

Mechanical behavior of materials

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Week-7

Lecture-36

Dislocation: Nucleation and Frank Read Source



Mechanical Behavior of Materials (Hindi)

Dislocation: Nucleation and Frank Read Source

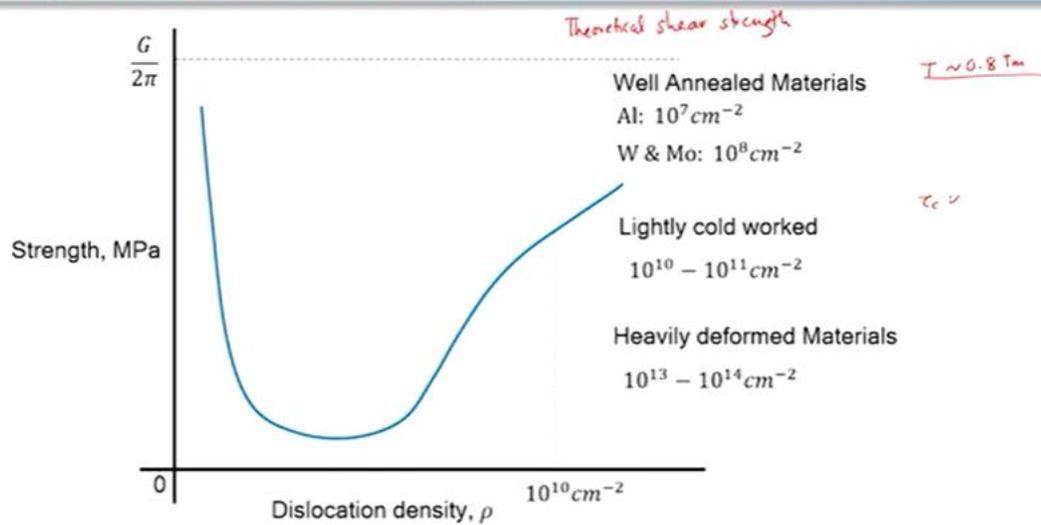
Namaskar phir se swagat karta hoon aapka is course mein mechanical behavior of material jo ki hum hindi mein padhenge last part mein humne dislocation configuration dekhe the stable configuration dekhe the aur uska strain hardening mein kya asar hota hai yeh bhi humne dekha tha is part mein hum dekhenge ki dislocation nucleation kaise hote hain aur usi ke liye hum dekhenge ki frank read source kya hote hai dislocation ke sabse pehle dekhte hain ki dislocation aur strength iska kya relation hai dislocation density ka to agar main strength yahan par plot karoon y-axis par aur dislocation density x-axis par is tarah se plot karu to aap dekh paa rahe honge ki agar mera crystal hai jo dislocation free hai to aapko kya strength milni chahiye aapko strength milni chahiye kuch is tarah se uski value rahegi ye humne dekha tha yeh jo value hai yeh meri theoretical shear strength hai ye theoretical shear strength hogi yahan par mere material ki yeh kab hota hai jab mere

dislocation mein ya ya mere material mein koi dislocation nahi hai yaani dislocation yahan par shunya to ye value yahan par is tarah se reach hogi ab hum dekhte ki strength kis tarah se change hota hai agar meri dislocation density change ho rahi hai to hum dekh sakte hain ki dislocation jo strength hai crystal ki kuch is tarah se vary hogi agar meri dislocation density increase ho rahi hai aur to strength yahan par decrease hogi kyunki humne dekha tha ki theoretical jo shear strength hai usse mera jo strength rahega crystal ka woh kaafi kam rehta hai to mera jo strength hoga jaise jaise main dislocation introduce kar raha hoon yaani defect introduce kar raha hoon mere material mein to strength yahan decrease hoga kuch is tarah se aur jab ek minimum value ke baad yaani minimum strength ke baad agar main dislocation density badha raha hoon to aap dekhenge ki ye dislocation density jaise jaise badh rahi hai waise waise strength meri badh rahi hai.

