

Mechanical behavior of materials

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Week-12

Lecture-61

Fracture & Theoretical Cohesive Strength of Materials

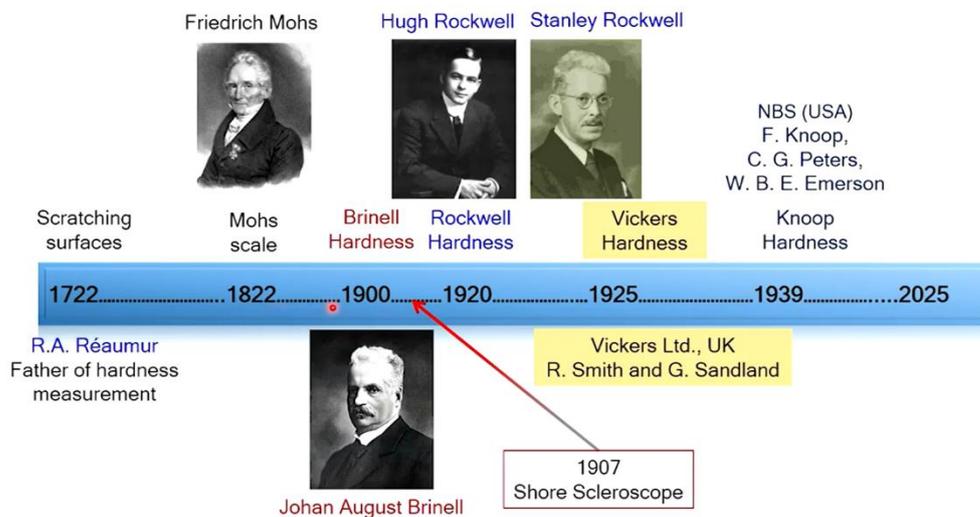
Course Title

Mechanical Behavior of Materials (Hindi)

Lecture-60 Hardness of Materials



Historical Perspective



Namaskar phir se swagat karta hoon aapka is course mein Mechanical Behavior of Materials jo ki hum Hindi mein padhenge is part mein hum hardness of material ki baat karenge hardness yeh term aapne suna hoga isko hum comparative strength ke saath bhi istemal karte hain par hardness kis tarah se strength se different hai ya vibhinn hai yeh hum is part mein samjhenge aur hardness kis tarah se evaluate karte hain yeh bhi is part mein samjhenge to hardness ke baare mein discuss karne se pehle hum pehle kuch hardness ki history dekh lete hain to yahan par kuch timelines maine yahan par mention kiye hai 1722 se 2025 tak to 1722 mein sabse pehle

documented hardness measurements huye the aur wo kiye the R A Reamur ne inko father of hardness measurement bhi kehte hain inhone jo hardness measurement kiye the wo minerals pe kiye the yaani ek mineral doosre mineral par scratch karke unhone ek relative hardness ki concept yahan par propose ki thi to ye 1722 mein sabse pehle hardness measurement chalu huye the janrally hardness jo value thi woh mineralogist istemal karte the us samay par 1822 mein ek relatively scale yahan par develop ki hai usko hum kehte hain Mohs scale yeh di thi Friedrich Mohs ne yeh scale minerals par hi dependent hai yaani yahan par 10 minerals ki baat karte

hain Mohs aur unki ek relative hardness ek chart mein present karte hai is baare mein bhi aaj hum is part mein padhenge uske baad ek instrument se hardness kis tarah se measurement hota hai yeh 1900 mein Johann August Brinell ne Brinell hardness ke dwara dikhaya tha is century mein is shatak mein humne dekhte hain ki hardness ki measurement kis tarah se progress hui thi 1920 mein Rockwell hardness ki concept aayi thi wahan par Hugh Rockwell aur Stanley Rockwell ne is method ko develop kiya tha uske baad 1925 mein Vickers hardness yeh company hai Vickers Limited UK ki aur ismein do jo scientist hai Smith aur Sandland

Hardness

“.....a measure of a material's resistance to 'localized plastic deformation' / 'permanent deformation' or 'indentation'.....”



Mohs Hardness Scale		
Name	Scale Number	Common Object
Diamond	10	
Corundum	9	Masonry Drill Bit / 8.5
Topaz	8	
Quartz	7	Steel Nail / 6.5
Orthoclase	6	Knife / 5.5
Apatite	5	
Fluorite	4	Penny (Copper) / 3.5
Calcite	3	
Gypsum	2	Fingernail / 2.5
Talc	1	

- Early hardness tests were based on natural minerals
- “Ability of one material to scratch another”

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inhone yeh technique develop ki thi 1939 mein Knoop hardness ka invention hua jahan par teen scientist Knoop Peters aur Emerson inhone kaam kiya tha yeh NBS US ke liye kaam karte the aur ek hardness technique hai jaise Shore Scleroscope yeh develop hui thi 1907 mein abhi bhi hardness mein bahut sara kaam chal raha hai research work chal raha hai aur hardness measurements ke naye naye tareeke bhi develop kiye ja rahe hain to yeh ho gayi ek brief history ho gayi hamare hardness ke baare mein abhi jaante hain ki hardness hai kya to agar aap textbook uthakar dekhenge to hardness is tarah se define hota hai yeh hai ek material ki property jo material ka resistance quantify karti hai ya measure

karti hai kis tarah se localized plastic deformation ya permanent deformation ya indentation ka resistance wo karti hai jaise koi bhi material localized plastic deformation ya permanent deformation ya indentation ko kis tarah se resist karta hai yeh hardness yahan par darshata hai maine yahan par indentation ki baat ki thi to yahan par aap is tarah se samajh sakte hain ki material main yahan par kuch draw karke aapko batana chahta hoon jaise mera ek sample hai

aur ek indenter jo ki hard material se bana hua hai is tarah se isko main indenter kahunga aur yeh indenter main is material mein push karunga uske wajah se kya hoga is material

mein plastic deformation hoga kuch is region mein aur yeh plastic deformation depend karega ki mera material kis tarah se resist karta hai is indentation process ko yahi hardness ki concept hai so sabse pehle jab hum baat karte hain hardness ki to jab hardness test carry kiye the wo natural minerals par carry kiye the jaise Mohs scale ki hum baat karenge to yeh natural minerals pe the aur tab hum dekhte hain ki ek ability hai material ki to scratch another to Mohs scale kuch is tarah se hai yahan par aap dekhenge ki 10 minerals yahan par darshaye gaye hain jaise Diamond aur Corundum Topaz Quartz Orthoclase Apatite Fluorite Calcite Gypsum aur Talc sabse

soft material hai is scale mein aur Diamond sabse hard hai to iska number humne 10 is tarah se de diya hai abhi hum dekhte hain ki common object jo hum zindagi mein use karte hain jaise abhi hum dekhte ki hamara finger nail iski hardness agar hum dekhenge to yeh is Mohs scale pe aati hai around 2.5 aur steel nail ki agar hum hardness dekhenge to yeh aati hai around 6.5 to yeh ek relative scale hai yahan par koi yeh jo scale hai yeh quantified nahi hai yeh ek relative scale hai yaani ek ability dikhata hai material ki isko hardness ko hum hardly quantify kar sakte hain jaise jaise hum aage badhenge us tarah se hum samjhenge ki hardness ek relative hi measurement hai to yeh measurement



Hardness: Introduction

- Small indenter is forced into the surface of a material to be tested, under controlled conditions of load and rate of application
- Measured hardness are only relative (rather than absolute)
- Care should be exercised when comparing values determined by different techniques

Hardness tests are performed more frequently than any other mechanical test for several reasons:

- They are simple and inexpensive – ordinarily no special specimen need be prepared, and the testing apparatus is relatively inexpensive.
- The test is nondestructive – the specimen is neither fractured nor excessively deformed; a small indentation is the only deformation.
- Other mechanical properties often may be estimated from hardness data, such as tensile strength

yeh material ke resistance ki ability darshata hai resistance kiske liye localized plastic deformation ya permanent deformation ya indentation yeh ho gaya hamara Mohs hardness scale abhi hum aage badhte hain aur hardness ke baare mein kuch introduction dekhte hain kuch bindu yahan par mein rakhna chahta hoon jaise hardness jo measurement abhi hota hai wo ek small indenter jo ki hamesha hard material hota hai janrally diamond ya steel se bana hota hai hardened steel se bana hota hai ye ek small indenter hum kisi material ke surface mein indent karte hain ek controlled load aur us rate of application mein yaani ek proper rate se us load indenter par load rakhte

