To yahan pe aap dekhenge ki agar mein is cycle pe operate kar raha hoon aur is stress pe agar kaam karunga to meri probability failure ki yahan pe 0.5 hogi. To yeh dikhata hai mere material ka statistical nature. Yahan par humne yeh do points yahan par mein mention karunga. To yahan pe C aur p ek empirical constants hain is equation mein. Aur hume ek condition pe almost 8 to 12 samples test karne padenge is probability ko find out karne mein. Yahan pe σ_m ki value yahan pe bhi shunya hai. To, ye dikhata hai mere S-N...

curve ka statistical nature. Iska matlab yeh hai ki aapko bahut saare samples test karke ek value nikaalni padegi. Probability of failure nikaalna padega P ke liye. Bahut saare statistical tools bhi available hai is probability ko find out karne liye. To ye ye jo value hai P = 0.5 iske corresponding jo stress strain curve rahega isko mein define karunga mere application ke liye. Isko mein kehta hoon median fatigue limit. Aur yeh jo fatigue limit milti hai hume humne jaana tha yeh milti hai hume ferrous aur titanium alloys ke liye. Similarly hum non ferrous materials ke liye bhi fatigue strength ko define kar sakte...

hain. Uske liye hume fatigue strength ko define karna padega. Jo hum define karte hain probability consider karke jahan pe material fail hoga. Uski probability 0.5 honi chahiye. To yeh ek introduction tha hamare fatigue of materials ke liye. Yahan tak humne dekha tha ki S-N curves kis tarah se mil sakte hain aur S-N curve ka statistical nature kya ho sakta hai. To is part mein humne jaana ki fatigue kyon important hai? Fatigue kis tarah se hota hai. Yeh hota hai cyclic loading ke dwara. Aur Wöhler ne jo methodology di thi S-N curves ki usko humne samjha. Next part se hum fatigue mechanisms kya hote hain? Micro mechanisms kya hote hain? Micromechanics kya hote hain? Iske baare mein hum samajhenge. Abhi ke liye rukta hoon. Dhanaywad.