To kuch points yahan pe mark kar lete hain hamare course ke liye jo important rahenge to ye jo value hai ye typical value hai yahan pe humein deformation ke dauran ya material jo rahega 10^{10} ye ye typical dislocation density yahan pe humein milti hai material mein yeh maine per centimeter square yahan par likha hai to well annealed material mein humein kuch dislocation densities kuch is tarah se milti hai aluminium mein aap dekhenge ki 10^7 cm^{-2} per centimeter square tungsten and molybdenum ye jo bcc material hai usmein 10^8 cm^{-2} humein milti hai to ab dekhenge ki well annealed material mein sabse lowest strength hoti hai well annealed material kya hota hai agar main koi material leta hoon aur usko main furnace mein rakh deta hoon kuch kisi high temperature pe high temperature yaani aap dekhenge ki high temperature close to 0.8 agar T_m mein yahan par rakh liya material ko aur phir furnace cool kiya usko us process ko hum annealing kehte hain aur yeh well annealed material mein hum dekhenge ki ye dislocation density mere paas kuch is tarah se rahegi aur mera jo strength rahega mere crystal ka mere material ka sabse lowest rahega ismein well annealed material mein lightly cold work mein humein thodi dislocation density yahan par badhegi work yaani hum strain badha rahe hain material to humne dekha ki yeh jo lightly cold work material mein 10^{10} ya 10^{11} humein kuch is tarah se dislocation densities milti hai ya per centimeter square aur heavily deformed material mein humein 10^{13} to 10^{14} cm^{-2} is tarah se dislocation density milti hai to yahan par hum humein yaad rakhna hai ki jo shear strength hai wo proportional hai mere dislocation density ke saath yeh main baat kar raha hoon is dauran yahan par well annealed se iske upar aap dekhenge ki yeh jo strength hai kuch is tarah se vary hogi to yeh hogi meri dislocation density ka mahatva strength ke upar to ya agar main dislocation density ko vary karunga mere material mein us tarah se main apne material ka strength change kar sakta hoon.



Strength Vs Dislocation density



Abhi hum dekhte ki nucleation dislocation kahan se hote hai humne dekha tha ki well annealed material mein bhi hamare paas 10^7 ya 10^8 is per centimeter square is tarah se dislocation densities hai to yaani yeh kaafi high number hai to yeh dislocation kahan se to nucleate hote honge isko hum dekhte hain ki kaun se kaun se sources hai dislocation nucleation ke to dislocation nucleation hota hai sabse pehle to hum dekhte hain ki agar hum koi material ya metal se alloy taiyaar kar rahe ya cool down kar rahe kuch high temperature se to solidification ya cooling se hamare paas nucleation ho sakta hai dislocations ka kuch is tarah se samajh sakte hain kyunki jaise hum cool karte hain yaani hum dekhenge ki agar mera material kuch is tarah se uska volume bahut jyada hai aap dekhenge large volume agar cool kar rahe to aap dekhenge ki kuch thermal gradient taiyaar hoga yaani uske center mein kuch ek temperature rahega aur surface par kuch temperature rahega to aap dekhenge ki ek temperature gradient taiyaar hoga is temperature gradient ki wajah se internal stresses develop hote hain local internal stresses develop hote hain aur is stresses ki wajah se yahan par dislocation nucleate hote hain yaani ek thermal gradients yahan par rehte hain hamesha change in composition dusra parameter ho sakta hai ki mera composition change ho raha hai aap dekhenge ki agar main solidify kar raha hoon alloy ko humne dekha tha ki surface hai uspe kuch composition aur rahega aur andar par kuch aur composition rahega wo kuch is tarah se samajh sakte aap dekh paa rahe honge ki yahan par maine ek example diya hai nickel copper system ka to aap dekhenge ki yahan par agar mera nickel hai yahan par is composition ko melt karke solidify karunga to mera yahan par nucleus taiyaar ho raha hai aur aap dekhenge ki yahan par composition jo hai yeh jo solid taiyaar ho raha hai yeh jo solid taiyaar ho raha hai yeh jo solid line hai yeh solid line ka composition dikhayega ki mera jo solid taiyaar ho raha hai uska composition hamesha alag rahega is part par agar main dekhunga yahan par jo solid taiyaar ho raha hai uska composition rahega 46 percent nickel is part par jo solid taiyaar hoga uska rahega composition 43 percent nickel aur jab yahan par aayega to is part pe aayega mera kuch is tarah se 35 percent jo nickel rahega inside to aap dekh paa rahe honge ki mera composition changes hote hain kyunki alloys mein ek temperature par solidification nahi hota hai to composition gradient ke wajah se bhi dislocation nucleations honge to yeh kyun hota hai kyunki yahan pe composition change hone ke wajah se lattice parameters change honge mere material ke.

