

Mechanical behavior of materials

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Week-5

Lecture-26

Geometrical Properties of Dislocation



Mechanical Behavior of Materials (Hindi)

Geometrical Properties of Dislocations

Namaskar phir se swagat karta hoon aapka is course mein Mechanical Behavior of Material mein jo hum Hindi mein padhenge. Last part mein humne dekha tha Peierls-Nabarro stress kya hota hai. Is part se aage hum dekhenge ki plastic deformation jab hoga yani dislocation jab move hoga to kya plastic strain develop hoga. Uske pehle hum humein yeh janna chahiye ki geometric properties kya hai dislocation yani dislocation ki kuch geometric properties hoti hai dislocation ke kuch नियम hote hain to woh is part mein hum janenge. Uske pehle jaane se pehle hum ek kuch concept revise kar lete hain dislocations ke baare mein to yeh humne dekha tha Volterra cut aur Volterra cut se kis tarah se hum dislocations ko taiyar kar sakte hain.

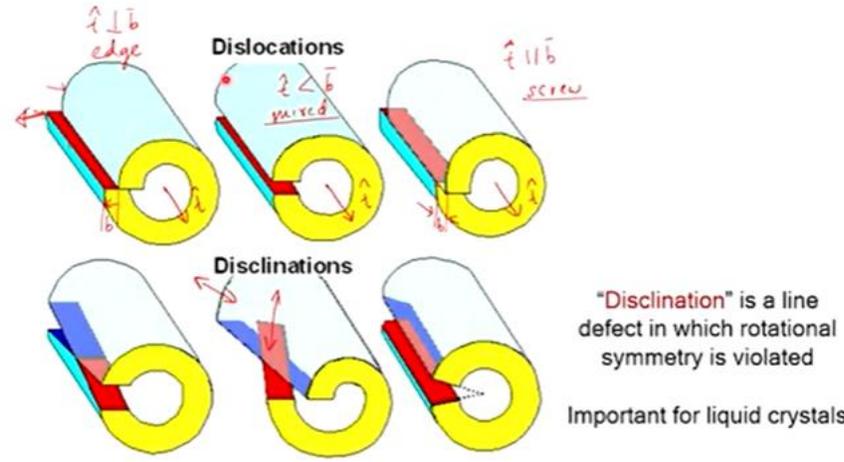
To yeh ek maan lete hain hamara ek cylinder hai yani ek continuum solid hai aur humne dekha tha ki Volterra cut Volterra knife se hum cut karenge is tarah se kuch cut karenge to humein aur displace karenge material ko to humein dislocations milenge. To dekh lete hain agar mera yahan pe maan lete yeh mera tangent vector hai is cylinder ke axis ke around in teeno cases mein to aap

dekhenge yahan pe maine cut kiya isme cut kiya aur yahan par is tarah se shift kiya isko is tarah se move kiya aur is part ko is tarah se lekar aaya to aap dekhenge ki yahan par yeh jo red part hai mark hai yahan par ek displacement mujhe mil raha hai to aap yahan par dekhenge yeh jo displacement hai yeh kaisa hai yeh t ko perpendicular hai to yeh ho gaya mera edge dislocation. Is case mein aap dekhenge ki ye jo displacement hai jab maine displace kiya solid ko yeh is direction mein hai yahan par t parallel hai Burgers vector se to yeh ho gaya mera screw dislocation. Aur is case mein aap dekhenge ki yeh jo t aur b hai ye kuch angle banayenge ek dusre ke saath to yeh ho jayega mera mixed dislocation. Yeh ho gaye dislocation ke prakar.

Par main Volterra cut se kuch aur cheez kar sakta hoon jaise maine ek continuum solid tha aur yahan par maine dekha ki ye kuch aise part maine cut kar diya aur yahan par jo red wala mark hai is tarah se kuch cut kar diya aur maine is part ko join kar diya yahan par is tarah se aap dekhenge ki blue aur red yahan par joint hai. Simply yahan par bhi aap dekhenge ki maine cut kiya aur maine jo upar wala part hai usko is tarah se rotate kiya aur jo bottom wala part hai usko kuch is tarah se rotate kiya aur inko join kar diya yahan par aur aap dekhenge ki maine kuch aise ek part cut kiya aur phir main is part ko join karunga to yeh jo mere paas defects taiyar honge yeh bhi line defects taiyar honge aur inko main kehta hoon Disclinations. Hum is disclination ke baare mein is course mein nahi padhenge par yeh just aapke information ke liye introduce kiya hoon yahan pe. Ye jo disclinations hai yeh related hoti hai ya rotational symmetry break hoti hai humne dekha tha rotational symmetry ke baare mein jaise jab humne n-fold symmetry ke baare mein baat ki thi crystals mein. To yeh kyun important hai disclinations yeh important hai hamare liquid crystals mein. To yeh ho gaye mere dislocation aur disclinations.