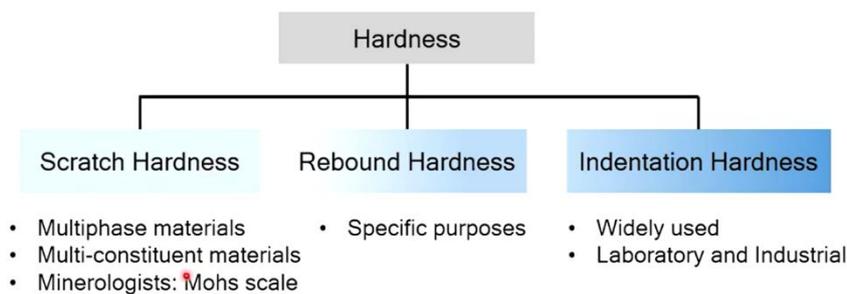
hain aur indenter push karte hain material mein ye hardness measurement ka ek central concept hai abhi hum dekhte hain ki yeh jo hardness measurement hai yeh relative hai rather than absolute ya hum isko absolute value nahi consider kar sakte ek just ability darshata hai material ki aur iske liye humein kuch careful techniques yahan par develop ki gayi hai hardness measurement ke liye abhi hum dekhte hain ki hardness ki upyukta kya hai jaise hardness test yeh frequently hum perform karte hain tensile test ke comparison mein kyunki jaise yeh jo test hai hardness test yeh simple hai aur inexpensive hai iske liye zyada paise ki zaroorat nahi hai ya aasani se yeh test ho sakti hai as compared to other

mechanical test jaise ki hum dekhte tensile test ya high temperature tensile test ya other fatigue test uske comparison mein yeh test hai yeh inexpensive aur simple hai iske liye humein koi sample specimen preparation ki ya zaroorat nahi special zaroorat nahi hai jo special sample humein kuch chahiye humein sirf ek flat sample chahiye yeh ek test hai jo non destructive hai iska matlab hai ki yeh material ko destroy nahi karta hai ek small portion hota hai material ka wahi sirf indent karte hain hum aur wahan par ek localized plastic deformation dekha jata hai to humein material ka itna loss nahi hota hai hum small volume mein bhi yeh test kar sakte



Hardness Measurement Methods

- Based on the mode of evaluating hardness



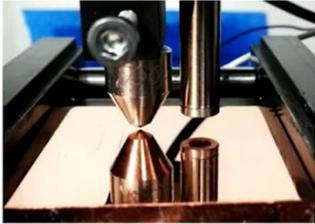
hain aur yeh test se hum jo properties milte hain woh hum compare kar sakte hain jaise hardness value hum compare kar sakte hain tensile strength ke saath ye hum dekhenge is part mein hum dekhenge ki kis tarah se hum hardness ko tensile strength ke saath compare kar sakte hain yeh ho gayi kuch hardness ke baare mein information abhi hum dekhte hain ki different hardness evaluation techniques kya hai to different methods different principle pe dependent hai jaise yahan pe teen hardness measurements ki techniques maine yahan pe methods yahan pe maine mark ki hui hai jaise scratch hardness rebound hardness aur indentation hardness yeh jo technique hai yeh sabse zyada

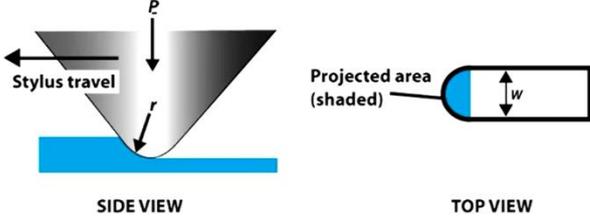
istemat hoti hai industry ya laboratories mein to yeh widely used hoti hai aur rebound hardness hum specific purposes ke liye istemat karte hain yeh bhi hum jaanenge ki rebound hardness hum kahan pe istemat karte hain scratch hardness ki upyukta yeh hai ki yeh multi phase material ke liye kaafi upyukt hai jaise yahan pe multi phase material ke agar different hardness hai aasani se scratch hardness se measure kar sakte hain jaise mere paas multi constituent material

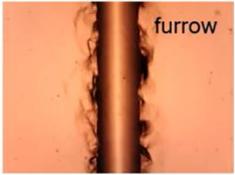
hai mineralogical samples hai to uske liye scratch hardness kaafi upyukt hai aur Mohs scale jo hai wo isi scratch hardness ke principle se bana hua hai to yeh to humne dekha Mohs scale ke baare mein abhi hum dekhte hain kuch yeh do hardness techniques

Scratch Hardness

Hard stylus is used to make a scratch







$$HSp = \frac{8P}{\pi w^2}$$

- Hardness of microconstituents
- Hardness of different phases

Test parameters	Value
Normal force	10 N
Sliding speed	20 mm/min
Sliding distance	10 mm
Atmosphere	Air
Temperature	24°C (room)

<http://nanovee.com/App-Notes/scratch-hardness-measurement.pdf>

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to scratch hardness ke baare mein jab jaanenge tab hum dekhte ki hard stylus hum istemal karte hain scratch banane ke liye jaise yahan pe ek image maine dikhayi hai to yahan par dekhenge ki yeh jo hai yeh ek hard stylus yeh jo tip yahan par dikh rahi hai ek hard stylus hai aur yeh jo surface hai yeh properly mirror finish surface hai aur is surface pe yeh stylus hum move karenge ya yeh jab stylus is surface p move karega aur across move karega to ek scratch taiyar karega to schematically kuch humne is tarah se dikhaya hai yahan par aap dekh sakte hain ki stylus mera kuch is tarah se hai aur yahan par main kuch pressure is stylus par apply karunga aur yeh jo material hai is material ke against ye

stylus hum move karenge is stylus ko is tarah se travel karenge to yahan pe ek scratch taiyar hogi is material pe aur wahi hum measure karenge as a scratch hardness to scratch kuch is tarah se humein dikhegi hum agar top view agar dekhunga to scratch meri kuch is tarah se hogi practically hum dekhenge to is scratch ko hum furrow bhi kehte hain agar hardness value agar report karni hai to hum dekhte hain ki hardness ye H value yahan pe dikhati hai ki hum hardness value measure kar rahe hain s jo hai vah dikhata hai ki main scratch hardness istemal kar raha hoon aur p jo hai yeh darshata hai ki main constant load pe kaam kar raha hoon yahan pe

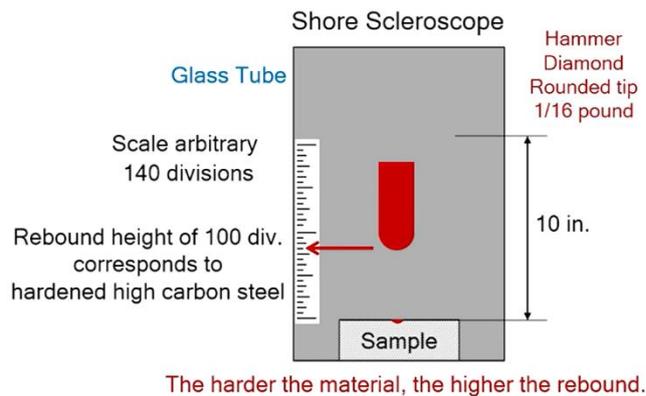
dekhenge ki yeh jo value hai yeh mujhe scratch hardness ki value degi yeh darshati hai $8P / \pi w^2$ yeh w hai yeh jo furrow hai iski width hai ye agar measure karenge hum microscope se to hum dekhenge ki main hardness ki value yahan pe nikaal sakta hoon to kuch test parameters yahan par maine mark kiye jaise maine bataya ki force main yahan par constant rakh raha hoon sliding speed kuch sliding speed 20 millimeter per minute se main move kar raha hoon stylus ko sliding distance 10 millimeter hai kitna distance mein slide karna chahta hoon yahan pe darshaya gaya hai atmosphere kis atmosphere mein aur kis temperature mein main

11:50 - 12:38

kar raha hoon yeh bhi yahan pe is test parameters mein include karenge abhi hum jo baat karenge scratch hardness ki tab maine kaha tha ki yeh jo hardness testing method hai yeh hum istemal karte ki different phases ke hardness ki values nikaalne mein aur iske wajah se humein unke jo material mein micro constituents hai ya micro constituent phases hai uski hardness aasani se pata kar sakte hain to yeh ho gaya scratch hardness ke baare mein kuch information abhi hum dekhte hain rebound hardness ke baare mein to rebound hardness yeh hum janrally measure karte hai Shore Scleroscope se ismein hum kya karte hain yahan pe ek hammer hota hai yeh hammer iski jo



