

**Mechanical behavior of materials**

**Dr Niraj Mohan Chawake**

**Department of Materials Science and Engineering**

**Indian Institute of Technology, Kanpur**

**Week-12**

**Lecture-62**

**Fracture & Theoretical Cohesive Strength of Materials**

Course Title

**Mechanical Behavior of Materials (Hindi)**

Lecture-61  
**Impact Testing of Materials**

Namaskar phir se swagat karta hoon aapka is course mein Mechanical Behavior of Materials jo ki hum Hindi mein padhenge. Last part mein humne Hardness Testing ke baare mein jaana. Is part mein hum Impact Testing ke baare mein jaanenge. Impact testing thoda different hai aap is tarah se samajh sakte hain ki hum roz kisi cup mein chai peete hain wo ceramic ka bana hua hai agar main us cup ko force karunga apne hathon mein dabane ki koshish karunga to aap dekhenge ki us cup ko aap tod nahi payenge par usi cup ko main kisi height se neeche zameen par daal dunga to cup disintegrate hoga toot jayega to wahi

jahan par main haath se dabane ki koshish kar raha hoon to wo cup tootega nahi par wahi cup main agar zameen par daal dunga to toot jayega to jahan par wo tootega wahan par ek impact hoga aur is impact loading ke wajah se material disintegrate hoga fail ho jayega to isi testing ko hi hum kehte hain Impact Testing to material disintegrate hota hai ya break hota hai jab material kuch impact load sustain karta hai ya experience karta hai to aaiye jaante hain Impact Testing ke baare mein is part mein to Impact Testing kyun important hai to abhi ek jo example diya humne ki cup jaldi toot jayega just impact ki wajah se usi tarah se

agar main kuch examples yahan par doon history se to aap dekhenge ki Titanic bhi ek impact kiya tha ek iceberg ko aur uske wajah se is jahaz mein crack aa gayi thi aur yeh jahaz doob gaya tha. Similar example hum Liberty Ship ka dekh sakte yahan par aap dekhenge ki material sudden break hua tha par yeh jo Liberty ship thi yeh kisi ko impact nahi hui thi yeh sudden break yahan par hua tha kyunki yahan par kuch cracks already ya defect already present the

aur yeh jo ships operate kar rahi thi yeh sub-zero temperature par operate kar rahi thi yani cold conditions mein operate kar rahi thi to ab dekhenge ki agar hum Indian context mein baat karenge to yeh achi case study hai



## Why Impact Testing?



Titanic

Sank in the North Atlantic Ocean due to impact on iceberg



Liberty ships, WW II

Sudden Hull and deck cracks

- Shock-induced failure of cannon barrels in the sub-Himalayan environments
- Materials that normally **ductile and tough at ambient temperature suffer brittle failure when exposed to sudden impact**, especially below some critical temperature known as ductile to brittle transition temperature (DBTT)
- Catastrophic structural failure

Britannica.com  
Google images

Images are for educational and teaching purpose only

392

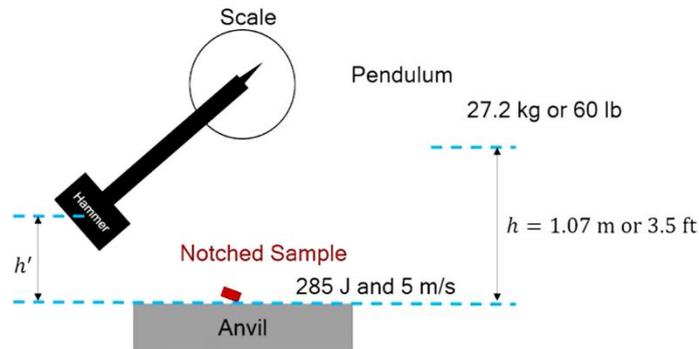
jahan par hum dekhenge ki cannon barrels ke jo failure hai sub-Himalayan environment mein wo shock induce ke wajah se fail hote hain normal condition mein normal temperature mein yeh cannon barrels fail nahi hote par aap dekhenge ki jaise hi main temperature ghata raha hoon to yahan par material fail hoga to ek yahan par main bindu yahan par mention karna chahta hoon jaise material kuch ductile ya tough rehte hain ambient temperature pe wo brittle failure dikhate hain jab sudden impact hota hai ya aap dekhenge ek temperature critical temperature main yahan pe define kar sakta hoon aur usko main kehta hoon Ductile to Brittle Transition Temperature isko main DBDT se sambodhit karunga yeh kyun important hota hai

jaise main agar impact testing ki baat karunga to ye important isliye hota hai kyunki material catastrophically fail hota hai yani material without any indication sudden fail hota hai aur wo hum nahi chahte kisi bhi application mein abhi dekhte hain ki impact testing kis tarah se ki jaati hai material pe to yahan par do standard techniques hum istemal karte hain ek Charpy aur Izod test. Yeh jo Charpy aur Izod impact testing hoti hai wo sirf sample ke placement ke upar hum differentiate karte hain wo hum baad mein dekhenge par is impact test ko carry karne ke liye humein ek sample chahiye jis par notch hogi aur wo