Volterra Cut and Disclinations



We will not be dealing with Disclinations in this course

Abhi jante hain ki hamare jo dislocation hai unke geometric properties kya hai. To yeh kuch geometric properties hai mere dislocation ki yani main isko observe kar sakta hoon. To dislocation cannot end abruptly in crystal humne dekha tha ki agar crystal defective hai aur line defect hai wahan par to humein dislocation milte hai aur jo line defect hai ye dislocation hai yeh abruptly mere crystal ke andar end nahi ho sakta yani khatam nahi ho sakta. To dislocation kahan-kahan

par ja sakte hain to dislocation kahan khatam ho sakte hain yeh hum dekhenge kahan end ho sakte hain. Dislocation hamare end ho sakte hain free surface par ya grain boundaries par ya kisi aur dislocations par yeh hum janenge unko nodes kehte hain ya kisi ya khud ke upar hi isko hum kehte hain loop.

To dekhte hain pehle yeh mera dislocation main is tarah se edge dislocation yahan par create kar raha hoon to aap dekhenge ki ye agar mera pura crystal hai is tarah se maine ek half plane insert kar diya to ek meri mera dislocation taiyar hoga aur humne bataya tha ki dislocation kya hota hai to ye jo dislocation yahan par line hogi ya defective yeh jo line hogi yeh meri dislocation line hai aur ab dekhenge agar yeh mera complete crystal hai to yeh jo part hoga front wala yeh mera free surface ho gaya yeh mera free surface ho gaya aur jo back part hoga yeh bhi mera free surface ho gaya. To hum dekhenge ki clearly is crystal mein jab maine defect taiyar kiya to yeh dislocation is free surface se chalu hua aur kahan khatam hua woh peeche wale surface mein jaake jo bhi free surface hai. To dislocation shuruat free surface se hui aur khatam hua ya end hua dusre free surface pe free surface yahan par bhi hoga peeche mein mera. To ye ek property ho gayi mere dislocation ki.

Abhi maan lete ki yeh jo mera half plane hai yeh main beech mein band kar raha hoon. To agar hum dekhenge ki is tarah se kuch kar raha hoon to ye ek mera half plane hai yani yahan maine yahan se shuru kiya aur ye half plane maine crystal ke khatam hone se pehle hi isko rok liya yani stop kar liya. To agar aap dekhenge ki dislocation line yahan par kaise hogi to dislocation line yahan se shuru hogi aur is tarah se jaake yahan pe end hogi. Agar main iska front view aur top view dekhunga to mera front pe kuch is tarah se dikhega aapko ye half plane is tarah se hai to dislocation line yahan pe hogi aur top view kuch is tarah se dikhega kyunki yahan par bhi aap dekhenge ki jo half plane hai upar se bhi is tarah se dikhega to aapko yeh milega top view is tarah se. To dislocation line yahan se nikal rahi hai to is tarah se dekhenge yahan par meri dislocation line aa rahi hai aur yahan se ja andar ja rahi hai to yahan par agar main view karunga 3D mein to is tarah se kuch jo neeli color ki mark hai yeh meri dislocation line hai. To aap dekhenge jo dislocation hai start kahan par hua free surface par aur aap dekhenge nikal ke aa rahi hai to yeh bhi mera free surface hai yeh dono mere free surface hai. To aap dekhenge ki jo dislocation hai yeh shuru ho sakte mere free surface par aur end ho sakte free surface par. To humne dekha ki dislocation crystal ke andar end nahi ho sakte abruptly. Theek hai to yeh free surface wala criteria ho gaya hamara ye hamari geometric property ho gayi dislocation ki.