The Rebound Hardness



- Dynamic hardness is a measure of the elastic energy stored in the material
- Portable and easy to handle

Should not be confused with Shore durometer which is used to measure hardness of rubbers and plastic

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tip hoti hai vo diamond rounded tip hoti hai aur iska weight hota hai 1/16 of pound aur yeh jo hammer hai yeh hum is glass tube mein rakhte hain aur sample bhi hamara is glass tube mein rehta hai yeh hammer yahan pe hang hua rehta hai iska distance hota hai samples ke surface se 10 inch aur yahan par kuch arbitrary scale yahan par mark ki hai janrally ismein 140 divisions hote hain abhi hum kya karte hain is hammer ko is sample par impact karte ya allow karte ki gravity ke saath is sample par fall ho aur jaise yeh fall hoga yahan par kuch interaction hoga aur iske wajah se yeh hammer bounce back karega kuch is tarah se abhi main is hammer ko release karunga aur yeh impact hua aur yeh bounce back hua

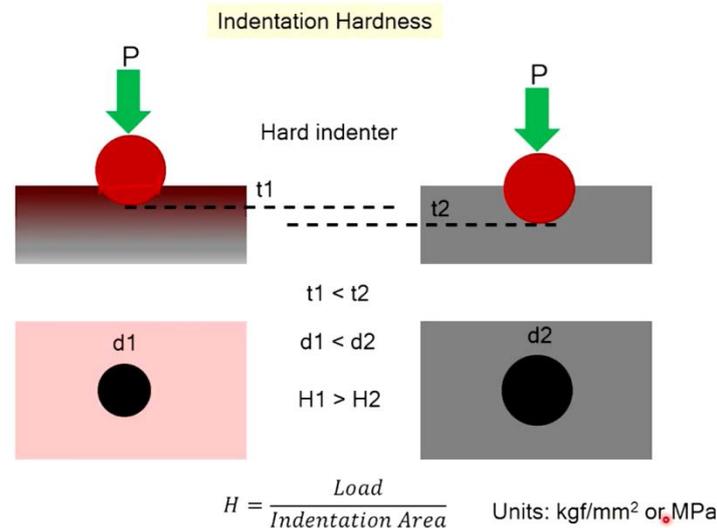
yeh jo bounce back hua ya rebound hua uski hum height measure karte hain to yeh to relative measurements hai abhi hum dekhenge ki yeh jo height hai agar vah 100 divisions tak pahunchti hai yahan se zero chalu hoga aur 100 division tak agar pahunchti hai to yeh height hoti hai hamare correspond karti hai hardened high carbon steel ke hisab se agar yeh 100 division se neeche hai to hum dekhenge ki material ki hardness hum compare kar sakte hai high carbon steel ke saath to jitna harder material utna higher rebound to aap dekhenge ki yeh material yahan par impact karega aur yeh impact ki wajah se yahan par hum dekhenge ki agar material plastically deform ho raha hai to is hammer ki energy wo absorb

karega absorb karega aur iske wajah se ye hammer kam rebound karega agar zyada hard hai to aap dekhenge ki yahan par zyada plastic deformation nahi hoga to yeh hammer kam energy lega yaani kam energy iski loss hogi is sample mein aur yeh zyada rebound ho payega to isliye hum yeh keh sakte ki the harder the material the higher the rebound to is test se hum yeh bhi

jo elastic stored energy of material yeh bhi hum compute kar sakte hain ya yeh bhi hum nikaal sakte hain yeh technique jo hai yeh portable hai aur easy to handle hai yaani iske liye koi skilled worker ki zaroorat nahi hai is Shore Scleroscope ko handle karne mein ek important point yahan par mention karna



Indentation Hardness: Central Concept



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chahta hoon ki aap yeh jo Shore Scleroscope hai isko Shore Durometer ke saath compare na karein ya iske saath confuse na hon Shore Durometer jo hai vah rubbers aur plastic ki hardness evaluate karne mein hum istemal karte hain to aap Shore Durometer ke baare mein bhi padh sakte hain yeh ho gayi hamari rebound hardness abhi hum dekhte hain ki teesri technique jo ki indentation hardness isko samajhne se pehle ek central concept samajh lete hain indentation hardness ki jaise yahan par maine do material dikhaye huye yeh ek material aur yeh doosra material ismein hum yeh karte ki ek hard indenter yahan par maine ek ball dikhaya is hard indenter ko is

material ke andar indent karte hain yaani push karte ek constant load ke saath aur constant rate of application ke saath to main ye force P yahan pe darshaya hua ye indenter par main apply karunga aur yeh indenter phir is force ke influence mein ye is material mein penetrate hoga ya indent hoga aur kuch samay ke tak main is force ko apply karke rakhta hoon aur phir is indenter ko wapas nikaal deta hoon to kuch is tarah se agar main isko indent karunga jaise yahan pe maine ek indent kiya hai is force ke dwara aur yahan pe main phir se ek indent karunga is indenter ko is force ke influence mein to main kya karta hoon yahan par main ye

indenter kitna andar indent hua hai iski thickness nikaal sakta hoon kuch is tarah se t1 aur ismein main t2 mark kar raha hoon agar main iska top view dekhunga to aap dekhenge ki yeh jo indentation area hai kuch is tarah se mujhe dikhega agar yeh spherical indenter hai to main dekh paunga ki yahan par mujhe ek circular cross section is tarah se dikhega to aap dekh pa rahe honge ki agar main is ye agar ye diameter consider karunga ye agar main diameter consider karunga to aap dekh paayenge ye ye diameter yahan pe mark ki huye hai to agar yeh material zyada hard hai to yahan par jo depth of penetration hoga vah kam hoga aur yeh jo surface area

yahan pe ya jo projected indentation area jo mujhe mil raha hai vah kam rahega main kuch is tarah se likh paunga agar iski is material ki hardness zyada hai to $t_1 < t_2$ aur $d_1 < d_2$ to main ye keh sakta hoon ki is material ki hardness is material se zyada hai badi hai to indentation hardness mein isko kuch is tarah se main likh paunga ye hardness value main is tarah se define karta hoon ki load / indentation area abhi hum dekhenge ki yeh indentation area total surface area bhi ho sakta hai ya projected surface area bhi ho sakta hai ye depend on ki kaun si indentation technique mein istemal kar raha hoon yeh hum aage padhenge par general jo central concept

Brinell Hardness

P = 3000 kg hard materials
P = 500 kg soft materials

Steel ball or
WC indenter for hard materials
Diameter = 10 mm

Sample

Units : kg/mm² or MPa
1 kgf/mm² = 9.81 MPa

$$BHN = \frac{Load}{Surface\ area}$$

$$BHN = \frac{P}{\pi Dt}$$

$$BHN = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$$

$$BHN = \frac{2P}{\pi D^2(1 - \cos\phi)}$$

Sample indented surface

$$d = \frac{d_1 + d_2}{2}$$

500 BHN or 500 HB: hardness measured as 500 kgf/mm²

hai is indentation hardness ka yeh hardness value deti hai load / indentation area to iske units kya honge iske units honge kgf / mm² ya MPa abhi is indentation hardness mein sabse pehle ek hardness technique mein yahan par introduce karna chahta hoon jo ki hai Brinell hardness ismein kya hai ek sample main yahan par consider kar raha hoon aur yahan par ek indenter main consider karunga jo ki steel ball hota hai ya tungsten carbide ball hum istemal karenge hard material ke liye aur iske diameter jo hoti hai vah 10 mm hoti hai aur ek force apply karunga aur is force ki value ya load ki value main kuch is tarah se rakhunga 3000 kg jo hard material

ke liye main higher load istemal karunga aur soft materials ke liye main 500 kg loads istemal karta hoon aur jab main isko indent karunga is load ke saath to main 30 seconds tak wait karunga is indenter ko is sample mein indent hone ke liye penetrate hone ke liye jab main yeh karta hoon tab aap dekhenge ki yeh indenter ismein material mein penetrate hoga kuch is tarah se abhi aap dekh paayenge ki yahan par yeh jo D maine capital D maine mark ki hai yeh diameter of indenter hai aur small d yahan par maine jo mark ki hai yeh indentation diameter hai small t yahan par jo mark ki hai yeh indentation thickness hai yaani is surface se leke yeh indenter kis depth tak penetrate hua hai ya indent hua