## Impact Tests: Charpy & Izod

Called as "Notch toughness"



The energy absorption, computed from the difference between  $h$  and  $h'$

$$\text{Impact toughness} = m \cdot g (h - h') \quad \text{Units: J or J/m}^2$$

393

notch fail karegi us notch ke taraf hum failure karenge jab us sample ko hum fix karenge anvil mein aur hum kya karte ek pendulum lete jo ek certain height par humne rok ke rakha hai aur uska weight hota hai lagbhag 27–28 kg aur yeh jo scale hai yahan par yeh scale darshayegi kitna yeh jo material hai ya sample hai kitna ek impact sehan kar payega kitna impact leta hai aur uska measurement kuch hum is tarah se karte hain aur usko hum kehte hain Notch Toughness to jo toughness value yahan par scale par humein milegi usko hum kahenge Notch Toughness kyunki jo sample hai yeh already notch hai iske baare mein hum dekhenge ki sample ki

geometry kis tarah se hoti hai next PPT mein to yeh jo hammer hota hai ek height par rok ke rakha rehta hai aur yeh height hoti hai lagbhag 1.07 m aur jab yeh hum hammer chodenge release karenge to yeh hammer jaake is notched sample ko takrayega ya impact karega aur uske wajah se yeh notched sample break hoga jab yeh notched sample break hoga to aap dekhenge ki agar yeh brittle way se break ho raha hai to yeh zyada energy absorb nahi kar payega aur uske wajah se yeh hammer is direction mein move hoga aur ye jo final height hai wo hum yahan par measure karte aur wo final height jitni jayegi wo scale ke

dwara hum quantify kar sakte hain kuch is tarah se yeh hammer maine hit kiya sample yahan par break hua aur abhi hum dekhenge agar hum isko phir se dekhenge to main phir se release karunga aur yeh hammer yahan par hit hoke is sample ko break karega aur yeh final height  $H'$  yeh yahan par maine mark ki hai aur in dono height ka difference mujhe kitni energy absorb

hui is sample ko fail hone mein yeh darshayegi is point of contact pe yeh jo hammer hai ya pendulum hai uski energy hoti hai lagbhag close to 285 J aur uski velocity hoti hai 5 m/s yahan par hum dekhte hain ki jo jo energy absorbed hui hai wo hum compute

karenge in dono ke difference ke beech kuch is tarah se isko main kehta hoon impact toughness aur yeh main calculate karunga  $mg(H - H')$  actually jo value hai wo ek energy difference to ab dekhenge ki jitni  $H'$  ki value kam utni meri impact toughness zyada yani iska matlab kya hai ki jaise main yeh hammer yahan par impact hoga agar yeh jo sample hai is impact ki wajah se is sample break hone mein jitni zyada energy lagegi utni is hammer ki energy yahan par kam ho jayegi aur yeh height yahan par aapko kam milegi agar yeh jo sample hai break hone mein kam energy le raha hai to utna hi yeh hammer zyada aage swing karega aur yeh height  $H'$  yahan par badhegi to yeh jo sample break ho

raha hai agar ye brittle way se break ho raha hai to isko kam energy chahiye yani catastrophically agar break ho raha hai to isko kam energy chahiye to ye height of pendulum aapko zyada milega ya height yeh final height aapko badi milegi agar yeh plastically deform ho raha hai yani energy absorb karega is hammer ki to ye jo final height hai yeh aapko kam mile aur is tarah se hum material ka impact toughness determine karte hain to jab main impact test ki baat karunga to maine Charpy aur Izod ki baat ki thi to iske liye hum ek standard dimension sample istemal karte hain aur dimension samples ke kuch is tarah se mark kiye yahan

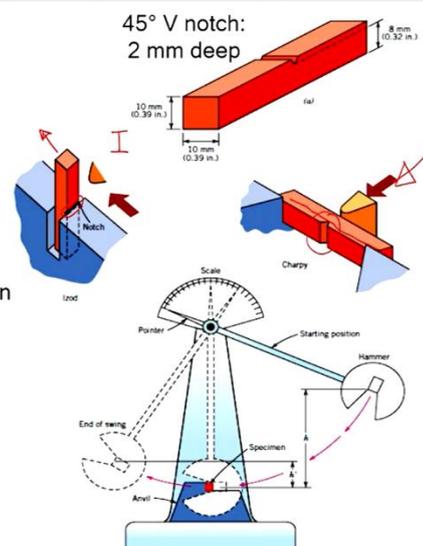


## Impact energy tests: Charpy & Izod

- Standard dimension sample
- Notch: acts as a point of stress concentration
- Charpy: India, Russia, Europe, USA
- Izod: UK
- Charpy is widely used
- Izod is rarely used
- Notch:
  - Triaxial state of stress & increases stress concentration
  - Suppresses any plastic flow by shear
- Easy to evaluate the influence of
  - Alloying elements, heat treatments, cold rolling etc.