Abhi hum dekhte hain dislocation agar andar khatam hota hai to uska kya implication hai. To humne baat ki thi ye ye mere free surface ho gaye ye mera dislocation yahan pe maine mark kiya edge dislocation aur ye tangent vector maine mark kiya aur yahan pe maine baat ki thi jo dislocation ki hum baat karte tab hum baat karte ki slip aur unslipped part ki humne baat ki thi ki dislocation line jo hai tangent vector hai woh kya bifurcate karta hai ye slip part aur unslipped part ko. Maan lete hain ek mera dislocation hai jo is tarah se hai yani woh crystal ke andar khatam ho raha hai to aap dekhenge ki yahan par agar mera slip part hai aur yahan par mera unslipped part hai to main slip part se unslipped part ko is tarah se move ho sakta hoon yani mujhe dislocation ki zarurat nahi yahan par. To yahan par aap dekhenge ki jo plane hai mera slip plane hai yani yeh kya darsha raha hai ki mere paas kuch slip part hai aur usi slip plane mein mere paas kuch unslipped part hai aur yani kuch yeh jo region hai yahan par mujhe pata nahi ki kya ho raha hai to yani slip se main unslipped par bhi ja sakta hoon aur unslipped se bhi slip ja sakta hoon yahan par mujhe mujhe koi displacement ya dislocation ki zarurat nahi hai to yeh valid nahi hai. Yeh valid nahi ho sakta kyunki aap slip se unslipped ja rahe ho aur koi displacement nahi hai yeh possible nahi hai.

To isliye yeh jo scenario yahan par ye dislocation crystal ke andar khatam hoga yeh possible nahi hai.

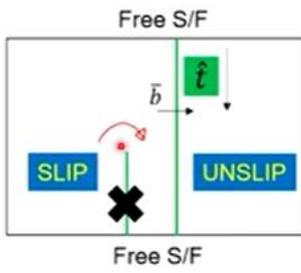


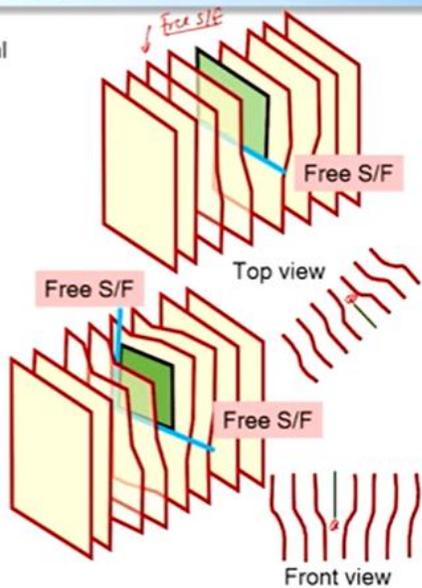
Geometrical Properties of Dislocations

Dislocation cannot end ABRUPTLY in a crystal

Dislocation must end at

- Free surface
- Grain Boundaries
- Other dislocations (Nodes)
- On itself (Loop)





To abhi humne dekha ki free surface ke baare mein dekha abhi dislocation ko dekhte hum grain boundaries pe end hote hain ki nahi. To hum dekhenge ki yeh jo polycrystalline material mein yeh jo boundaries hai inko kehte hain grain boundaries. To ye jo grain boundaries hai yani yeh jo ek grain hai ye hum ek single crystal ki tarah kar sakta hoon consider kar sakta hoon aur isme agar dislocations hai to yeh mere grain ho gaye aur ye grain boundaries ho gayi aur ye kuch dislocations maine mark kiye. To aap dekhenge ki ye kuch dislocations hai ye start ho rahe grain boundary aur end ho rahe dusre grain boundary pe to yeh scenario possible hai yeh ho sakta hai. Maan lete hain agar mera dislocation kuch is tarah se hai to humne last slide mein dekha ki mera dislocation kya determine karta hai slip aur unslipped part to main is tarah se kuch kahunga ki agar mera yeh deformation chalu hua to yeh mera slip part hai aur unslipped part hai. To is case mein ab dekhenge ki main slip aur unslipped part mein dislocation ko cross kiye bina hi slip aur unslipped part mein ja sakte ho aur yeh possible nahi hai isliye jo scenario hai yahan par dislocation crystal ke andar khatam hoga ya grain ke andar khatam hoga ye possible nahi hai. Dislocation ek to kisi bhi grain mein grain boundary se shuru hone chahiye aur grain boundary pe hi khatam hone chahiye. To yeh scenario mera possible nahi hai dislocation ke baare mein.