hai isko main indentation depth kehta hoon isko t maine mark kiya hai agar main kuch geometric construction karunga aur yeh indenter symmetrically is sample ko indent kar raha hai to yeh angle main 2ϕ consider karunga aur agar main is angle ko kuch bisect karke ϕ aur ϕ likh sakta hoon abhi hum dekhte hain ki yeh jo hardness kuch is tarah se define hota hai isko hum kehte hain BHN yaani yeh hardness hai Brinell hardness number aur

isko hum define karte hain load / surface area yaani jo total surface area hoga indentation ka isko hum consider karte hain yahan par is hardness ko evaluate karne mein kuch is tarah se jaise agar main top view dekhunga to mere

paas kuch is tarah se agar kyunki ye circular indenter hai sorry spherical indenter hai to mujhe yahan pe circular cross section is tarah se milega agar main ye diameters measure karunga to average diameter main kuch is arithmetic mean se nikaal sakta hoon aur yeh small d ki value mujhe mil jayegi aur spherical cap ki jo surface area hogi vo main yahan pe istemal karunga to BHN main kuch is tarah se likh paunga yahan pe load p hai aur surface area main likh sakta hoon πDt agar aap spherical cap ka surface area nikaalne ki koshish karenge to aapko πDt yeh equation milega to yahan par agar main t ki value replace karunga to t ki value main kuch geometry understanding ke saath is tarah

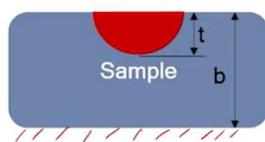
se likh paunga $D - \sqrt{D^2 - d^2}$ aur agar ϕ ke saath likhne ki koshish karunga to kuch is tarah se mujhe yeh BHN ka relation milega to is tarah se main Brinell hardness number yahan pe define kar paunga agar main iske units dekhunga to aap dekhenge ki units yahan pe kg / mm^2 ya MPa aur aapko pata hai $1 \text{ kg} / \text{mm}^2 = 9.81 \text{ MPa}$ hota hai jaise main agar is test ke dwara mujhe kuch number milta hai 500 BHN to yaani ye Brinell hardness number hai ya isko main is tarah se bhi likh sakta hoon 500 HB yaani yeh darshata hai hardness in Brinell to ye hardness measured hai at $500 \text{ kgf} / \text{mm}^2$



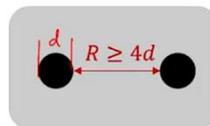
Brinell Hardness

- Large size indentation
- Averages out surface irregularities, scratches and surface roughness
- Thinner sections??

$$t = \frac{P}{\pi D BHN} \quad \text{thickness, } b \geq 10 \frac{P}{\pi D BHN} = 10t$$



$$BHN = \frac{2P}{\pi D^2 (1 - \cos \phi)}$$



R distance between two indents

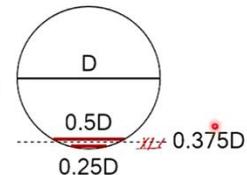
Geometrical similitude

For BHN and ϕ to remain constant

$$\frac{P_1}{D_1^2} = \frac{P_2}{D_2^2} = \frac{P_3}{D_3^2}$$

To avoid deep indentations, the indentation diameter lies between 0.25 D and 0.5 D

Ideally, i.e., $d = 0.375 D$



abhi jab main Brinell hardness ki baat karunga to hum dekhte hain ki wahan pe load zyada hone ki wajah se jo indentation hoga uska size bhi large rahega par iska ek advantage hai ki jo surface irregularities hai ya scratches hai ya surface roughness hai iske baare mein humein zyada ye zyada problem create nahi karenge jab main Brinell hardness ko determine karne ki koshish karunga par agar material thinner sections hai to indentation zyada hone se humein kuch errors yahan pe mil sakte hain to humein thinner sections ka kuch khayal rakhna padega kuch is tarah se agar main thickness yahan pe nikaalne ki koshish karunga hum agar previous formula dekhenge to thickness main is tarah se nikaal

sakta hoon $p / (\pi D \times \text{BHN})$ to yeh mera Brinell hardness number hai to main thickness kuch is tarah se define ka sakta hoon yeh jo yeh jo aap thickness yahan par dekhenge indentation thickness hai aur yeh B jo hai yeh material thickness hai to humein ek minimum material thickness yahan par honi chahiye jo ki main kuch is tarah se determine kar sakta hoon yeh jo B hai vo kam se kam 10t honi chahiye yaani 10 times thickness honi chahiye agar aap yeh value dekhenge thickness ki value hai to ye kam se kam 10 times thickness honi chahiye meri sample ki thickness agar yeh kam hogi to kya hoga yeh sample jis substrate par rakha hoga yeh sample jis substrate par rakha hoga

us substrate ka humein response milega to yeh avoid karne ke liye humein thickness yeh B jo value hai almost 10 times thickness honi chahiye similarly agar main do indent kar raha hoon ek sample par to inke beech ka distance yeh more than 4d hona chahiye d jo hai vah meri indentation diameter hai yahan par main isko main mark kar sakta hoon yeh meri indentation diameter hai to ye more than or equal to 4d hone chahiye yaani distance between two indents to BHN maine kuch is tarah se likh sakta hoon yeh formula humne derive kiya hai aur yahan BHN aur ϕ constant kab rahenge jab hum dekhte hain ki yeh jo ratio hai p / D^2 yeh constant hona

chahiye isko hum kehte hain geometric similitude yaani $p_1 / d_1^2 = p_2 / d_2^2 = p_3 / d_3^2$ isko is tarah se samajhte hain agar main ek hi material ko maan lete is material ko main indent kar raha hoon aur maan lete ki maine ek load yahan par istemal kiya aur doosra load maine istemal kiya to mujhe hardness material ka same hi aana chahiye kyunki main ek hi technique istemal kar raha hoon aur vo aane ke liye yeh jo term hai yeh meri constant honi chahiye jaise main p1 load apply karunga to mujhe jo diameter milegi indentation indenter ki diameter hai yeh main yahi istemal karna chahiye agar p2 hai to mujhe yeh istemal karni padegi nahi to humein different different

hardness value milegi different different load ke saath aur vo problematic hai janrally hum kya karte jo indentation jo diameter hai vah janrally .25D yeh jo indenter ki size hai ya diameter hai iske .25 honi chahiye ya .5 maximum ho sakti hai in donon ke beech mein honi chahiye kuch is tarah se samajhte hain jaise agar ye maan lete meri indenter ki diameter hai capital D to yahan pe maine kaha hai ki indentation diameter in donon value ke beech mein lie honi chahiye agar hum main .25D agar main consider karunga to .25D kuch is tarah se length hogi aur .5D kuch is tarah se length hogi to aap dekhenge ki yeh jo part hai itna hi part mera indenter ka material mein indent karega tab

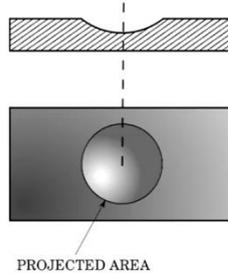
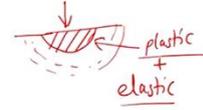
mujhe tab mujhe jo valuez milegi vah valuez accurate rahegi otherwise humein deep indentation milegi ideally mujhe yeh value honi chahiye .375D yeh jo value hai yeh meri yeh value jo hai vah average value hai in donon ki ideally yeh value hum istemal karte hain indentation nikaalne ke waqt abhi hum dekhte hain ki ek Meyer hardness main yahan par define karna chahta hoon yeh isliye define karna chahta hoon ki jab main Brinell hardness evaluate karunga tab dekhte hain ki distribution of stresses yeh symmetrical hai about axis of load but jo load main apply