### Ductile to Brittle Transition Temperature (DBTT)

Charpy impact energy,  $C_v$  or  $CVN$



par aap dekhenge ki iska cross section  $10 \times 10$  mm ka hai aur yahan par aap dekhenge yeh jo V-notch hai yahan pe yeh 2 mm deep hai is surface se aur yeh jo dekhenge yeh  $45^\circ$  notch ek standard specimen hum yahan pe istemal karte hain yahi specimen hum istemal karte hain dono test mein Charpy aur Izod ke liye par aur ek hi setup yahan par hum istemal karte hain Charpy aur Izod ke liye sirf difference yeh hai ki ye jo sample hai iski position kya hai aap dekhenge ki kuch is tarah se hai aur yahan par yeh jo impact ho raha hai kuch is direction mein ho raha hai isko mark kar lete hain agar main sample

ki sample par impact ho raha hai to kuch is direction mein ho raha hai aur notch yahan par yahan par present hai to main is tarah se samajhta hoon aur is tarah se remember karta hoon Izod mein sample aapka 'I' ki tarah khada rehta hai Charpy mein aap dekhenge yeh jo Charpy sample hai yahan par crack is direction mein aur iske opposite direction se impact hota hai to isko hum kehte hain Charpy test sirf hamare position sample ke alag alag hai to notch jo hai yahan par humne mark kiye  $45^\circ$  V-notch to yeh act karta hai stress concentration ki tarah humne dekha tha ki jab hum fracture padhe the tab ye cracks hamesha stress concentration ki tarah act hota hai hum ki material sirf isi region mein

fail ho jahan par crack present hai to isliye yeh standard crack ya standard notch hum yahan par introduce karte hain jo Charpy test hai wo India, Russia, Europe aur USA mein famous hai Izod jo hai wo UK mein zyada istemal karte hain Charpy jo test hai wo widely use hoti hai Izod rarely use hoti hai yeh kuch historical reason ki wajah se to abhi hum dekhte hain ki yeh jo notch hai yeh ek triaxial state of stress yahan pe create karegi just crack ke saamne aur hum dekhenge ki yeh jo triaxial state of stress hai yeh increase karegi stress concentration ko aur yeh ek koi bhi plastic flow ko suppress karegi ya shear flow ko suppress karegi yeh

isliye important hai ki humne dekha tha ki material catastrophically fail hota hai to hum yeh jaanna chahte hain ki jab koi flow present hai material mein to material kis tarah se energy absorb karta hai impact testing ke waqt hum dekhte hain ki yeh jo hai impact energy jo absorb hui wo depend karegi mere material ke composition ke upar jaise alloying elements hai ya material ke processing ke upar jaise heat treatments hai ya cold rolling is tarah se jo processes hum istemal karte hain specially metals aur alloys ke liye aur isko hum jaante hain is tarah se Ductile to Brittle Transition Temperature ke

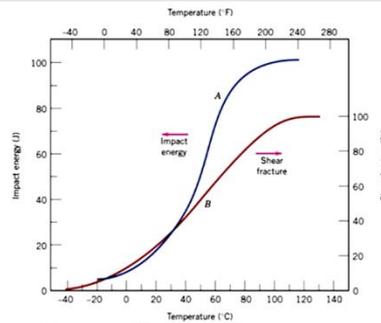
dwara aur yeh jo impact test hum mark kar rahe isko main is tarah se denote karta hoon yeh hai Charpy Impact Energy  $C_v$  aur Charpy V-Notch Energy CVN is tarah se jab main impact

energy aur versus temperature ki baat karunga to mujhe kuch is tarah se curve milta hai aap dekhenge yahan par maine impact energy plot ki hai Y-axis par aur X-axis par yahan par temperature hai aur yeh jo hai shear fracture main yahan par percentage shear fracture yahan par nikal sakta hoon wo main fractography karke nikal sakta hoon hum thodi der mein isko dekhenge to yahan par do material maine mark kiye A aur B ek blue mein hai aur ek red mein hai to aap dekhenge ki yahan par jo