Change in crystal structure yeh bhi aasaani se hum samajh sakte hain ye ek aur reason ho sakta hai dislocation nucleation ka to yeh crystal structure hum baat karenge phase transformation ke dauran to jaise main baat kar raha hoon austenite to alpha ferrite yaani fcc to bcc transformation humne dekha tha ki yahan par ek volume increase hoga ye volume increase hoga ya lattice parameters change honge aur iske wajah se dislocation nucleate honge aur kuch transformation dekh sakte hain yahan par main gamma iron jaise austenite ko quench kar liya mere paas kuch martensite milega yahan par bhi large volume changes milenge to yeh jo large volume change honge uske wajah se dislocation nucleate honge to yahan par aap dekhenge ki agar mere paas yeh jo austenite hai isko maine martensite mein convert kar liya quenching ke dwara to jo interface bhi honge wo bhi stressed honge wahan par bhi strains develop honge aur un strains ki wajah se dislocations nucleate honge to yahan pe mujhe large increase in dislocation density mil sakti hai abhi yeh equation humne dekha tha jab hum high temperatures ki baat kar rahe jaise maine dekha tha ki equilibrium concentration of vacancies humne baat ki thi jo thermal equilibrium defects hai ye temperature ke saath humne correlate kiya tha to aluminium mein aap dekhenge ki quench in vacancies jaise agar main aluminium ko heat kar raha hoon kisi high temperature pe garam kar raha hoon aur usko quench kar diya to kya hoga us high temperature pe mere paas kuch vacancies rahengi kuch is tarah se maan lijiye mera lattice hai ye kuch high temperature pe hai mere paas aur ye high temperature pe maine heat kiya to wahan pe vacancies taiyaar hongi vacancies kyun taiyaar honi chahiye kyunki wo thermal defects hai thermal equilibrium defects hai to mere paas kuch ek thermal equilibrium concentration rahega is vacancies ka agar maine inko aap dekhenge ki vacancies agar main inko quench karne ki koshish karunga to yahan pe aap dekhenge ki vacancies kuch is tarah se bhi arrange ho sakti hai join ho sakti hai combine ho sakte hain aur unko maine agar quench kar diya to ye vacancy ya structure collapse ho jayega aur mujhe kuch quench in vacancies milengi yeh dekha tha humne ki prismatic loop taiyaar karenge aap dekhenge ki agar ye aap 3d mein consider kare agar ye yahan pe join ho gaye aur yahan pe to aap dekhenge ki ye extra half plane ho jayenge ek extra plane ho jayenge aur isko hum 3d volume mein consider karenge to mere paas ek kuch loop ki tarah ho jayega to ye ho jayega mera quench in vacancies ke wajah se ek prismatic loop taiyaar hoga aap dekhenge ki yahan pe jo nature hai mere loop ka wo edge nature hai to ye ye bhi kuch is tarah se mere paas dislocation ke nucleation ke sources hai ye saare.

To humne dekha tha ki dislocation kis tarah se nucleate hote hain material mein to aap dekhenge ki material mein well annealed material mein bhi kuch is tarah se 10^7 to 10^8 orders ke orders ki dislocation density hoti hai aur yeh jo high number hai woh kuch is jo processing ke wajah se aata hai yaani yeh jo processing jo kar rahe material ka uske wajah se humein dislocation ke nucleation ke sources milte hai.



Nucleation of dislocations



Solidification or Cooling down from high temperatures

High local internal stresses Thermal gradients

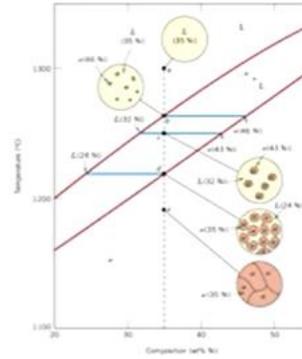
Change in a composition: Change in lattice parameter

Change in a crystal structure: Phase transformation

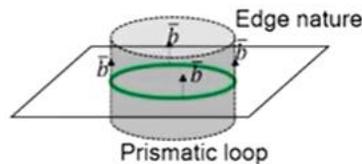
$\gamma_{Fe} \rightarrow \alpha_{Fe}$ Volume increase

$\gamma_{Fe} \xrightarrow{\text{quench}} \text{martensite}$ Large change in volume
Large increase in ρ

Al: quenched-in vacancies $\frac{N_v}{N_0} = \exp\left(-\frac{Q}{kT}\right)$



well. Annealed
 $10^7 - 10^8 / \text{cm}^2$



Metals Sci & Eng An Intro, WD Callister
Introduction to dislocations, Hull & Bacon

