Mechanical behavior of materials

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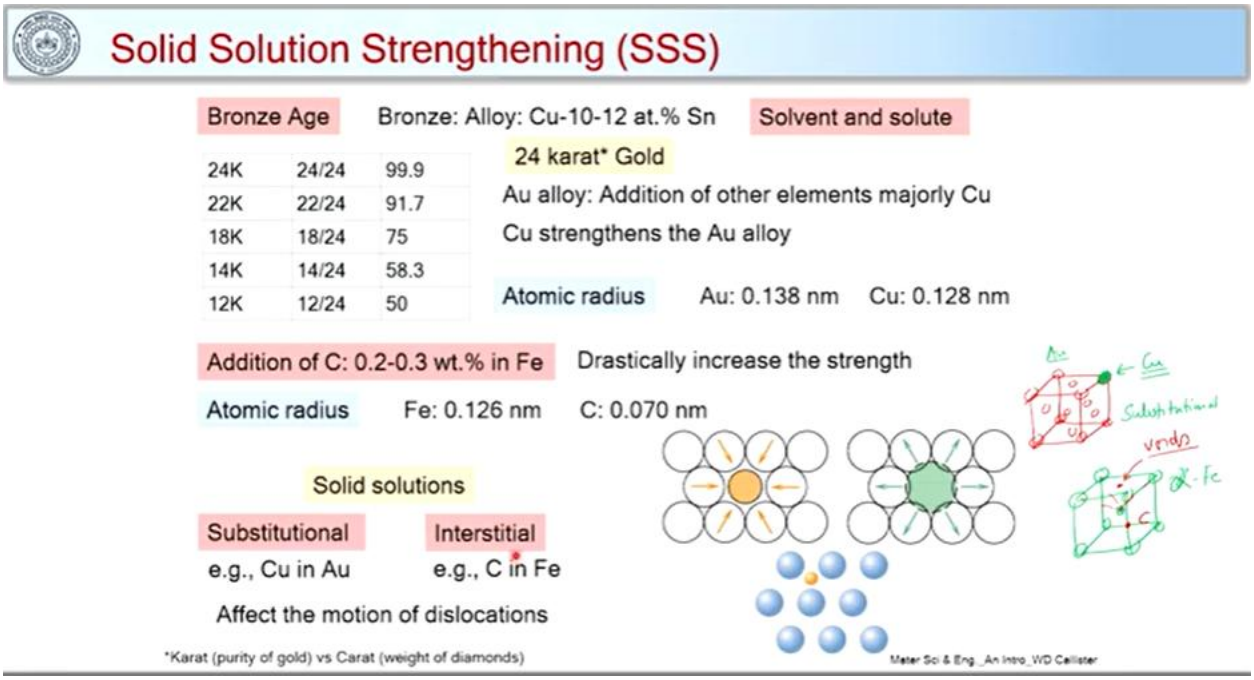
Solid Solution Strengthening

Namaskar phir se swagat karta hoon aapka is course mein mechanical behavior of material jo ki hum hindi mein padhenge last part tak humne strain hardening ke baare mein padha is part se hum jaanenge ki strength kis tarah se badhayi jaati hai jab hum solid solution strengthening ki baat karte hain agar aap solid solution ki baat karenge to solid solution main ek acche example se bata sakta hoon aapko kyunki humne dekha tha ki kuch yugon ke naam ek material par rakhe the jiska naam tha Bronze Age to humne bataya tha ki bronze ek alloy hota hai copper tin aur 10 se 12 percent atomic percent jo hota hai woh tin rehta hai usmein yeh ek alloy hai copper ka to aap dekhenge ki ye jo alloy hai bronze ismein jab main tin daalta hoon to copper ki jo strength hai wo badh jaati hai to tin ke daalne se aisa kya ho raha hai material mein jiske wajah se meri strength badhti hai yahi hum jaanenge solid solution strengthening ke dwara to yahan pe hum dekhenge ki jo mera copper hai wo solvent hai aur tin jo hai yahan pe solute karke act kar raha hai yaani solvent jo hota hai wo solute ko dissolve karta hai apne andar to yahan pe solute aur solvent ki concept aati hai solid solution strengthening mein to aur ek accha example hum dekh sakte ki jab hum 24 karat