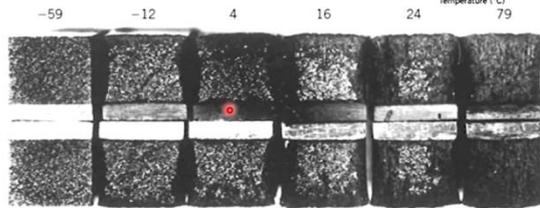


## Impact energy Vs Temperature

- As T increases, Impact energy increases
- Below certain T,
  - The mode of fracture is brittle



- Granular
- Shiny texture
- Cleavage



- Shear character
- Fibrous
- Dull texture

impact energy hai A material ki zyada hai is temperature ke baad aur B material ke liye bhi hum dekhenge ki kuch temperature ke baad impact energy jo absorb ho rahi hai wo zyada hai to aap dekhenge ki jaise jaise main temperature badha raha hoon waise waise impact energy in material mein ghat rahi hai to ek hum temperature define karenge uske neche material brittle fail hoga isko hum kehte hain Ductile to Brittle Transition Temperature to iske baare mein samajhte hain jaise jaise main temperature badha raha hoon waise waise yahan pe impact energy badh rahi hai below certain temperature hum dekhenge ki mode of fracture yeh brittle ho raha hai yahan pe aap dekhenge ki maine shear fracture ka

percentage is tarah se mark kiya hai jaise jaise shear fracture ka percentage yahan pe ghatega uska matlab material brittle way se fail ho raha hai is hum dekhenge ki is temperature pe let's say yahan par is B material ke liye aap dekhenge ki 100° ke upar mostly jo failure hai wo shear fracture se hai to material yahan par ductile behave karega is material ke liye A ke liye aap dekhenge ki already yeh jo fracture hai wo shear fracture hai wo almost 40° ya 50° ke upar hi

pahunch gaya hai to hum dekhenge ki 50° ke upar yeh material sirf ductile fail hoga to kuch is tarah se main temperature ke sath measurements kar sakta jaise yahan par yeh

temperatures mark kiye -50° to 79°C to yahan par aap dekhenge ki jaise jaise material shiny hai yahan par dekhenge ki shiny texture yahan par kam hote ja raha hai jaise jaise main temperature badha raha hoon yeh do material ke aur ab dekhenge ki yeh jo failure hai yahan par granular kuch aapko mil raha hai aur yahan par aap failure dekhenge ki fibrous ya dull texture aapko mil raha hai yahan par shiny surface yahan par kam ho gaya hai isko hum kehte hain shear character yani material shear way se deform ho raha hai aur yahan par jab humein shiny surface milta hai to isko hum kehte hain cleavage fracture ya material brittle way se yahan par



## Criteria for transition temperature

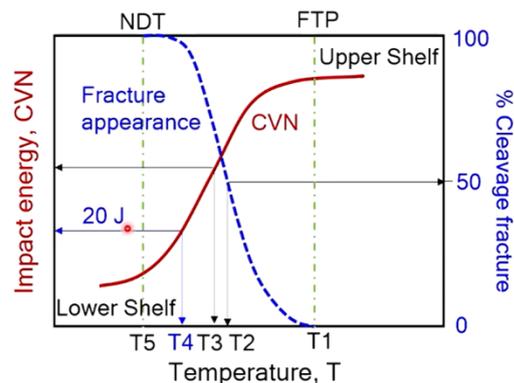
Criteria from **Energy Vs Temperature** or Fracture appearance Vs Temperature

T1: most conservative criteria: Fracture Transition Plastic (FTP)

The probability of brittle fracture is negligible above FTP

T2: 50 % cleavage & 50 % shear : Fracture appearance transition temperature (FATT)

T3: Temperature average of upper and lower half shell



T4: Ductility transition temperature

- Most accepted
- No brittle fracture was observed when  $C_v = 20 \text{ J}$

T5: Nil ductility temperature (NDT)

- Fracture with essentially no prior plastic deformation
- The probability of ductile fracture is negligible below NDT