Abhi ek question aayega ki dislocation density badhni kyun chahiye to agar hum ek scenario consider karte is tarah se humne yeh edge dislocation ki baat ki thi agar mere paas ek single crystal hai aur yahan par ek half plane maine introduce kiya tha aur agar main isko shear karta hoon to is tarah se agar main shear karta hoon to humne dekha tha ki yeh displacement vector hai aur yeh yahan isko humne burgers vector kiya tha aur yeh maan ke chala tha ki yahan par ye jo crystal hai baad mein yeh perfect crystal ho jayega yahan pe dislocation bahar aa gaya surface par aa gaya to surface par aane ke baad yahan par to koi material mein koi defect nahi hai to single crystals mein bhi humne dekha tha ki hum dekh paate hain ki dislocation density increase hoti hai jaise jaise main deformation badhata hoon to yahi maine yahan par schematic ke dwara dikhane ki koshish ki ki dislocation surface par aa gaya aur to dislocation density yahan par to decrease honi chahiye yahan par dekhiyega koi dislocation yahan par present nahi hai to logically agar aap dekhenge ki dislocation density decrease honi chahiye jaise jaise mera deformation badhta hai par aap humne dekha tha ki dislocation density badhti hai jaise jaise deformation badhta hai to yeh equation humne istemal kiya tha to humne bola tha ki jo plastic strain hai plastic strain jaise jaise badhega waise waise mere mobile dislocation density badhni chahiye ye equation is tarah se mujhe batata hai par ye jo scenario maine consider kiya hai us case mein aap dekhenge ki yahan par dislocation disappear ho raha hai surface pe aake to yeh equation batata hai dislocation density badhni chahiye yeh contradiction ho gaya hamare observation aur yeh equation ke hisaab se humne yeh bhi dekha tha ki practically jaise jaise mera dislocation density badh rahi hai waise waise mera jo shear strength hai deformation ke liye wo badhna chahiye to yeh bhi humne practically dekha tha ki jab cold work karta hoon to mera yield strength badhta hai to practically humein dikh raha hai ki dislocation density badhni chahiye aur yeh scenario main consider kar raha hoon tab dislocation density ghatni chahiye to yeh problem solve kiya gaya tha ki is crystal mein kuch to aisa mechanism hona chahiye jiske wajah se dislocation density badhni chahiye to humne dekha tha ki yeh do equation humne istemal kiye the likh lete in dono equations ko yeh mera orowan equation tha aur yeh mera taylor hardening equation tha in dono ko humne istemal karke bataya tha ki jaise jaise plastic strain badhta hai waise waise dislocation density badhni chahiye aur is dislocation density ki wajah se mera jo shear strength hai wo bhi badhna chahiye to yeh jo problem hai yaani

jo do contradiction hai yeh solve kiye the frank aur read ne yeh 1950 mein solve kiya tha in dono ne to ye dono ek conference mein mile the aur conference mein dono ne discuss kiya tha inhone yeh simple thought process diya tha ki agar mera dislocation annihilate ho raha hai surface par aake to crystal ke andar koi source hone chahiye dislocations ke jo is dislocation ko hamesha generate kare aur in dono ne ek source ko naam diya tha ek source propose kiya tha us source ke baare mein hum jaanenge isko kehte frank read source to yahan par hum dekhenge ki yahan par dislocations exist hote hai yaani dislocation sources exist hone chahiye mere material ke andar and jo operate karenge plastic deformation ke waqt jaise jaise yaani yeh sources yahan pe to present rahenge par ye operate karenge plastic deformation ke dauran.

Why increase in a dislocation density?

Dislocation coming out on the surface and disappearing

Dislocation density must decrease

$\gamma = \rho_m b \bar{x}$ Dislocation density increases

$\tau_c = \alpha G b \sqrt{\rho}$ As density increase, critical stress required to move the dislocation increases

FC Frank and T Read (1950)

Existence of sources of dislocations inside the crystals

Operate during plastic deformation

Orowan

Taylor hardening

To humne baat ki hai frank read source ki to aaiye jaante hain ki frank read source hota kya hai maan lete mere paas ek aisa kuch crystal hai aur yahan pe ek plane hai yahan pe ek slip plane maine mark kiya hai aur ek dislocation hai yahan pe kuch is tarah se aur aur humne crystal ke dimension mark kar liye x_1, x_2 aur x_3 aur ek do point mark kar liye yahan par maine yeh do point hai a aur b aur is point par yeh dislocation pinned hai ya yahan par ye dislocation move nahi ho sakta hai in dono ke beech mein move hota hai par is point ke baad yeh move nahi honge to yeh scenario aata hai crystals mein jab hum is tarah se dekhenge ki mera dislocation kuch is tarah se hai main mark kar raha hoon is tarah se agar mera dislocation line hai aap samajh sakte ho agar meri dislocation line kuch is tarah se ja rahi hai ye mera tangent vector main yahan pe draw kar raha hoon to aap dekhenge ki agar mera dislocation is tarah se ja raha hai aur ye jo planes hai yahan pe is planes pe ye dislocation ki movement nahi hogi ya is is plane pe ye jo blue color ke jo planes hai inpe dislocation ko koi movement nahi hogi aur ye jo grey plane hai ya a aur b ke point ke beech mein jo dislocation line segment hai iski hi movement hogi to hum ye keh sakte hain ki dislocation mera pinned hai point a aur point b ke beech mein to ye kab hota hai abhi dekhte hain ye aap samajh sakte ho jaise maine abhi yahan pe burgers vector mark kiya hai to ye maine ek continuous dislocation yahan pe mark kiya aur is dislocation ka burgers vector agar mark kiya maine b to ye burgers vector same hona chahiye saare dislocation line ke liye humne dekha tha ki dislocation line ke liye ek kisi dislocation line ke liye jo burgers vector hota hai wo invariant hota