Meyer Hardness

- In Brinell hardness: Distribution of stresses and the indentation are symmetrical about axis of load
- Though hardness depends on P, **Surface area is not proportional to P**
- More rational to use “the projected area of indentation”
- Mean pressure at the indenter surface and the indentation

$$BHN = \frac{\text{Load}}{Sf \text{ area}}$$



$$\text{Meyer hardness, } HM = \frac{P}{\pi d^2 / 4} = \frac{4P}{\pi d^2}$$

karunga vah load ki wajah se jo surface area hai vah proportional nahi rehta is load ke saath jo surface area mein evaluate istemal kar raha hoon yahan par humne Brinell hardness is tarah se define kiya tha load / surface area to ye jo surface area hai vo proportional rehta p ke saath vo change hota hai vo linear agar hoga tab yahan par errors kam aayenge to sabse Meyer ne yeh propose kiya ki projected area indentation ka istemal kiya jaye kyunki projected area hum dekhte hain ki yeh proportional ho sakta hai more or less higher loads ke saath ye agar main consider karunga projected area to ye value hardness ki kuch is tarah se mujhe

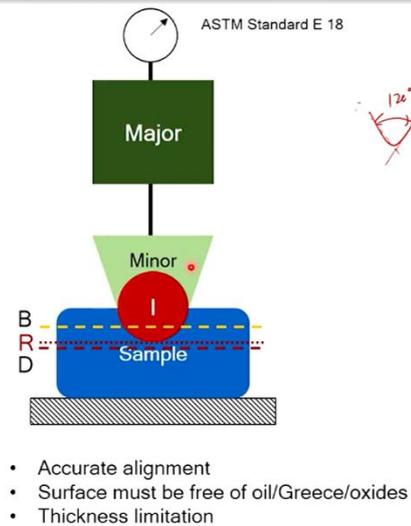
milegi $p / (\pi d^2 / 4)$ ye agar main projected area to yeh circle ho jayega aur yeh circle ka area aa jayega $\pi d^2 / 4$ to Meyer hardness ki value kuch is tarah se aayegi $4p / \pi d^2$ agar main is value ko dekhunga ya is value ko dekhunga yeh darshata hai kuch mean pressure at the indenter surface and the indentation to hum dekhte hain ki yeh jo surface area hai yeh proportional kyun nahi rehta hai do reason hai yeh is part mein hum padhenge ki jab main indent kar raha hoon kisi surface ko yahan par aap dekhenge agar yeh indenter is tarah se indent ho chuka hai to yahan par material do tareeke se deform karega ek to ek

plastic deformation aur doosra hoga elastic deformation agar main plastic deformation ki baat karunga to yeh permanent deformation hai par elastic deformation yeh recover hoga jaise hi main indenter wapas loonga waise hi yeh jo surface area yahan par change hoga to aapko jo value milegi wahan par errors zyada honge aur main jab projected area istemal karta hoon to yahan par zyada elastic recovery nahi hoti isliye jo hardness ki value main evaluate karunga projected area ke saath to wahan par errors kam honge yeh ho gayi Meyer hardness ke baare mein kuch information



Rockwell Hardness

- Simple to perform and require no special skills
- Indenters **spherical and hardened steel balls**
 - Diameters: 1/16, 1/8, 1/4, and 1/2 in.
- A **conical diamond** (Brale) indenter, which is used for the hardest materials.
- A hardness number: the difference in depth of penetration resulting from the application of an initial minor load followed by a larger major load
- When specifying **Rockwell and superficial hardnesses**, both hardness number and scale symbol must be indicated. Hardness has an arbitrary units specified by the dial gauge measurement based on the depth of penetration.
- The scale is designated by the symbol **HR**



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abhi main doosri technique yahan par introduce karna chahta hoon jo ki Rockwell hardness testing hai is test mein hum kya karte hain ki sample yahan par rakhte hain aur yahan par hum do load apply karte hain ek minor load aur major load yeh jo test hai yeh aap iska standard yahan par is tarah se dekh sakte hain ASTM standard E18 to yeh test jo hai vah simple hai aur iske liye koi special skill ki zaroorat nahi hai iske liye hum do indenters istemal karte hain ek spherical indenter jo hardened steel ball se bana hua hota hai aur uski diameters hoti hai 1/16, 1/8, 1/4 aur 1/2 inch aur doosra hai conical diamond ya Brale indenter to yeh indenter ka

shape kuch is tarah se hota hai yahan pe darsha deta hoon yeh indenter kuch is tarah se hota hai aur yeh jo hota hai conical shape ka hota hai aur inke beech ka angle hota hai 120° isko hum kehte hain Brale indenter bhi aur yeh hard material ke liye hum istemal karte hain abhi jab main ye measurement karunga to to sabse pehle main kya karta hoon yeh jo minor load hai yeh main apply karta hoon material par yeh minor load maine is tarah se apply kiya aur aap dekhenge ki dial gauge yahan par kuch readings darshayega yeh darshata hai ki kitna material mein indentation hua hai depth ke saath yeh dial gauge proportionally move hota hai ab main kya karta hoon is minor load par major load add karta hoon ya yeh depth pehle

maine measure kar li aur yeh major load yahan par maine add kar diya aur is major load ke saath yeh minor load donon milke is sample ko phir se indent karenge kuch is tarah se yahan par aur indentation mujhe milega to yeh depth maine yahan par measure kar li is dial gauge se abhi kya karenge is major load ko main remove kar deta hoon to is major load ko maine abhi remove kar liya retract kar liya to aap dekhenge ki jo elastic deformation hai vah bhi recover hoga aur uske wajah se yahan pe jo indentation depth mili thi vah kam hogi yaani kuch is tarah se humein elastic recovery milegi aur yeh jo recovery yahan pe mil rahi hai kuch is tarah se main r se mark karunga aap dekhenge ki ye dial gauge ki value yahan pe ghat gayi hai to ye jo

final value yahan par milti hai usko hi hum kehte hain hardness value is test mein to yeh jo dial gauge ki value jo main represent kar raha hoon to jitna zyada indentation depth utni zyada yeh dial gauge ki value aur utna zyada hardness utna kam hardness material ka to aap dekhenge ki yeh jo value hai hardness ki yeh ek arbitrary value hai yeh hardness number main jo define karta hoon ye define karta hoon main difference in depth of penetration resulting from initial

and minor and major load aur do Rockwell hardness testing hum yahan pe consider karte hain ek one hai Rockwell hardness aur doosri hai superficial

hardness testing isko bhi hum samjhenge agle slide mein aur yeh jo hardness value hai isko ek arbitrary units hai yeh depend karta hai jaise maine kaha ki ye dial gauge ke measurement pe depend karta hai aur ye depend karega depth of penetration pe aur jo scale designated hai vo HR hai yaani hum yahan pe H represent karta hai hardness R represent karta hai Rockwell abhi hum jaante hain ki major aur minor loads kya hain aur kaun se indenters hum istemal karte hain iski measurement ke liye humein kuch cheezein ki zaroorat hai jaise accurate alignment major aur minor loads accurately align hone chahiye surface clean hona chahiye jaise oil grease aur oxides is



Rockwell and Superficial Rockwell

- **Rockwell Hardness**

- The minor load: 10 kg
Major loads: 60, 100, and 150 kg
- Each scale is represented by a letter of the alphabet; corresponding indenter and load

- **Superficial Rockwell**

- The Minor load: 3
Major Load: 15, 30, and 45 kg
- These scales are identified by a 15, 30, or 45 (according to load), followed by N, T, W, X, or Y, depending on indenter.
- Superficial tests are frequently performed on thin specimens

- **80 HRB represents a Rockwell hardness of 80 on the B scale**
- **60 HR30W indicates a superficial hardness of 60 on the 30W scale**

Rockwell		
Scale Symbol	Indenter	Major Load (kg)
A	Diamond	60
B	$\frac{1}{16}$ -in. ball	100
C	Diamond	150
D	Diamond	100
E	$\frac{1}{8}$ -in. ball	100
F	$\frac{1}{16}$ -in. ball	60
G	$\frac{1}{16}$ -in. ball	150
H	$\frac{1}{8}$ -in. ball	60
K	$\frac{1}{2}$ -in. ball	150