396

fail ho raha hai to jaise jaise main temperature ghata raha hoon waise waise material brittle way se fail hota hai aur jab hum chahte hain material catastrophically fail na ho to hum chahte ki material ductile way se fail ho to hum dekhenge ki temperature ke neche material brittle way se fail hota hai aur yahi humein determine karna hai ki Ductile to Brittle Transition Temperature kya hai to hum kuch criteria yahan pe dekhte hain transition temperature ko define karne ke liye to humne dekha tha ki humne pichle slide mein impact energy plot ki thi Y-axis par aur X-axis par yahan par temperature plot kiya tha aur yahan par main % cleavage fracture mention kar raha hoon ya isko hum shear

fracture keh sakte to aap dekhenge ki jaise jaise aap dekhenge ki fracture appearance mein kuch is tarah se plot kar raha hoon to yahan par aap dekhenge ki % cleavage fracture cleavage yani brittle fracture ka percentage wo hum fractography se determine kar sakte yeh 100% pahunch gaya aur is is temperature ke baad aap dekhenge ki yeh jo fracture percentage hai ye zero hai to in dono conditions ko main yahan par is temperature ke baad ko main Upper Shelf kehta hoon aur is temperature ke baad main is portion ko main Lower Shelf kehta hoon aur yahan par yeh jo red color mark hai yeh meri CVN hai ya impact energy

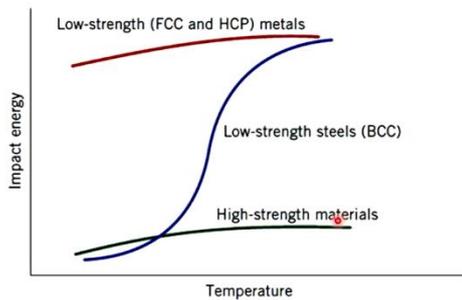
hai to aaiye jaante hain ki kuch kuch temperature transition temperature kuch is tarah se define karte hain aur wo define karte hain hum energy versus temperature plot se is plot se ya fracture appearance versus temperature ke plot se yani % cleavage fracture versus temperature ke plot se to hum dekhenge ki pehla temperature main define karta hoon T1 temperature isko main kehta hoon Fracture Transition Plastic yani yahan par yeh temperature T1 maine mark kiya yahan par main consider kar raha hoon yeh Fracture Transition Plastic yahan par aap dekhenge ki jo percentage of cleavage fracture hai wo is temperature ke baad zero hai yani main keh sakta hoon ki the probability of brittle fracture

yeh negligible hai is temperature ke upar isliye isko hum kehte hain Fracture Transition Plastic yani fracture jo hai wo plastically hi deform hoga ya wo transit kar raha hai se plastic deformation ke doosra temperature hum is tarah se define karte hain jo 50% cleavage aur 50% shear to agar main 50% cleavage fracture consider karunga to yeh jo point hoga yahan par is fracture appearance pe yeh jo temperature yahan par define hoga isko main kehta hoon Fracture Appearance Transition Temperature (FATT) yahan pe fracture appearance ke sath main define kar raha hoon is temperature abhi main T4 temperature kuch is tarah

se define karunga main impact energy ke dwara istemal karunga aap dekhenge ki maine ek value yahan pe set ki hai 20 J to yeh jo impact energy hai yahan pe hum dekhte hain ki is energy ke upar material mostly ductile fail hote hain aur iske neeche hum consider kar sakte hain ki material brittle way se fail hote hain ye mostly accepted temperature transition temperature hai isko hum kehte hain Ductility Transition Temperature ye mostly accepted temperature hai T5 main define karunga aap dekhenge ki T5 pe yeh jo hai ye NDT temperature hai isko kehte hain Nil Ductility Temperature aap dekhenge ki ye jo % cleavage



## DBT: Crystal structure



- Low-strength FCC metals (e.g., Cu, Al) and most HCP metals do not experience a ductile-to-brittle transition
- High strength materials ( $\sigma_0 > E/150$ ) e.g., high-strength steels and titanium alloys, the impact energy is relatively insensitive to temperature, however, these materials are also very brittle, as reflected by their low impact energy values.

- Characteristic ductile-to-brittle transition is shown by low-strength steels that have the BCC structure
- Ductile to Brittle transition
  - Metals: 0.1 - 0.2  $T_m$  (absolute melting temperature)
  - Ceramics: 0.5 - 0.7  $T_m$

WD Callister, Mater Sci & Eng, John Wiley & Sons, 1993.

Images are for educational and teaching purpose only

397

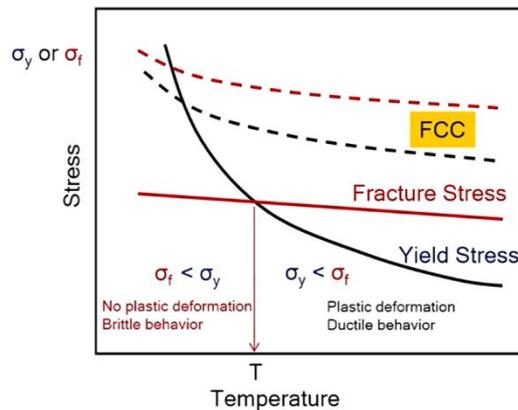
fracture hai wo almost 100% pahunch gaya yahan par to is temperature ke neeche material sirf brittle way se fail hoga yani yahan par material koi ductility nahi dikhayega isliye is temperature ko hum kehte hain Nil Ductility Temperature abhi yahan par humne dekha hai  $T_1$ ,  $T_2$ ,  $T_4$  aur  $T_5$  abhi main  $T_3$  ko define karunga kuch is tarah se to  $T_3$  mera ek average temperature hai is FTP aur NDT ka to is dono temperature ka average value wo main mark karunga aur isko main naam dunga  $T_3$  to yeh ho gaye mere transition temperatures mostly application mein hum  $T_4$  istemal karte hain jo mostly accepted hai metals aur alloys ke liye yani yeh jo temperature hai wo define karte hai impact energy 20 J