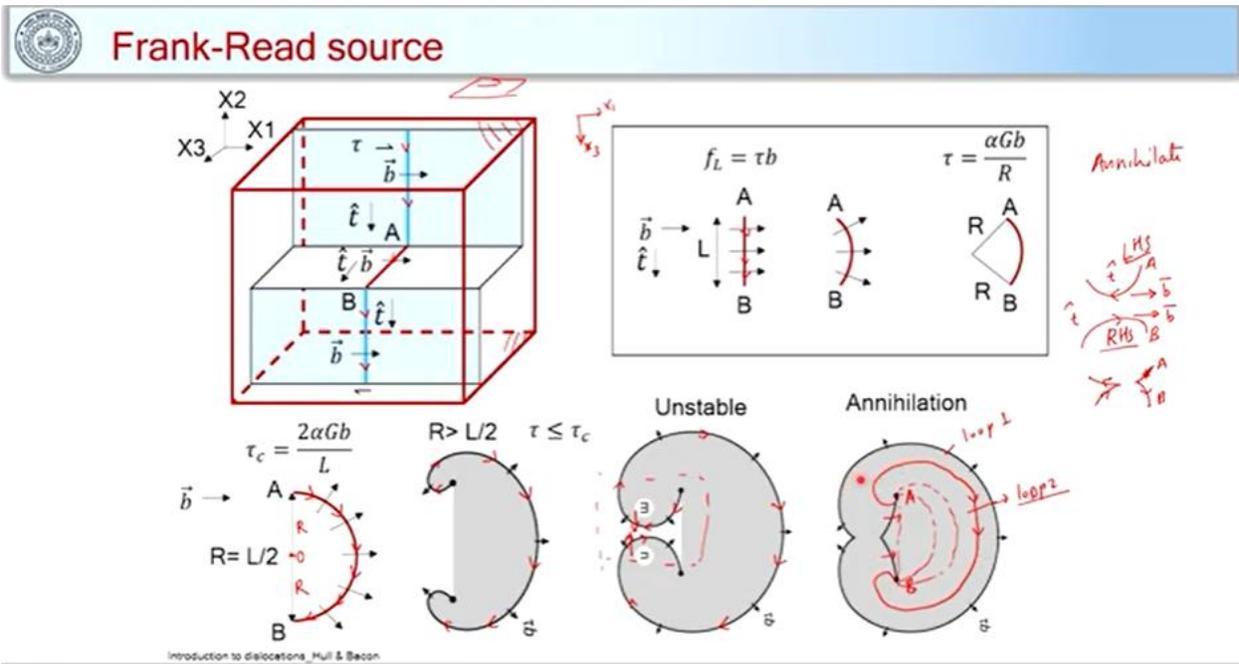
hai aur uske magnitude aur direction dono same rehte hain abhi tangent vector bhi mark kar liya maine kuch is tarah se to yeh mera tangent vector hai abhi main kuch shear stress apply karunga to shear stress main kahan apply kar raha hoon aap dekhenge shear stress main kuch is plane par operate kar raha hoon yaani main x_2 plane par operate kar raha hoon shear stress jo mera x_2 plane hai yeh wala upar wala plane shear stress yahan lag raha hai aur ek bottom plane hai yeh bhi x_2 hai negative x_2 plane hai yahan par mera shear stress lag raha hai yeh jo direction mark ki maine shear stresses ki is tarah se to aap samjhe ki is plane par mera shear stresses lag raha hai to humne dekha tha ki yeh jo shear stress hai yeh shear stress kis direction mein yeh shear stress hai hamara burgers vector ke direction mein par yeh jo shear stress hai woh kis plane ko parallel hai yeh yeh jo grey plane hai is plane ko parallel hai aur ye blue planes ko parallel nahi hai to ye shear stress act ho raha hai is plane par hi yeh jo grey plane hai to hum dekhenge ki shear stress jab apply hoga to yeh jo line segments hai blue line segment hai mere dislocation ki yeh nahi move hogi sirf jo red wali line segment hai yahi move hogi is stress ke application ke dwara to aap dekh sakte hain ki yeh line segment jab move nahi hogi to hum bol sakte hain ki mera dislocation yahan pe point a aur point b pe pinned hai aur yahan par yahi jo dislocation line segment hai yahi meri glide karegi ya yahi move karegi abhi hum dekhte hain ki iska movement kaise hota hai shear stress ke dauran.