gold ki baat karte hain to yahan par hum dekhenge ki 24 karat yaani mera 100 percent ya close to 99.9 percent jo hai wo mera gold hai to agar main baat karunga jaise 12 percent 12 karat ki to aap dekhenge ki yahan par 50 percent jo hai woh mera gold hai aur baaki jo 50 percent hoga uske andar woh dusra alloying elements hoga to jaise jaise mera karat kam ho raha hai gold ka us tarah se meri purity of gold kam ho rahi hai to jab main jewelry bana raha hoon tab hum jo sona jo hai usko ya gold jo hai 24 karat jo gold hai woh bahut ductile ya bahut delicate hota hai usko strong banane ke liye hum copper ka addition karte hain to 18 karat gold mein aap dekhenge ki yahan pe 3 percent yaani 75 percent sirf gold hai baaki jo other percent hoga wo copper ka hoga yaani 75 25 percent mera copper hoga to is tarah se main gold ki strength ke saath variation kar sakta hoon to yahan par humne yeh gold ke baare mein dekha to yahan par aap dekh rahe honge ki jaise jaise main copper daal raha hoon gold mein meri strength gold ki badhegi to yahan pe hum ek aur cheez dekh sakte ki strength kyun badhti hai to yahan par aap dekhenge ki main jab atomic radius ki baat karunga to aap dekh rahe honge ki jahan par gold hai aur copper hai yahan par gold ki radius hai 0.138 nanometer aur copper ki radius hai 0.128 nanometer to jab main solute aur solvent ki jab baat kar raha hoon tab aap dekhenge ki jo solute hai iski jo radius hai ya atomic radius hai wo solvent se alag hogi par is case mein jab hum baat karenge to solid solution ki baat karenge to yahan par copper aur gold ki jo atomic radius hai wo itni bhi different nahi hai abhi kuch aur example dete hain jaise ki hum dekhte ki steels mein to hum wahan pe carbon add karte hain jahan pe 0.2 to 0.3 weight percent carbon hota hai iron mein jo ki drastically change kar deta hai mere iron ke properties ko mechanical properties ko yaani strength ko ye bhi humne dekha tha aur jab yahan pe hum atomic radius ki baat karenge to yahan pe iron ki atomic radius hai 0.126 nanometer aur carbon ki jo hai wo hai 0.07 nanometers to yahan pe aap dekhenge ki dono ke atomic radius mein kaafi antar hai to jab main solid solution ki baat karunga to yahan pe do concept hum dekh sakte hain ki jab atomic radius mein jyada variation nahi hai to ek type ka solid solution banta hai aur atomic radius mein bahut difference hai tab dusre type ka solid solution banta hai to aap dekhenge ki jab atomic radius mein jyada difference nahi hai jaise aap dekhenge yahan pe yeh solvent hai aur solid atom hai yeh smaller hai par in dono ke atomic radius mein itna antar nahi hai yahan par aap dekhenge ki yeh solvent hai white aur green color ka hai yeh solute hai par atomic radius thodi badi hai to kuch is tarah se hum dekhenge solid solution form ho rahe hain inko kehte hum Substitutional Solid Solution aur yeh jo case hai jahan par aap dekhenge ki yeh jo solvent hai solvent jo hai blue color ka aur yeh jo void hai yahan par solvents ke beech mein yahan par mera solute atoms ja rahe hai jaise ki hum dekhenge ki carbon ja raha hai yeh kuch voids ke andar yeh jo solid solution banta hai inko kehte hain hum Interstitial Solid Solution to main do type ke solid solution yahan par likh sakta hoon substitutional solid solution aur interstitial solid solution.