Abhi hum dekhte hain ki dislocation dusre dislocation pe yeh part jo hum baad mein dekhenge abhi dekhte hain ki dislocation khud ke upar jab end hote hai to kya hota hai. To yeh maan lete hain mera slip plane hai aur dislocation khud ke upar end ho raha hai yani shuru khud se ho rahe hai aur khud par hi khatam ho rahe hai to maan lete hain humein ek loop milega. Ye meri ho jayegi dislocation line yani dislocation line hai nahi ye mera tangent vector is tarah se kuch milega mujhe maan lete hain iska ek Burgers vector hai is dislocation ka. To yeh jo dislocation ka Burgers vector hai yeh Burgers vector humne dekha tha kisi bhi dislocation line ke liye ye invariant hota hai isko likh lete hain to ye jo Burgers vector hai iska magnitude aur direction change nahi hota hai kisi bhi dislocation line ke liye. To maan lete hain yeh mera Burgers vector hai aur mera tangent vector

yahan se shuru hua aur is tarah se kuch tangent vector hai humne baat ki thi ki tangent vector current ki tarah move hota hai aur aap dekhenge ki ye jahan pe maine shuru kiya wahan pe end hua to ye mera tangent vector ho gaya yahan pe. To ye tangent vector kuch is tarah se jayega dislocation line mein to aap dekhenge ki yeh jo dislocation loop hai yani ek loop taiyar hua ye mera slip part aur unslipped part ko bifurcate kar raha hai to yeh mera slip part hai aur yeh mera unslipped part hai. To yeh dislocation khud ke upar shuru hua aur khud ke upar end hua yeh possibility ho sakti hai yeh hoti hai do loops material mein dikhte hain.

To abhi dekhte hain is yeh jo loop hai yahan par hum dekhenge ki jo Burgers vector hai aur ye tangent vector hai ye ek hi slip plane mein hai Burgers vector aur tangent vector same slip plane pe hai to to is loop ko hum kehte hain Glide Loop isko hum kehte hain Glide Loop. To abhi hum janenge ki is Glide Loop ka kuch speciality hai agar hum dekhenge ki main yeh jo dislocation loop hai yeh agar aap dekhenge yahan par maine tangent vector mark kiya to tangent vector kuch is tarah se ja raha hai to ab dekhenge ki tangent vector yahan par case mein is case mein Burgers vector se parallel hai. Agar tangent vector Burgers vector se parallel hai to dislocation ka nature kya hona chahiye yahan par Screw hona chahiye. Similarly yahan par agar main baat karunga to tangent vector kuch is tarah se hoga is direction mein yani Burgers vector se perpendicular rahega. Is case mein aap dekhenge ki tangent vector Burgers vector se parallel rahega par opposite direction mein rahega aur is case mein jab yahan par main baat karunga to tangent vector is direction mein rahega yani Burgers vector se perpendicular rahega. To humne dekha tha ki tangent vector parallel hai to kya hota hai tangent vector jab parallel hota hai aur same direction mein hai to ye mera Right Hand Screw hoga. Similarly ye jo part hoga ye mera Left Hand Screw hoga. Abhi hum dekhenge ye jo part hai aap jaan pa rahe honge agar tangent vector perpendicular hai Burgers vector se to ye hoga mera Edge part yani Edge nature hoga yahan pe mere dislocation ka aur yahan pe bhi mera Edge nature hoga. To ye jo hoga mera Edge Negative Edge hoga aur yahan par mujhe Positive Edge milega. To is tarah se mera kuch Glide Loop hota hai jahan par main dekh pa raha hoon ki mere paas jo dislocation ka nature hai woh change ho raha hai ya Right Hand Screw phir Positive Edge phir Left Hand Screw aur Negative Edge.