pe yeh ho gaye kuch transition temperature abhi hum dekhte hain ki Ductile to Brittle Transition Temperature mere crystal structure ke sath kis tarah se defined hai yahan par impact energy plotted hai aur yahan par temperature plot hai to aap dekhenge ki yahan par kuch material maine plot kiye unki DBDT plot kiye Ductile to Brittle Transition Temperatures plot kiye temperatures ke sath yahan pe ductile to brittle transition plot kiye temperatures ke sath wo kis tarah se vary hoti hai impact energy unki to yahan pe low strength material jaise maine plot kiye FCC aur HCP aur high strength material yahan pe maine plot kiya to kuch observations

yahan par dekh sakte hain in low strength FCC aur HCP metals ke sath ki hum dekhte hain ki yahan par koi humein transition nahi mil raha hai jo impact energy hai wo temperature jaise jaise badhega waise waise badh raha hai usi tarah se hum hum dekhenge ki high strength

material mein impact energy slightly increase ho rahi hai to hum dekhte hain ki high strength material mein yeh jo energy hai impact energy low strength material ke tulna mein bahut kam hai par yeh jo variation hai yeh drastic temperature ke sath dependent nahi hai to hum dekh sakte hain ki high strength material aur low strength FCC ya HCP metals ye kuch sharp transition

 **DBT: Crystal structure**



Fracture stress is not so sensitive to T

Griffith Theory

$$\sigma_f = \left( \frac{2E\gamma_s}{\pi a} \right)^{1/2}$$

E - the elastic modulus

γ<sub>s</sub> - the surface energy

a - a crack length

**BCC: yield stress is a strong function of temperature**

- Austenitic steel is preferred over mild steel for cryogenic applications

temperature demonstrate nahi karte but aap dekhenge ki yeh jo ductile to brittle transition hai yani aap dekhenge ki ye low strength steels ke liye specially BCC structures ke liye aap dekhenge ki humein kuch is tarah se impact energy ka variation milta hai temperatures ke sath to BCC structure hi hai jo humein Ductile to Brittle Transition sharp Ductile to Brittle Transition Temperatures demonstrate karte hain yeh low strength steels hote hain agar main transition temperatures ki baat karunga ductile to brittle transition ki to metals ke liye yeh lagbhag 0.1 to 0.2 T<sub>m</sub> hota hai aur ceramics ke liye ye 0.5 to 0.7 T<sub>m</sub> hota hai aur jo T<sub>m</sub> hai ye absolute

melting temperature kelvins mein hum isko likhte hain to ye ho gaya kuch ductile to brittle transition crystal structure ke sath aur kuch high strength aur low strength steel ki tulna humne yahan pe kiye yahan par main ductile to brittle transition jab main crystal structure ki baat karunga to hum kuch is tarah se samajh sakte hain jaise maine yahan par stress plot kiya hai jaise ki σ yani yield strength ya σ<sub>f</sub> yani fracture stress agar main plot karunga temperature ke sath to mujhe kuch is tarah se variation milta hai agar main fracture stress ki baat karunga to

mujhe fracture stress is tarah se milta hai aur yield stress mera material ka kuch is tarah se decrease

hota hai schematically yahan pe humne present kiya hai ki transition temperature main kis tarah se determine kar sakta hoon agar main dekhunga ki fracture stress ye zyada sensitive nahi hai temperature ke sath ye hum dekhte hain Griffith theory se agar main fracture stress ki baat karunga to aap dekhenge ki yahan pe koi temperature term nahi hai temperature term nahi hai par phir bhi yeh decrease ho raha hai to yahan par yeh jo elastic modulus hai wo temperature ke sath decrease hota hai isliye hum dekhte ki fracture stress gradually yahan par decrease ho raha hai par yeh zyada sensitive nahi hai as compared to mere yield stress ke sath to hum

dekhte hain ki BCC mein jo yield stress hai yeh jo function hai yield stress temperature ka yeh strong function hai mere temperature ka ya jaise jaise main temperature badhaunga waise waise mera yield strength ghatega BCC drastically ghatega to aap dekhenge ki agar yahan pe is temperature pe is temperature ke neeche mera fracture stress dominate karega yield stress ke upar yani fracture stress kam hai smaller hai yield stress ke tulna mein to aap dekhenge ki material yahan pe brittle fracture karega is temperature ke upar aap dekhenge ki yield stress smaller hai mere fracture stress ke sath to aap dekhenge ki material yahan par plastic deformation hoga to material ductile fail