To substitutional solid solution mein kya hota hai isko aasaani se is tarah se samjhenge agar mere paas jaise main maan leta hoon ki gold hai gold ke andar main gold mera FCC hai to main yahan par kuch atoms mark kar raha hoon aur face centers pe kuch atoms mark karunga gold ke to aap dekhenge ki is yahan pe ye gold ke jo atoms hai wo replace honge mere kuch atoms jo hai agar main yahan pe copper agar add kar raha hoon yahan pe gold ki baat kar raha hoon to Au likhunga Ag silver hota hai copper copper kya karega agar dono ki radius same hai gold aur copper ki lagbhag same hai to kuch atoms hai yahan par inko substitute karega yeh mera copper atom hai yeh substitute karega yahan par main dekhunga yeh red jo hai wo mere gold atoms hai aur copper atoms ye substitute karenge isliye inko kehte hain substitutional solid solution agar main steel ki baat karunga maan lete mere paas BCC structure hai yahan par to yaani alpha iron hai alpha iron BCC structure alpha iron alpha iron mein main dekhunga ki carbon ismein color change kar lete

hain carbon kuch interstitial voids pe jayega jahan par yahan par agar dekhenge kuch is tarah se interstitial void main yahan par draw kar raha hoon is surface ke yahan par to ya yahan par ja sakta hai edge ke centers pe carbon mera ja raha hai yeh mere interstitial voids hai isliye in solid solutions ko hum kahenge interstitial solid solution ye isliye ho raha hai kyunki atomic radius jo hai dono solvent aur solute ki yeh inmein agar jyada antar hai to humein interstitial solid solution mil sakte hain aur jyada difference nahi hai tab hum substitutional solid solution milte hain to yahan par hum dekhenge substitutional solid solution mein copper in gold aur interstitial mein dekhenge carbon in iron to yeh jo hai dono solid solution jab hum strength ki baat kar rahe to yeh dono solid solution affect karte hain mere dislocation ki motions ko isko hum acche se samjhenge is part mein ya iske aane wale parts mein.



To hum dekhenge jab solute atoms mere dislocation ke saath kis tarah se interact karte hain to kuch kuch interactions hai to pehla interaction hai jo hai Elastic Interaction elastic interaction mein hum dekhenge ki jo mere solute atom hai ya solute atom jab solvent atoms solvent ke crystal mein jaate hain to kuch distortion taiyaar karte hain to kuch stress field taiyaar karenge apne around aur wo jo stress field hai elastic stress field hai wo interact karegi mere dislocation ke stress field se aur uske wajah se ek dusre ke upar woh ek force act karenge us force se hi hamari elastic interaction result honge aur hamari strength badhegi to ye hum ye bhi hum dekhenge acche se is part mein dusra hai Modulus Interaction modulus interaction jab hota hai jab solute aur solvent atoms ke jo elastic modulus hai elastic constants mein bahut difference hota hai tab hum dekhenge ki modulus interactions bhi hota hai ek Electrical Interactions hai electrical interaction aap samajh paa rahe honge ki yahan par kuch electrostatic interactions hoti hai agar mere paas kuch ionic solids hai ionic crystals hai to unmein jo atoms rahenge ya hum kahenge cations ya anions rahenge wo interact karenge solute atoms ke saath aur dono ke beech mein kuch electrostatic interaction hoga isko hum kehte hain electrical interaction chautha hai Chemical Interaction yeh hota hai jab kuch chemical potential ya chemical concentration alag hai mere material mein kuch defects pe aap dekhenge jaise ki kuch defects hum stacking faults ya dislocation ispe agar segregation ho raha mere solute atoms ka to aap dekhenge ki matrix ke se jyada is defects pe solute concentration badh

jayega to ek humein chemical interaction is tarah se milta hai to aur yeh jo segregation hai yeh hamare strength ko badhate hain.