Is tarah se kuch aur loops bhi hote hain woh is tarah se hum janenge ek maan lijiye mera slip plane hai aur yahan par maine mera ek loop hai yane jo dislocation shuruat hua hai woh khud ke upar hi end ho raha hai aur maan lete yahan par Burgers vector ek angle bana raha hai ya perpendicular is tangent vector ke saath. To aap dekhenge yahan pe ek special loop hai yahan pe mera tangent vector agar main draw karunga to ye kuch current ki tarah jayega humne dekha to ye mera tangent vector hai to yahan pe saare positions pe saare points pe is dislocation ke jo Burgers vector hai woh hamesha perpendicular rahega mere tangent vector se. Isko hum kehte hain Prismatic Loop. To ye jo nature hoga Prismatic Loop ka yahan par aap dekhenge ki tangent vector kya hai perpendicular hai mere Burgers vector se to yeh yahan par jo nature hoga mere dislocation loop ka woh Edge hoga. To mera Prismatic Loop hamesha Edge nature ka rehta hai. To agar hum dekhenge yeh jo dislocation hai to Glide Loop to is slip plane mein move ho sakta hai kyunki dono tangent vector aur Burgers vector ek hi plane mein par is case mein is tarah se nahi hai. Agar mujhe dislocation ko move karna hai to yeh Edge nature ho gaya yahan par already to ye jo movement hogi dislocation ki yeh is kuch is tarah se cylinder par hogi cylinder ke surface ke around hi hogi yani yeh dislocation is is tarah move hoga up move hoga to yeh jo hai isko main keh sakta hoon Prism isliye isko Prismatic Loop kehte hain aur yeh taiyar hota hai yeh kab taiyar hota hai yeh taiyar hota hai jab koi Face Centered Cubic material ya Close Pack material jab hote hain inko main sudden quench karta hoon quench karta hoon yani main high temperature par gaya aur bahut

high cooling rate se usko room temperature par laya sub-zero temperature par laya usko us process ko main Quenching kehta hoon yani mere paas cooling jo rate hai woh bahut high hota hai tab kya hota hai jo high temperature par vacancies bani hoti hai woh ek loop taiyar karegi ya woh collapse karegi vacancy loops kaise taiyar hote hain aur mostly inka nature Prismatic hota hai Close Pack structure.

To humne dekha yahan par ki dislocation free surface pe end honge grain boundaries pe end honge aur khud pe end honge. Abhi hum jante hain dislocation kisi aur dislocation pe jab end hote hain usko hum kehte hain Nodes.

Geometrical Properties of Dislocations

Dislocation must end at

- Free surface
- Grain Boundaries
- Other dislocations (Nodes)
- On itself (Loop)

Dislocation loop

Dislocation ending on itself

b magnitude & direction invariant
 b \perp same slip plane
of edge loop

Grain Grain Boundaries

Edge nature
 $\hat{e} \perp \hat{b}$
edge

Vacancy loop in closed packed structure
Forms during quenching

To ek Frank Rule hai jiske baare mein hum discuss karenge. To jab dislocation ek dusre ke upar end hote hain tab hum yeh Frank Rule ko apply kar sakte hain. Maan lete hain mere paas dislocation lines hai yani ye different tangent vectors dikhaye yahan pe dislocations ke to ye jab ek dusre ko mil rahe ye point jo hai isko hum kehte hain Node. To yeh jo node hai par jab hum ye tangent vector ki baat karenge to node pe kya hota hai ye jo tangent vector hai ye ek to node ki taraf point karenge ya node se opposite taraf point karenge yani ek to node ki taraf rahenge ya away from node rahenge. To yeh jo tangent vector hai saare tangent vector hai yani teen dislocation hai red black aur blue jo maine mark kiye yahan pe aap dekhenge inke tangent vector ek to is taraf aayenge nahi to away from the node honge to yeh property hai mere node ki jab mere dislocation ek dusre ke upar end hote hain.

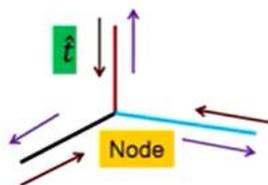
Abhi ye case consider karte hain mere paas ya ek node hai yahan par pe aur ye dislocations ek dusre ke upar end ho rahe hain maan lete hain inke tangent vector kuch is tarah se yani node ke upar jaake end ho rahe hain yani towards node hai ye. To maan lete hain ye jo region hai mera crystal ka yani slip plane ka ye yahan pe koi slip nahi hai yahan pe koi deformation nahi hai iska matlab par jab main ye dislocation ko cross karunga to yahan pe kuch displacements honge aur ya deformation ho gaya yani hum baat karte hain jab dislocation kisko bifurcate karta hai slip aur no slip region ko to yeh yahan pe kuch deformation hogi to yeh mera ho gaya slip region aur jab main ye dislocation ki baat kar raha hoon tab yahan se main is region mein jaana chahta hoon to yahan