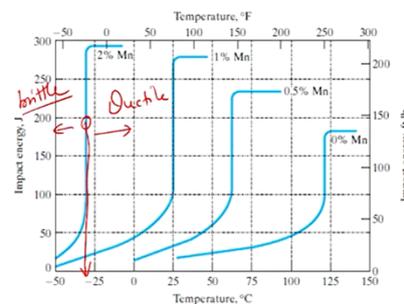
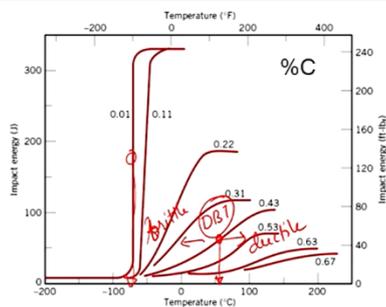
ho hoga is temperature ke neeche material brittle phase se fail hoga is temperature ko hum transition temperature keh sakte hain abhi hum dekhte hain FCC material ke liye humein jo  $\sigma_y$  ya  $\sigma_f$  jo variation milta hai kuch is tarah se to aap dekhenge ki yahan pe yeh jo  $\sigma_f$  hai wo aur  $\sigma_y$  hai kuch lower temperatures par jaake intersect hoga to aap dekhenge ki jo transition temperature aayega FCC material ke liye wo bahut low rahega ya main keh sakta hoon ki yahan par yield strength jo hai wo zyada dependent nahi hai temperature ke upar as compared to mere BCC material isliye BCC material mujhe sharp Ductile to Brittle Transition

temperature yahan par demonstrate karte as compared to mere FCC material to isliye hum low temperature pe Austenitic steel hum prepare karte hain jiska FCC structure hai over mild steel for cryogenic application yani sub-zero temperatures ya liquid nitrogen temperatures ke liye hum BCC structure prefer nahi karte cryogenic applications ke liye to ye ho gaya ductile to brittle transition jo mere crystal structure pe dependent hai abhi hum dekhte hain ki effect of alloying elements kya hota hai steels mein specially hum dekhte hain to yahan pe ek plot diya hai Impact Energy versus Temperature ka aur yahan par hum dekhenge ki

jaise jaise % Carbon mera badh raha hai waise waise impact energy ghat rahi hai par yeh jo sharp transition hai wo yahan pe dikh nahi raha hai to yahan pe jaise jaise carbon mera badh raha hai waise waise impact energy ghat rahi hai yani mera material brittle way se fail hoga jaise jaise carbon percentage yahan pe ghat raha hai to aap dekhenge ki ek sharp transition mujhe yahan pe milega yeh jo % Carbon rahega wo mera low strength steels ke sath rahega yeh high % Carbon mera high strength steels ke sath rahega to yahan par low strength steels aap dekhenge ki transition temperature yahan par ghat gaya hai aur in case mein transition temperature yahan par badh rahe hai to



## DBT: Effect of alloying elements in steels



- Increase in C content **increase** strength of steel, decreases toughness of steel
- Increase in Mn **lowers** the transition temperature
- **Mn:C = 3:1** is maintained for satisfactory notch toughness
- P in steel raise DBTT by 7°C for each 0.01% P
- O in steel, increase from 0.003% to 0.057% increases DBTT from **-15°C to 340°C**

WD Callister, Mater Sci & Eng, John Wiley & Sons, 1993.