To maine yeh plane mark kar liya hai kuch is tarah aur yeh line segment mark kar li hai ab maine burgers vector mark kar liya kuch is direction mein aur tangent vector kuch is direction mein mark kar liya to aap dekh paa rahe honge ki yeh jo plane hai yeh mera x_2 plane hai yaani kuch is tarah se x_2 plane hai kyunki ye plane x_2 direction ko perpendicular hai aur hum dekhenge ki shear stress maine apply kiya aur yeh jo line segment hai iski length main maan leta hoon L yahan par aur jab main shear stress apply karta hoon to force per unit length of dislocation kuch is tarah se niklega F_L ko main is tarah se likh sakta hoon $\tau \cdot b$ ye mera shear stress hai humne dekha tha ki jo glide force hoga ya jo shear force per unit length of dislocation hoga is line segment pe act hoga isko main F_L likhunga aur yeh aayega iska magnitude $\tau \cdot b$ humne dekha tha abhi shear stress ke wajah se aap dekhenge ki yeh jo dislocation line segment hai yeh a aur b point par move nahi ho sakti yaani pinned hai par is point par to yeh move ho sakti hai aur yeh move movement kis tarah se hoga perpendicular to tangent vector to yeh mera tangent vector hai to aap dekhenge ki par is a aur b point par move nahi honge to mere paas kuch is tarah se curvature aayega is dislocation line ka kyunki a aur b pe move nahi ho raha hai to is tarah se mera tangent vector change hoga aur dislocation line is tarah se move hogi aur main maan leta hoon ki agar a aur b aur ye maan lete ki iska ek radius hai R ye humne dekha tha jab humne dislocation tension ki baat ki thi line tension ki baat ki thi to kuch is tarah se humne formulations kiye the to mera ye line segment aise bow ho gaya ya bend ho gaya ya curve ho gaya kyun curve hua kyunki maine shear stress apply kiya hai aur humne shear stress nikaala tha yeh τ nikaala tha agar mujhe radius pata hai ye to humne yeh shear stress kuch is tarah se nikaala tha $\tau = \alpha Gb/R$ to yeh mera ho gaya shear stress abhi jaise jaise main shear stress apply karunga badhaunga to aap dekhenge ki yeh jo curve hai yeh badhega aur ek stage par yeh curve jo hai woh semi circle ban jayega dekhenge ki jo curve hai wo semi circle ban gaya yahan par aur burgers vector mera kuch is direction mein wo to change nahi ho raha hai wo invariant hai aur yeh jo length yeh jo R hai ye aap dekhenge ki yeh jo R hogi radius ye $L/2$ hogi humne maan ke chala tha ki yeh length hai yeh L hai yeh to change nahi ho rahi par aap dekhenge ki yeh jo radius hai agar yeh semi circle ho gaya to mera origin kuch yahan par aayega aur ye ho gayi meri radius to main radius ko kuch is likh sakta hoon radius $R = L/2$ aur agar main yeh is equation mein rakhta hoon to mere paas kuch $\tau_{critical}$ is tarah se aayega maine R ki jagah sirf $L/2$ yahan par rakha hai to yeh 2 upar chala jayega to mere paas aa jayega $2\alpha Gb/L$

kya hai yeh L hai distance between two pinned points to aap dekhenge ki mere paas ek $\tau_{critical}$ yaani shear stress ki critical value aayegi value isliye bol raha hoon kyunki yeh jo curve hai yeh semi circle se jyada badh nahi sakta yeh maximum curvature mujhe kuch is tarah se milega kyunki yahan par aap dekhenge ki jo radius hai woh $L/2$ hogi yeh jab condition aati hai tab mujhe critical shear stress milega aur agar main shear stress abhi halka sa bhi badhata hoon to aap dekhenge ki yeh jo dislocation line movement hai kuch is tarah se hogi perpendicular to its tangent vector to yahan par bhi tangent vector nikaal dete tangent vector mera kuch is direction mein hai kuch is tarah se to aap dekhenge ki dislocation line segment aur move hone ki koshish karegi to movement jab hogi to kuch is tarah se hogi aap dekhenge ki yeh meri critical value hai yeh critical value agar main maintain kar raha hoon to dislocation line segment move honi chahiye to move hogi kuch is tarah se yahan par abhi scope nahi hai kyunki isse jyada se wo move nahi ho sakti to dislocation line segment kuch is tarah se movement chalu karegi yeh kab hoga jab R greater than $L/2$ hoga to aap dekhenge ki R agar greater hai $L/2$ se to aapko kuch is tarah se relation milega aur aap dekh paa rahe honge ki τ jab $R > L/2$ aayega to τ ki value less than or equal to τ_c honi chahiye to yeh jab condition meet hoti hai tab aap dekhenge ki dislocation line segment meri kuch is tarah se move ho rahi hai ab iska bhi tangent vector hum mark kar lete hain to tangent vector kuch is tarah se ja rahe mere dislocation ke critical value ke baad aap dekhenge ki yeh jo line segment hai yeh is tarah se bend ho jayegi ya move hogi is points ke around aur phir mujhe koi extra stress nahi chahiye hoga yeh line segment ab is yeh stress agar cross ho jayega ya equal ho jayega to aap dekhenge ki dislocation line segment kuch is tarah se hogi aur aap dekhenge yeh jo part yahan par abhi aap focus kariye aur yeh jo configuration ye meri unstable hai unstable yaani isliye kyunki mujhe koi extra stress nahi chahiye yeh configuration laane ke liye dislocation ke liye isliye isko main unstable kehta hoon jaise is point pe main pahunch gaya jaise hi is point par pahunch gaya mera dislocation move hoga ya dislocation line segment bow hone ki koshish karega bend hone ki koshish karega par yeh to semi circle hai iske baad aap dekhenge ki dislocation is tarah se move hoga yeh mera unstable region hai yaani mujhe koi extra stress nahi chahiye is dislocation ko is configuration mein laane ke liye.