Superficial Rockwell		
Scale Symbol	Indenter	Major Load (kg)
15N	Diamond	15
30N	Diamond	30
45N	Diamond	45
15T	$\frac{1}{16}$ -in. ball	15
30T	$\frac{1}{16}$ -in. ball	30
45T	$\frac{1}{16}$ -in. ball	45
15W	$\frac{1}{8}$ -in. ball	15
30W	$\frac{1}{8}$ -in. ball	30
45W	$\frac{1}{8}$ -in. ball	45

surface pe nahi hone chahiye ya thick limitation yahan pe bhi hoti hai sample ki hum vo jaanenge agli slide mein yahan par hum dekhte hain ki maine yahan pe Rockwell hardness measure ki Rockwell hardness yahan pe mention kiya hai to sabse pehle jo minor load hoti hai uski value yahan pe 10 kg hai aur major loads yahan pe teen major loads hum istemal kar sakte hain 60, 100, 150 aur each scale ko hum represent karte hain ek alphabet se corresponding to the specific indenter and load jaise yahan par scales kuch measure ki hai Rockwell mein jaise A, B, C, D, E, F, G, H, K to aap dekhenge yahan pe different indenters yahan pe maine measure kiye aur ya different sizes un indenters ke maine

measure kiye yahan pe major loads ki value yahan pe mark ki gayi hai abhi main superficial hardness Rockwell hardness ki baat karunga to minor load yahan pe 3 kg hota hai aur major load yahan pe 15, 30 ya 45 kg ho sakta hai aur is scale mein bhi hum kuch alphabets istemal karte hain jaise N, T, W, X aur Y depending on indenter aur iske jo designation hai nomenclature hai vo jaise 30N ya 30T is tarah se hum mention karte hain yahan par aap dekhenge ki major aur minor load donon ki valuez kam hai as compared to Rockwell hardness test to aap dekhenge ki jo indentation depth hogi vah kam rahegi superficial Rockwell ke liye isliye hum thin specimens ko bhi yahan pe test kar paayenge superficial Rockwell

karte hain yaani hardness in Vickers ya diamond pyramid hardness DPH aur VPH yeh other names hai is Vickers hardness ke



Vickers Hardness

$$VHN = \frac{\text{Applied Load}}{\text{Surface area of the indentation}}$$

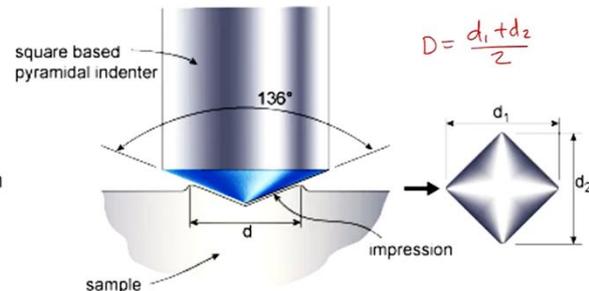
$$VHN = \frac{2P \sin(\theta/2)}{D^2} = \frac{1.854 P}{D^2}$$

P load in kg (1-120 kg)

D is the arithmetic avg. of two diagonals in mm

- Smaller loads as compared to Brinell
- Smaller indentation size
- Careful surface finish is needed

- No need of load or indenter has to be changed
- In VHN, indentations are geometrically similar irrespective of their size and depth of penetration
- VHN proportional to P/D^2
- VHN: 5 -1500 (soft to very hard) one scale



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

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liye abhi Vickers hardness kis tarah se evaluate hota hai hum dekhte hain to yahan par yeh diamond indenter hum istemal karte hain material mein indentation laane ke liye to humein jo area milega indentation area milega kuch is tarah se milega humein square shape milta hai aur in do diagonals ko hum measure karte square ke d1 aur d2 aur jab main VHN define karunga to VHN main is tarah se define karta hoon applied load / surface area of the indentation agar main surface area nikaalne ki koshish karunga to yeh istemal mein relation mein istemal karunga aur value jo aati hai VHN ki vo aati hai $1.854p / d^2$ jo theta ki value hai yahan par main 136° istemal

karunga aur yeh jo d hai vah arithmetic mean hai jaise maine ye do diagonals measure kiye hain microscope se to yeh arithmetic mean ho jayegi aur iske advantages kuch is tarah se kyunki yahan par hum dekhenge ki jo smaller loads main apply karunga as compared to Brinell aur iske wajah se mujhe smaller indentation size milega par aap dekhenge ki agar small load se aap dekhenge ki yahan par 120 kg aur Brinell mein hum almost 500 aur 3000 kg istemal karte hain to uske wajah se indentation size yahan par kam milega to humein surface finish ke baare mein zyada careful rehna padega yahan pe hum dekh sakte hain ki jab main yahan par jo indentation material

istemal kar raha hoon vo diamond hai aur humne Mohs scale par dekha tha ki sabse hardest material hai to isliye yeh jo indenter hai vo main soft material se hard material tak istemal kar sakta hoon aur VHN ki value jo aati hai vo 5 to 1500 values aati hai aur ek scale pe hi hum measure kar sakte hain jaise humne Rockwell mein dekha tha ki humein different scales chahiye ya different indenters chahiye vo disadvantage yahan par VHN mein nahi hai yeh already mentioned hai ki VHN jo number hai vo proportional to $1 / d^2$ hai aur yahan par humein load ya indenter change karne ki zaroorat nahi hoti hai yeh kuch advantages ho gaye Vickers hardness

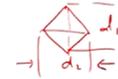


Microhardness tests

- Area and depth of indentations are smaller
- In microns range (typically $< 100 \mu\text{m}$)
- Can measure hardness of microconstituents

Vickers microhardness test

- No different from standard Vickers hardness
- Loads are smaller (20 - 1000 g)
- Some modern testers can go up to 2 g
- Need: surface finish, flatness of sample, good microscope assembly



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ke yeh jo hardness abhi tak humne baat kiye the vah macro hardness mein aate hain abhi main jab micro hardness test ki baat karunga tab aap dekhenge ki area aur depth of indentation ye chhote hote hain aur typically ye less than 100 microns hote to iska ek advantage hai ki agar material mein kuch micro constituents hai ya phases hai different phases hai uska hardness main aasani se measure kar paunga micro hardness test ke dwara to most popular technique yahan par main Vickers micro hardness test yahan pe mention karna chahta hoon to yeh standard Vickers hardness ki tarah hi hai par jo load apply aap yahan pe kar rahe vo 2 to 1000 gram hai yaani less than 1 kg load hum

istemat karte hain kuch kuch modern testers mein hum 2 gram load tak bhi ja sakte hain par yahan par humein kuch zaroorat hai padti hai kyunki load agar kam hai to aap dekhenge ki indentation size jo hai indentation depth vo small hoti hai to humein surface finish ya flatness of sample ka zyada khayal rakhna padta hai aur humein good microscope assembly chahiye us indentation size ko measure karne ke liye jaise humne dekha tha ki Vickers mein humein diameters measure karna to agar yeh microns mein hai kuch is tarah se agar mujhe yeh measure karne to aapko kuch achhe microscope assembly ki zaroorat



Knoop Hardness (pronounced as 'nup')

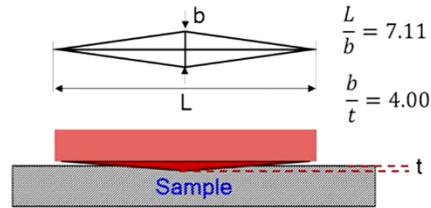
- To overcome some shortcomings of Vickers hardness test
- Pyramidal Shaped Knoop Diamond Indenter

L- long diagonal, b-short diagonal,
 $L \sim 30t$ (all in mm), Load P in (kg)



$$KHN = \frac{\text{Applied Load}}{\text{unrecovered Projected Area}}$$

$$KHN = \frac{14.2P}{L^2} \quad \begin{array}{l} \text{Geometric shape: 14.2} \\ \text{Supplied by the manufacturer} \end{array}$$



Advantages

- The **elastic recovery confined to the short diagonal**
- As indentations can be placed together much closer, thus **steep hardness profiles** can be measured
- Depth and area of the indentation** much smaller than Vickers hardness
 - Thin surface layers and brittle materials