se agar main is region ki taraf ja raha hoon to yahan se ek dusra deformation yani dusra displacement hoga jisko main b_2 ke naam se yani dono ka magnitude alag hai yahan pe displacements ka to maine ek slipped yani ek deformed region se dusre deformed region mein ja raha hoon par yahan pe jo degree of deformation hai ya displacement hai woh alag honge is case mein to ek slip part hai aur ek yahan par ek dusra slip part hai isko main slip 2 ka naam de raha hoon. Phir yahan se main agar main yahan se yahan ja raha hoon aap dekhenge ki same slip plane hai aur yahan par ek dislocation hai to yahan se jab main aa raha hoon to yahan pe ek slip hai to humne dekha tha ki dislocation bifurcate karta hai slip aur no slip region mein ya different slip regions mein to yahan se jab main aaunga to mera jo yahan par displacement hoga woh shunya ho jana chahiye jab main b_3 ko add karunga to yahan par mujhe koi deformation nahi milna chahiye yahan par no slip hona chahiye.

To ab janenge ki jab node is tarah se hai to at a node main is tarah se likh paunga jo displacement ki baat karunga to main $b_1 + b_2 + b_3$ ko jab add karunga to mujhe displacement shunya milne chahiye. To yahan se shuruat ki maine aur yahan pe end ho raha hoon no slip pe to main kuch is tarah se likh paunga yeh relation likh paunga. Maan lete maine yahan se bhi shuruat ki yahan par gaya to b_2 aur b_3 yahan par deformation nahi mila aur mujhe phir se is displacement tak wapas aana hai to mujhe b_1 add karna padega. To yeh jo rule hai node pe The Sum of the Burgers Vectors at the Node should be equal to Zero to isko kehte hain hum Frank's Rule yani summation of all the Burgers vectors at node ye important hai at the node should be equal to zero. To humne dekha ki dislocation khud ke upar jab end hote to loop hota hai par jab dusron ke upar end hote hain usko hum node kehte hain. To yeh to maine abhi 2D mein dikhaya aap isko imagine kar sakte ki 3D mein isko visualize kar sakte ki 3D mein kya ho sakta hai. Yahan par simple cases maine dikhayi hai ki simple cases teen vectors ke saath maine dikhayi yahan par multiple vectors bhi ho sakte hain node par bahut saare dislocation intersects ho sakte yahan pe par yeh jo points hai aapko yaad rakhne hain.

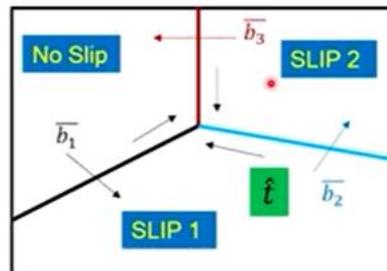
 **Frank's rule**

Dislocation ending on other dislocation



Either all $\hat{\tau}$ pointing towards the node or away from the node

Here it is 2D
Visualize in 3D



$$\bar{b}_1 + \bar{b}_2 + \bar{b}_3 = 0$$

Sum of the burgers vector at the Node = 0

Frank's Rule $\sum \bar{b}_i = 0$

To abhi main main summarize karna chahta hoon is lecture ko to humne yahan pe disclinations ke baare mein dekha jo hum padhenge nahi is course mein par ek introduction ke liye dekha tha disclinations aur humne dislocations ke geometric properties dekhi. To humne dekha ki dislocation kahan end ho sakte hain. Dislocation end hota hai free surface pe grain boundaries pe ya main interface ki baat kar sakta hoon grain boundary ya interface okay ya phase boundaries koi bhi boundary hogi wahan par dislocation end ho sakte hai. Khud ke upar on self so isko hum kehte hain Loop aur on other dislocations isko hum kehte hain Node. To humne ye property isliye dekhi hai kyunki jab dislocation ki movements ki baat karenge tab humein ye properties yaad rakhni hai. To abhi ke liye yahan pe rukta hoon next part se hum janenge ki jab dislocation move hoga to kya amount of plastic strain develop ho sakta hai material mein. Dhanyavad.