Abhi is point par focus karte hain yahan par bhi hum tangent vector draw kar dete hain yahan par agar main tangent vector draw kar raha hoon kuch is tarah se point a se point b ki taraf ja rahe to yeh part yahan par aap focus kariye yeh part main abhi yahan par draw karunga yahan par aap dekhenge mera kuch is tarah se dislocation configuration hai yeh mera point a hai mera point b hai aur yeh mera tangent vector hai kuch is tarah se maine draw kiya hai tangent vector is tarah se draw kiya aur burgers vector aap dekhenge to burgers vector to ek hi direction mein rahega to aap dekhenge ki yahan par is configuration mein mera burgers vector jo hai wo opposite hai tangent vector ke direction pe aur yahan par hum dekhenge ki yahan par tangent vector hai burgers vector ke parallel hai par burgers vector ke direction mein hi hai to aap dekhenge ki yeh jo dislocation hai yeh mera negative edge dislocation ho gaya aur ye jo dislocation ho gaya ye mera left hand screw ho gaya agar hum dekhenge ye mera left hand screw ho gaya aur ye jo dislocation ho gaya ye mera right hand screw ho gaya kyunki dono burgers vector aur tangent vector parallel hai ek mein wo opposite direction mein ek mein ek same direction mein hai to mere paas left hand screw aur right hand screw aur abhi humne dekha tha ki agar mere paas do opposite nature hai screw dislocation to woh ek dusre ko attract karenge aur attract is tarah se karenge aap dekhenge ki ek dusre ko force act karenge to yeh force kuch is tarah se act karenge so that yeh do dislocation ek dusre ko attract karke ek dusre ko meet karenge aur annihilate karenge isko bhi hum likhenge ki humne annihilation likha tha nasht karenge ek dusre ko aur kis tarah se nasht karenge abhi hum dekhte hain woh is tarah se nasht karenge aur yeh jo line segment hai ek dusre ko mil jayegi yaani

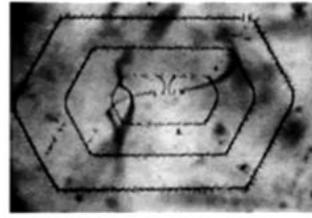
ek dusre ko paas aayenge to yahan par aap dekhenge kuch is tarah se mera tangent vector change hoga aur line segment kuch is tarah se aayenge to yahan pe annihilation ho gaya yeh part nasht ho jayega to yahan pe perfect crystal taiyaar ho jayega aur aapki line segment kuch is tarah se ho jayegi abhi bhi main shear stress agar apply kar raha hoon to yeh dislocation phir se act karega yahan par mera point a aur b to pinned hai to agar main phir se shear stress apply kar raha hoon to yeh line seedhi ho jayegi seedhi isliye hogi kyunki straight ho jayegi kyunki aap dekhenge ki iski energy jyada hai iski length jyada hai to straight ho jayegi phir se main shear stress apply karunga to yeh phir se bowing chalu ho jayegi iski kuch is tarah se bowing hogi ye phir se kuch semi circle banega is tarah se aur phir yeh bowing is tarah se hogi to aap dekh paa rahe honge ki ye line segment is tarah se bow hogi aur ye ek dislocation source ki tarah act karegi yahan pe aap dekhenge ki ye mera pehla loop taiyaar ho gaya ye mera pehla loop ho gaya loop one aur ye jo dusra process hai yahan pe main nikaala tha ye loop two taiyaar ho jayega aur ye dislocation operate karega operate kab karega jab mera shear stress kuch is value par rahega to aap dekh paa rahe honge ki plastic deformation par yeh jo dislocation source yeh yaani a aur b dislocation source ki tarah act honge aur yeh loops dislocation loops yahan par crystal mein generate honge to aap dekh paa rahe honge jaise jaise loop badhenge waise waise dislocation density badhegi aur isi source ko hum kehte hain frank read source yeh ho gaya mera frank read source.



Aaiye dekhte hain ki frank read source hota kya hai to yahan par aap dekhenge is crystal mein yeh dekhiye aap yeh point yahan par frank read source ki tarah act kar rahe ek loop taiyaar ho gaya yahan par abhi dusra loop ban raha hai yeh bhi waise hi taiyaar hoga aur yeh crystal mein propagate hoga to yeh ho gaya mera frank read source yahan par bhi aap dekh paa rahe honge ek kitaab se li gayi ek figure hai yeh silicon crystal ke liye aap dekh paa rahe honge ki yahan par ye jo do points hai yahan pe dislocation loops taiyaar ho rahe hain ye aap dekh paa rahe honge ye pehla loop taiyaar ho gaya ye dusra loop andar wala aur ye teesra loop phir se taiyaar ho raha hai to aap dekhenge ki mere dislocation ki number increase ho rahi hai is loops ki wajah se aur ye jab loops badhenge to mere dislocation density badhegi to aap bol sakte hain ki ek loop ek source act kar raha hai mere crystal ke andar jab koi shear stress ya plastic deformation ho raha hai mere material ke andar.