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padegi isi ismein main ek Knoop hardness ko yahan par introduce karna chahta hoon iska pronunciation Knoop hota hai ismein kuch Vickers hardness test ki shortcomings hum overcome karte hain ismein bhi hum pyramidal shape diamond indenter istemal karte hain kuch is tarah se uska dimension hota hai aur aap dekhenge ki yeh jo indenter ki dimension hai kuch is tarah se ek mere paas long diagonal hai aur ek short diagonal hai to yeh jo long diagonal hai yeh almost aap dekh sakte ki 30 times hota hai aapke indentation thickness ke dwara aur kuch is tarah se ratio hum maintain karte hain jaise L / b ka ratio hota hai 7.11 aur $b / t = 4$ to aap dekh

paayenge ki jo length hai aap dekhenge ki is direction mein jo indentation length hogi vah badi hogi aur main sirf isi dimension ke according indentation length measure karunga par Vickers hardness mein main do tarah se measure karta hoon main yahan par mark kar leta hoon jaise humne Vickers hardness mein dekha tha ki mujhe donon diameter istemal karne padte yeh disadvantage hum yahan par Knoop hardness mein remove karte hain jaise sirf main isi indenter isi diagonal ke around main yeh diameter indentation diameter measure karunga aur KHN main is tarah se define karta hoon yeh Knoop hardness number hai ya isko HK bhi likh sakte hain yeh define karta hoon main

applied load / unrecovered projected area to yahan pe yeh value KHN ki kuch $14.2p / L^2$ jo L hai vah mere long diagonal ki length hai aur yeh jo 14.2 hai yeh geometric shape hai aur yeh supply karte hain manufacturer isko supply karte hain yeh aap jab kisi jis make se jis manufacturer se aap le rahe ho vo yeh number aapko supply karenge aur yeh number based ho yeh ratio ke upar jaise L / b aur b / t kuch advantages dekh lete hain Knoop hardness ke jaise yahan par hum dekhenge ki jo elastic recovery hai vah aapki short diagonal par confined rahegi kyunki is diagonal ke

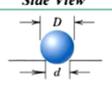
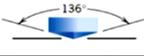
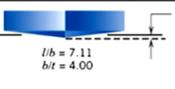
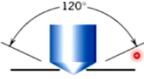
around aap zyada plastic deformation hoga to recovery aapki is diagonal ke around kam hogi to hum isi diagonal ke around hum measure karte hain to errors hamare measurement mein kam aayenge hum dekh paayenge ki is agar main is tarah se Knoop hardness measure kar raha hoon to yeh jo indenter hai main kuch is tarah se paas paas place kar paunga to in donon ka distance jo hoga vah main ghata paunga to hum ek steep hardness profile bhi yahan par measure

kar sakte hain yaani agar main distance agar kam hai to main ek agar hardness measure karunga to ek steep profile mujhe milegi yaani ek localized

information bhi mujhe Knoop hardness se mil sakti hai iska ek major advantage jo hai Vickers hardness ke upar ki hum yeh thin surface layers aur brittle material ke liye bhi istemal kar sakte hain yeh ho gayi Knoop hardness ki information abhi yahan par jo bhi hardness testing humne discuss ki thi uski ek summary maine yahan pe di hai jaise humne Brinell hardness Vickers hardness Knoop aur Rockwell hardness ke baare mein padha yahan par shape aur size of indentation humne indenter material yahan par kaun se istemal ke yahan par mention kiye load yahan par mention kiya gaya hai aur formula jo hardness value hum nikaalenge uske liye yahan par mention kiya gaya Rockwell mein koi

Hardness Testing Techniques

Summary

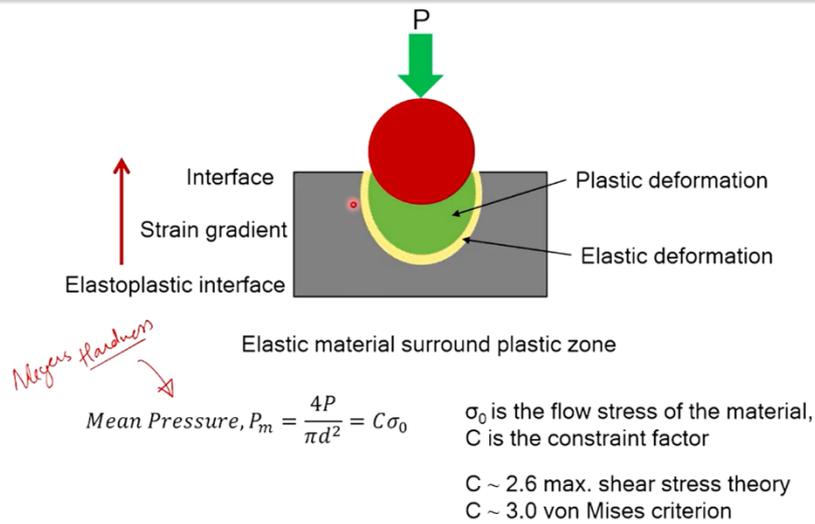
Test	Indenter	Shape of Indentation		Load	Formula for Hardness Number ^a
		Side View	Top View		
Brinell	10-mm sphere of steel or tungsten carbide			P	$HB = \frac{2P}{\pi D [D - \sqrt{D^2 - d^2}]}$
Vickers microhardness	Diamond pyramid			P	$HV = 1.854P/d_1^2$
Knoop microhardness	Diamond pyramid			P	$HK = 14.2P/l^2$
Rockwell and superficial Rockwell	<div style="display: flex; align-items: center;"> <div style="font-size: 2em; margin-right: 5px;">{</div> <div style="font-size: 0.8em; margin-right: 5px;">Diamond cone; 1/16, 1/8, 1/4, 1/2 in.-diameter steel spheres</div> </div>			<div style="display: flex; align-items: center;"> <div style="margin-right: 5px;">60 kg } 100 kg } 150 kg }</div> <div style="margin-right: 5px;">Rockwell</div> </div> <div style="display: flex; align-items: center;"> <div style="margin-right: 5px;">15 kg } 30 kg } 45 kg }</div> <div style="margin-right: 5px;">Superficial Rockwell</div> </div>	

^aFor the hardness formulas given, P (the applied load) is in kg, whereas D , d , d_1 , and l are all in mm.

formula nahi hai kyunki humne kaha tha ki Rockwell jo value deta hai vah arbitrary hota hai to vo represent karte hain hum relatively aur humein uske liye scales bhi mention karni padti hai yeh ho gayi hardness testing techniques abhi hum jaante hain ki jaise maine elastic aur plastic deformation ki baat ki thi jab indenter indentation hardness measurement hoti hai tab to jaise ye mera material hai aur ye indenter hai aur maine kuch load apply kiya aur us load ke saath ye indenter material mein indent karega to material mein do deformation hogi ek plastic deformation kuch is tarah se maine mark kiya yahan pe material plastically deform ho raha hai aur yahan



Elastic Plastic Deformation around Indentation



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pe material elastically deform ho raha hai to ye ho gaya ek interface mera aur is interface mein mujhe strain gradients hamesha milenge strain gradients yaani aap dekhenge ki yahan par plastic strain zyada hai yahan par elastic strain kuch is tarah se to jaise jaise main yahan se is is direction se aage badh raha hoon to aapko ek elastoplastic interface hamesha milega aur yahan par elastic recovery bhi milegi jab main yeh indenter ko wapas nikaalunga kyunki yeh jo elastic deformation hai vo recover karega aur mere paas ye plastic deformation rahega to yahan par kuch mujhe changes milenge surface to isko avoid karne ke liye ye ek mean

pressure main define karna chahta hoon jaise mean pressure jo hai vah $4p / \pi d^2$ yahan par aap dekhenge ki ye $\pi d^2/4$ agar main consider karunga yeh jo area hoga yeh projected area hoga aur maine kaha tha ki projected area pe elastic jo deformation hai uska effect kam hota hai aur isko hum dikha sakte hain yeh jo value hai $C \times \sigma_0$ aur ye σ_0 jo value hai yeh flow stress of the material hai kyunki hum connect karna chahte ye jo value hai yeh material ke properties ke saath kis tarah se connected hai aur ye jo C hai yeh constant factor hai to aap dekhenge ki yeh jo value hai yeh nothing but meri Meyer's hardness ki value thi to aap Meyer's

hardness ke baare mein padh sakte hain to yeh Meyer's hardness ki hi value hai mean pressure janrally hum dekhte hain ki ye jo C value hai agar main kuch theory istemal karunga to jaise maximum shear stress theory istemal karunga to C ki value 2.6 hogi ya agar Von Mises criteria istemal karunga to C ki value yahan pe teen milegi to hum hardness ko connect kar sakte ek material ke flow stress ke saath to yeh ho gaya elastic plastic deformation around indentation abhi hum iske implication dekhte hain ki kya ho sakta hai jaise hum dekhenge ki kuch is tarah se mujhe indentation surface ya indentation area milta hai jaise ridging type aur sinking type yeh depend



Elastic Plastic Deformation around Indentation



Ridging type

- Hard or work hardened materials
- No strain hardening:
 - Pile up of material
- Overestimate indenter diameter
- Lower hardness determination