To hum pehle start karte hain elastic interactions se to hum ek simple example lenge ki elastic interactions kis tarah se ho sakte hain to maan lete hain mere paas ek FCC structure hai aur ek BCC structure hai jab main FCC structure ki baat kar raha hoon tab mere paas atoms hai corners pe is tarah se cube ke aur kuch atoms hai mere face centers pe to is tarah se mera FCC structure hai aur BCC structure agar main dekhunga to mere paas atoms se corners pe aur ek atom hai mera body centered pe to ye jo black color ke atoms yahan pe dikhaye ye mere solvent ke atoms hai abhi hum baat karenge ismein elastic interaction kis tarah se hote hai to main jab FCC structure yahan pe consider kar raha hoon tab tab main consider karunga ki ye alpha iron hai aur ye jo hai wo gamma iron hai yaani austenite hai ye ek simple do structure main consider kar sakta hoon aur is structure ko consider karke main ek concept explain karunga abhi hum dekhenge ki yahan par alpha iron aur gamma iron mein jab main carbon daalta hoon humne dekha tha ki carbon ki atomic radius bahut kam thi 0.07 thi to abhi hum dekhenge ki yeh jo carbon hai yeh kuch interstitial voids mein jaate hain to yahan pe in dono case mein alpha iron ho ya ferrite ho ya austenite ho ya gamma iron ho in dono case mein yeh jo carbon jaata hai yeh jaata hai Octahedral Void pe to yahan pe kuch octahedral void hum mark kar lete hain jaise ki main face centered cubic pe mark kar raha hoon yahan pe to aap dekhenge ki ye jo yeh jo agar main face center se yahan ke kuch is tarah se join kar lu to mujhe ek octahedron milega aur woh octahedron ka jo center hoga yahan pe agar dekhenge jo octa yahan par maine ek octahedron mark kar liya kuch is tarah se face centers mark karke to ye jo atom hai yeh mera carbon atom hai aur carbon atom is octahedral void mein jayega to to aur BCC ke case mein aap dekhenge main octahedron kuch is tarah se mark kar raha hoon agar main yeh face consider kar raha hoon top wala aur do body centered atoms consider kar raha hoon yahan pe ye body centered atom hai aur ye jo atom hai ye iske upar wala jo unit cell hoga iska body centered atom hai to agar main in do body centered atoms ko is face ke atoms ke saath connect karta hoon to mujhe ek octahedral void milega aur uska jo center rahega yahan pe yeh rahega mera octahedral void BCC ke case mein to yahan pe mera carbon atom jayega to main FCC ke case mein yahan pe aur kahan pe octahedral voids hai wo maine mark kiye yahan pe aap dekh

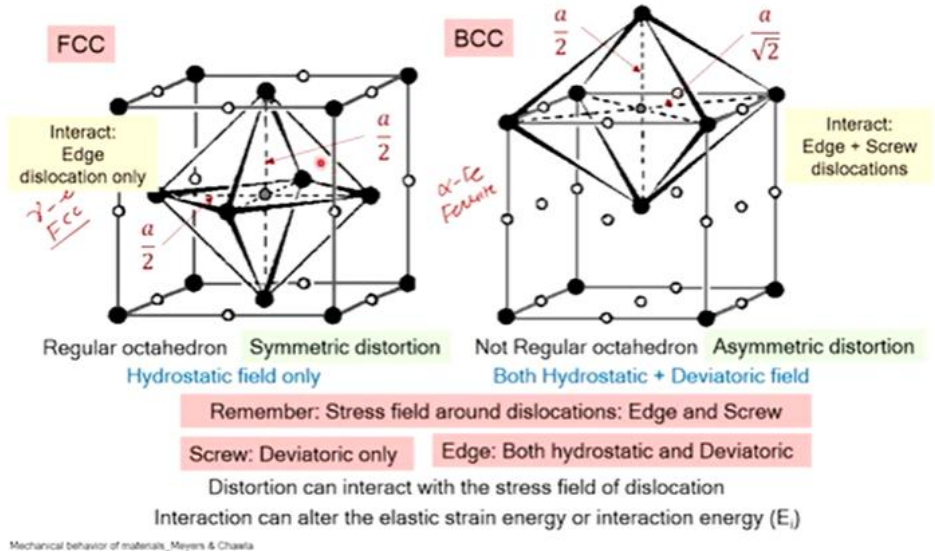
paa rahe honge ki yeh jo edge centers hai yahan pe aur octahedral voids main mark kar sakta hoon yahan pe bhi aap dekh paa rahe honge ki main octahedral voids kuch is centers pe aur yahan pe face center pe mark kiya to yahan pe face centers pe bhi mere octahedral voids honge to is tarah se carbon atom mera octahedral voids mein jaata hai dono case mein gamma iron aur alpha iron yahan par maine galti kar li yeh jo BCC hai yeh main alpha iron kahunga to yeh hai mera ferrite kyunki ye BCC structure hai aur yeh hai gamma iron yeh alpha iron hai isko gamma iron karte ye hai FCC structure ye hai mera austenite to mere FCC aur BCC ke is case mein dono case mein aap dekh paa rahe honge ki gamma iron aur alpha iron mein carbon jo jaata hai wo octahedral voids mein jaata hai.