Images are for educational and teaching purpose only

399

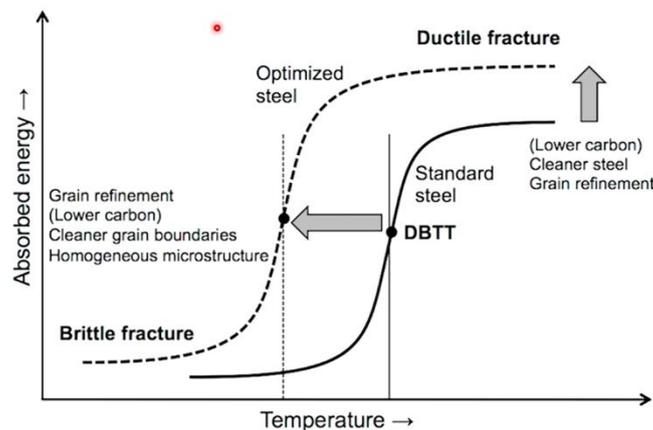
% Carbon jaise jaise badhega waise waise mera transition temperature Ductile to Brittle Transition Temperature wo badhega aur aap yahan par dekhenge yeh Manganese ka percentage hai to yahan par main per Manganese se 2% Manganese add kar raha hoon to jaise jaise Manganese main add kar raha hoon to yeh jo Ductile to Brittle Transition Temperature hai yeh yahan par kam ho raha hai yani is temperature par aap dekhenge material ductile fail hoga aur iske neche material brittle way se fail hoga similarly aap yahan par bhi dekh sakte hain yeh temperature mujhe % Carbon yahan par mila hai aur yahan par agar main is tarah se define

karoon Ductile to Brittle Transition Temperature to mujhe kuch is temperature ke upar ductility milegi aur yahan pe iske neche mujhe brittleness milega brittle failure milega to % Carbon aur % Manganese determine karta hai ki mera DBTT temperature kya ho sakta hai to jaise hum dekhte hain ki Carbon content increase hota hai to steels mein to toughness of steel decrease

hoti hai aur increase in Manganese lowers the transition temperature generally humein jab notch toughness ki main baat karunga to generally application ke waqt ya design ke waqt Manganese aur Carbon ka percentage hamesha 3:1 hum rakhte hain so that hamare paas ek achi satisfactory notch

toughness rahe kuch other elements bhi impact karte hain DBDT to hum dekhte hain ki agar main Phosphorus add kar raha hoon steel mein to aap dekhenge ki  $7^\circ$  rise hoga is DBDT mein just mere 0.01% for phosphorus increase agar hoga steel mein to Oxygen agar hum baat karenge to Oxygen agar main increase kar raha hoon 0.003% se 0.057% tak to aap dekhenge ki DBDT  $-15^\circ$  se  $340^\circ$  tak badh sakta hai to aap dekhenge ki mera material jaise steel 340 ke neeche brittle fail hoga agar itna percentage Oxygen hai to to humein Oxygen ka percentage bhi control karna hota hai

## **Decreasing DBT of Steels**



- Grain Refinement improves strength and fracture toughness

Phosphorus ka percentage bhi humein control karna hota hai agar mujhe acha lower DBDT chahiye to to iska understanding is plot mein ya schematic mein main dena chahta hoon jaise absorbed energy hai aur temperature ki main plot kar raha hoon aur ek standard steel ke baare mein main agar baat karunga to aap dekhenge ye yahan par DBDT maine plot kiya hai mark kiya hai aur yeh DBDT agar main decrease karna chahta hoon yahan pe dekhenge ki is temperature ke baad material ductile fracture dega neeche mein yahan pe brittle fracture dega is temperature ke neeche to kuch criterias yahan pe ya kuch processing mujhe karni padegi yahan pe main

agar carbon low karta hoon ya steel ko cleaner rakhta hoon jaise Phosphorus ya Oxygen kam karta hoon ya main grain refine bhi karta hoon to aap dekhenge ki yeh DBDT ya impact energy ka curve hai wo kuch is tarah se shift hoga yeh optimized steel mein jab baat karunga tab main yahan par mere paas lower carbon hai ya cleaner grain boundaries hai wahan par koi foreign elements ya foreign particles nahi hai ya mere paas kuch homogenous micro structure hai ya main grain agar refine kar raha hoon to aap dekhenge ki DBDT decrease hota hai to hum ek point yahan par main mention karna chahta hoon ki agar main grain refine kar raha hoon to mere paas

strength bhi badhti hai aur fracture toughness bhi badh yahan par main baat kar raha hoon notch toughness ki to dono yahan par notch toughness aur fracture toughness ya strength dono badhti hai grain refinement mein humne strength ki baat ki thi Hall-Petch relation ke dwara aap yaad kar sakte hain to grain refinement hi ek aisi process hai ki jo meri strength aur fracture toughness dono badhati hai to yeh ho gaya schematically main represent kiya ki jo factors affect kar rahe DBDT ductile to brittle transition of steels to is part mein humne Impact Testing of Material ke baare mein padha aur impact testing yani impact of impact

testing ka kya importance hai material ke behavior mein usko kis tarah se hum define kar sakte Ductile to Brittle Transition Temperatures kya hote hain different transition temperatures kya hote hain yeh bhi humne padha hai to yahan pe main rukna chahta hoon Impact Testing of Materials par next part mein hum kuch aur properties padhenge abhi ke liye rukta hoon dhanyavad