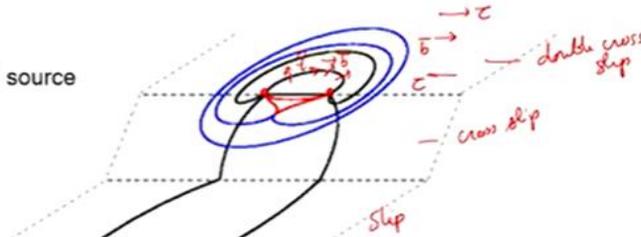
Frank-Read Source



Frank-Read source in a silicon crystal

Plastic stress
↓
strain
↑
Dislocation source

Cross slip: Frank-Read source



<https://blogs.cornell.edu/mse4020/2015/11/06/videos-depicting-frank-read-source-simulation-and-in-situ-tem/>
Introduction to dislocations, Hull & Bacon
Mehner et al., Mater Theory 2, 3 (2018)

Frank read source ko kuch is tarah se bhi samajh sakte hain jab humne pinning ki baat ki thi do points ke beech mein to aap dekh paa rahe honge ki humne ek baat ki thi slip cross slip aur double cross slip to humne yeh baat ki thi yahan par slip ho raha tha mera loop ek yeh cross slip ki baat ki thi humne jab humne fcc material ki baat ki thi aur yeh mera double cross slip ho gaya to aap dekh paa rahe honge ki ye jab double cross slip hoga aur mera shear stress kuch is tarah se tha mera shear stress kuch is tarah se tha is material pe aur burgers vector is direction pe tha aur ye tangent vector aap samajh sakte ho kuch is direction mein hai to aap dekh paa rahe honge ki yeh dislocation jo hai yahan pe pinned tha is point pe agar move nahi ho payega kyunki aap pe dekhenge ki yahan pe ek mera edge nature taiyaar ho jayega aur yeh jo part hai yahan pe aap dekh paa rahe honge yahan pe main tangent vector agar main mark kar raha hoon yahan pe burgers vector hai to ye screw dislocation hoga par yahan pe is point pe ye edge part hoga to is shear stress ke dwara yahan par bhi shear stress mark kar lete hain plane pe agar shear stress lag raha hai to is shear stress dwara yahan par koi deformation nahi hoga but yeh jo part hai yahan pe ye yahan pe is direction mein move hoga aap dekhenge is direction mein move hona chahiye to main keh sakta hoon ki ye do point hai mere pinned points hai aur is pinned point ke wajah se mera dislocation jo yeh jo do point hai yeh act karenge dislocation source ki tarah aur yahan par loops yahan pe wo generate karenge kuch is tarah se aap dekh paa rahe honge yeh pehla yahan par pehla loop taiyaar hua tha yeh ye yahan par aap red wala mark dekhenge yahan par dislocation annihilate ho rahe hai aur ye dusra loop taiyaar ho raha hai aur jab main stress mark kar raha hoon to yahan par phir se bowing hogi to to ye is tarah se loop mera operate hoga to aap phir se hum is tarah se dekh sakte hain is video mein phir se main dikhana chahta hoon aap dekh rahe hain ki ye loops kuch is tarah se operate honge pehla yahan par annihilate ho gaya aur phir dusra loop preparation mein chal raha hai to ye is tarah se mera frank read source operate hota hai to humne yeh dekha jaise jaise mera plastic stress plastic stress yaani stress jab rahe to ek strain taiyaar hoga to jab ye strength kyun taiyaar hoga aur strain jab taiyaar hoga to mera dislocation density kyun badhta hai dislocation density isliye badhna chahiye kyunki wahan pe dislocation sources act honge dislocation sources jitne operate honge us tarah se meri dislocation density badhegi aur dislocation density agar badh rahi hai to yeh strain ko quantify karegi aur is strain ki wajah se meri strain hardening bhi hogi ya

mera strength jo hai crystal ko deformation ke liye badhna chahiye to ye ho gaya mera frank read source to is part mein humne dekha ki crystal jo hai jab deform karta hai to dislocation surface pe aake disappear ho jaata hai to crystal mera defect free hona chahiye tha aur wo defect free nahi hota hai humne dekha tha ki plastic strain jaise jaise hum apply kar raha hoon waise waise dislocation density badhti hai to ye dislocation density isliye badhti hai kyunki wahan pe dislocation sources act hote hain to abhi ke liye main yahan pe rukta hoon next part se hum jaanenge ki dislocations ke aur kya interactions ho sakte hain dhanyavad