To abhi dekhte hain ki yeh octahedral void kis tarah se inke dimensions kya hai to agar main yahan se distance consider karu center se yaani octahedral void ke jo center hai yahan se isse yeh center tak face center tak ye distance hoga mera $a/2$ similarly yeh jo distance hoga yeh bhi mera $a/2$ hoga aur yahan se yeh distance jo hoga is atoms ka ye bhi $a/2$ hoga aur ye bhi $a/2$ hona chahiye aur ye bhi $a/2$ hona chahiye to main dekhunga ki mere paas ye jo dimensions hai saare $a/2$ hai yeh saare dimensions yahan pe $a/2$ hai to is case mein BCC ke case mein hum dekhenge yeh jo distance hai yahan se body centered atom tak ka yeh hai mera $a/2$ par aap jab yeh distance yahan se ya yeh distance ye jo atoms hai is face pe atoms jo hai yahan par distance aap dekhenge yeh jo distance hai yeh hai mera $a/\sqrt{2}$ To aap dekhenge ki yeh jo distance hai aur yeh jo distance hai dono distance alag-alag hai to aap dekh paa rahe honge ki yahan par jo octahedron void hai ya yeh jo hai yeh mujhe regular octahedron mil raha hai yahan par aur yahan pe mujhe non-regular octahedron mil raha hai aur uske wajah se kuch cheezein hongi woh abhi hum dekhenge agar mera carbon atom is octahedron mein jaata hai to aap dekhenge ki is carbon atom ka distance jo hai saare atoms se lagbhag same hai jo ki $a/2$ hai par is case mein agar carbon atom jaata hai to aap dekhenge ki yeh jo distance hai yeh $a/2$ hai aur yeh jo distance hai yeh $a/\sqrt{2}$ Hai to aap dekhenge ki yeh jo atoms hai woh kuch dusre doori par hai aur yeh jo atoms hai yeh kuch aur dusre doori par hai to yaani yeh jo atoms hai yahan ke aur yahan ka jo distance hai yaani jo body centered ka aur yahan ka distance hai ye alag hai aur is face pe jo atoms hai inmein jo distance hai wo alag hai to agar carbon atom yahan pe jayega is case mein non-regular octahedron mein yaani BCC ke case mein to aap dekhenge ki ye carbon atom alag tarah se push karega is atom ko aur is atom ko aur in charon atoms ko alag tarah se push karega jabki agar FCC ke case mein agar ye carbon atom is yahan par jaata hai to aap dekhenge ki yeh jo carbon atom hai in charon jo ya is face pe hai in charon atoms ko equally aur in dono atoms ko bhi equally displace karega ya move karega to hum dekhenge yahan pe mujhe symmetric distortion milega FCC ke case mein BCC ke case mein mujhe milta hai asymmetric distortion to agar mere paas symmetric distortion hai to mere paas kaun si field honi chahiye mere paas hydrostatic field taiyaar hogi aur jab mere paas asymmetric distortion hota hai tab aap dekhenge ki mere paas hydrostatic plus deviatoric stress field hogi to aap dekhenge ki ek carbon atom jaake yahan pe jab distortion hoga wo distortion field jo taiyaar hogi wo symmetric hogi aur symmetric field main hydrostatic field se represent kar sakta hoon aur asymmetric field main hydrostatic aur deviatoric stress field se explain kar sakta hoon to ab hum yaad karenge ki jab humne edge aur screw dislocations ki baat ki thi to unke around bhi kuch stress field hoti hai to kaun si stress field hoti hai yahan par hum dekhenge ki mere paas screw jab rehta hai tab mere paas sirf deviatoric stress field rehti hai aur edge jab dislocation rehta hai to mere paas dono stress field rehte hydrostatic aur deviatoric ye humne acche se padha tha to ab aap dekhenge yahan par agar mere paas sirf hydrostatic stress field hai aur yahan par mere paas dono stress field hai hydrostatic plus deviatoric stress field to BCC ke case mein ye jo carbon atom hai

wo dono dislocation ke saath interact karega screw ke saath aur edge ke saath is case mein waise nahi hoga to aap dekhenge ki distortion ke wajah se ek stress field taiyaar hogi aur is stress field ke wajah se mere jo edge dislocation hai aur screw dislocation hai wo mere BCC ke case mein is carbon atom ke saath interact karenge to ye hum jaan sakte hain ki meri interaction energy jo hogi wo elastic strain energy aur interaction energy par depend karenge ye term abhi ke liye aap samajh lijiye ye hum aage jaake bhi padhenge iske baare mein elastic strain energy aur interaction energy kya hoti hai solute atoms aur dislocations ke saath ya defects ke saath to ye yahan pe ek hum dekhenge yahan par is case mein FCC ke case mein austenite ke case mein is case mein hum dekhenge ki yeh jo dislocation hai woh sirf edge dislocation yahan par interact karega kyunki yahan par hi hydrostatic stress field hai aur mere paas edge dislocation ke paas hi hydrostatic stress field hai to yahan par sirf jo carbon atom hai wo interact karega edge dislocation ke saath par is case mein mere paas dono dislocations hai jo interact kare karenge aur iske wajah se kya hota hai aapko agar yeh question hai ki agar carbon alpha iron mein ja raha hai aur gamma iron mein ja raha hai to kismein jyada strengthening dega to hum yeh bol sakte hain confidently ki wo BCC ke case mein mujhe jyada strengthening dega aur yeh practically bhi observed hai ki hum jab jaise carbon alpha iron mein daalte hain to mujhe strength acche se milti hai aur gamma iron mein jab daale daalte carbon to mujhe jo strength milti hai itni improvement nahi milti jitni mujhe BCC mein milti hai aur isko hum jaan sakte hain elastic strain energy aur interaction energy ke dwara to ye ho gaya mera solid solution strengthening aur ye jo ho gaye ye elastic interactions elastic interactions yaani kis tarah se elastic interactions kyunki ye jo carbon atom hai ya solute atom hai yahan pe jo ki interstitial atom hai yahan pe interstitial solid solution hai dono case mein ye jaata hai mere octahedral void pe FCC ke case mein wo symmetric distortion karta hai BCC ke case mein wo asymmetric distortion karta hai symmetric distortion ke wajah se mere paas hydrostatic stress field taiyaar hogi aur asymmetric case ke wajah se mere paas hydrostatic aur deviatoric stress field taiyaar hogi aur iske wajah se is case mein FCC ke case mein mere paas sirf edge dislocation interact karenge is stress field ke saath aur is case mein BCC ke case mein mere paas jo ye jo hydrostatic aur deviatoric stress field hai distortion ki wajah se wo interact karegi edge aur screw dislocation ke saath to isliye mujhe yahan par strength jyada milegi BCC ke case mein as compared to FCC ke case mein aur yeh ho gaya mera elastic interactions solute atoms ke saath

SSS: Elastic interactions

Why does C show more strengthening in $\alpha - Fe$ as compared to $\gamma - Fe$?



Remember: Stress field around dislocations: Edge and Screw

Screw: Deviatoric only

Edge: Both hydrostatic and Deviatoric

Distortion can interact with the stress field of dislocation

Interaction can alter the elastic strain energy or interaction energy (E_i)

Mechanical behavior of materials_Meyers & Chawla

Isko hum aur acche se jaanenge agle part mein abhi ke liye yahan par rukta hoon dhanyavad