Sinking type

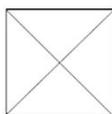
- Soft or annealed materials
- High Strain hardening:
 - NO Pile up of material
- Measured indentation diameter is smaller
- Higher hardness determination

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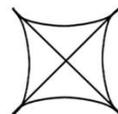
karta hai mere material ke behavior ke upar jaise mere paas kuch hard aur work hardened material hai to aap dekhenge ki mujhe ridging type milega aur soft aur annealed materials se mujhe to sinking type behavior milega aur aap dekhenge ki yeh kyun aata hai kyunki yahan pe yeh material already hard hai to yahan pe strain hardening kam hogi aur yahan pe aapko milega pile up of material aur is pile up of material ke wajah se aap dekhenge ki jo indentation diameter aap measure karoge ya indentation dimension jo aap measure karoge vo over estimate karoge agar ye dimension over estimate ho raha hai to aap dekhenge ki hum jo hardness value evaluate karenge vo lower rahegi actual value se uski ke



Elastic Plastic Deformation around Indentation

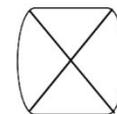


Perfect



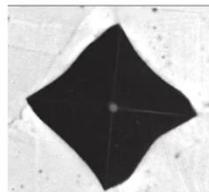
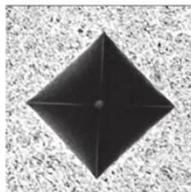
Pincushion (sinking type)

- Well annealed metals
- Overestimate of indentation diagonals
- Lower hardness determination



Barrel (ridging type)

- Cold worked metals
- Reduced length of indentation diagonals
- Higher hardness determination



Hardness measurements

- Errors
- Measuring the diameter of the indentation
- Elastic recovery

Images are for educational and teaching purpose only

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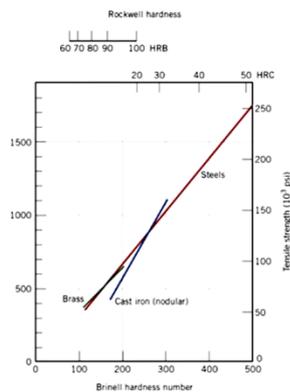
tulna mein agar mere paas soft aur annealed material hai to aap dekhenge ki yahan pe strain hardening hoga material ka aur yahan par koi pile up nahi hoga material ka material deform ho

sakta hai aur yahan par aap dekhenge ki yeh jo diameter hai sinking type mein yeh measure diameter hai vah smaller rahegi aur jo hardness hum estimate karenge vah higher hoga actual value se to yeh kuch errors develop ho sakte hain mere elastic plastic deformation around indentation ki wajah se hum is type ke defects bhi dekhte hai jab main Vickers hardness ki baat karunga to perfectly humein kuch is tarah se milna chahiye par humein kuch pincushion type milta hai ya

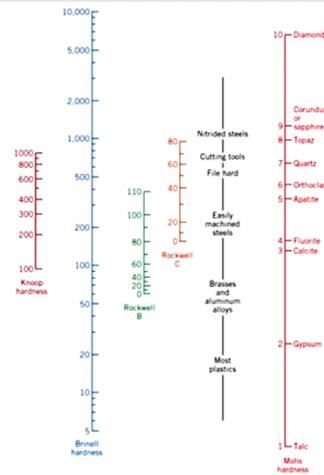
Hardness Conversion

- Often becomes necessary to convert
- No universal hardness conversion relationship exists
- Empirical
- ASM Metals Handbook

Hardness & Tensile strength



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



For Steels only (not valid for other systems)

$$TS(MPa) = 3.45 HB$$

$$TS(psi) = 500 HB$$

Tabor's relation



“Like the storminess of the seas, is easily appreciated but not readily measured...”

Hugh O'Neil, The Hardness of Metals and Its Measurement (The Sherwood Press, Cleveland, Ohio, 1934).

- The Hardness of Metals, By D. Tabor, Oxford University Press, 2000.

barrelling type indentations milte hain to yeh bhi humein pincushion type ya sinking type milta hai jo humne dikha ye well annealed metals mein milta hai yahan par hum over estimate karte hain diagonal ko aur humein hardness ki jo value milegi vo lower milegi ridging type humein milta hai jab cold work metals rehta hai aur yahan par hum dekhenge ki ye jo indentation

diagonals se vo reduced length milegi aur hum iski higher hardness determination hogi kyunki length yeh reduced milegi to yeh errors aayenge mere jab main measure karunga material ki properties ya hardness jab elastic plastic deformation rahega mere indentation ke around kuch is tarah se humein milega to yahan

par aap dekhenge ki mujhe perfect square mila hai par is kes mein aap dekhenge ki yahan par yeh jo dimension hai kuch alag hai yaani mere paas perfect square kuch is tarah se mil nahi raha hai Vickers hardness mein to yahan par humein errors ki sambhavna zyada hai to is wajah se humein errors milenge kyunki jo diameter ya dimension hum measure karenge vah alag honge actual value se kyunki humein hamare paas elastic recovery hogi to yeh ho gaya elastic plastic deformation around indentation to iske baare mein aapko material ke behavior ke baare mein ya material ke nature ke baare mein already pata hona chahiye aur us hisab se load aapko istemal karna

hoga abhi hum dekhte hain ki jaise hardness conversion humein bahut zaroori hota hai kuch kis kis case mein jaise hum hardness ko convert karna padta hai strength ke saath to humein yeh hardness conversions pata hone chahiye however yeh jo hardness conversion hai vah empirical hai aur yeh koi universal relationship nahi hote hai aap ASM Metal Handbook refer kar sakte hain is kuch hardness conversion ke liye ye empirical relations ke liye to yahan par kuch example main yahan par dena chahta hoon humne different hardness techniques istemal kiye jaise humne dekha tha Mohs hardness phir yahan par kuch material maine mark kiye aur yahan par hum dekhenge ki Rockwell C humne

istemal kiya yahan pe Rockwell B istemal kiya hai yahan pe Brinell istemal kiya hai yahan pe Knoop hardness istemal kiya hai to agar maan lete hain ki agar main kuch yeh easily machined steels ko main hardness test kar raha hoon Rockwell C se hardness test kar raha hoon to aap dekhenge ki Rockwell C mein uski value agar 20 aa rahi hai to Rockwell B mein uski value lagbhag 90 aayegi ya Brinell mein uski value aa sakti hai around 200 aur yahan pe Knoop hardness mein uski value aayengi close to 250 ya agar main Mohs scale par jaunga to iski value aayegi 4 se 5 ke beech mein maan lete 4.5 to aapko agar main is Rockwell C mein agar convert kar raha hoon

aur doosra material main Knoop hardness se test kar raha hoon jaise thin material se to agar aap in donon ki tulna agar aapko karni hai to aapko conversion chahiye is Rockwell C se Knoop hardness ke liye aur yeh jo conversion hai vo empirical hote aur yeh jo relationships hai available is metal handbook mein to yeh relative marking yahan par humne dikhayi hai jab main hardness aur tensile strength ke conversion ki baat karta hoon to aap dekhenge ki yahan par maine Brinell hardness number plot kiya hai aur ye HRB scale yahan pe mark ki hai aur yahan pe tensile strength kuch is tarah se plot kiya hai to aap dekhenge ki linear relation mil raha hai mujhe yahan pe

teen different material dikhaye Brass Cast Iron aur Steels to ek kuch relation yahan par likh sakte yahan par maine steels ke liye relation diya hai jaise tensile strength steel ki main convert kar sakta hoon agar main HB mein measure kar raha hoon hardness to yeh ho jayegi 3.45 hardness in B scale to yahan pe yeh jo value hai tensile strength ki vo MPa mein hai agar main PSI mein dekunga to yeh close to 500 HB hai to agar mujhe hardness pata hai steel ki to agar main 3.45 se multiply karunga to main janrally tensile strength predict kar sakta hoon similarly agar main brass ke liye dekhunga ya cast iron ke liye dekhunga to unka relation yahan pe mention kiya hai ye sirf steels ke liye valid hai to aapko

careful hona padega ki aap kis relation ko kis empirical relation ko istemal kar rahe hain apne hardness to tensile strength ke conversion mein to is part mein humne hardness ki importance dekhi yeh jo line hai yeh Hugh O'Neill ne di thi The Hardness of Metals and its Measurement yeh book mein aap isko refer kar sakte ho unhone kaha tha ki jo sea mein samundar mein jo laate hoti hai ya waves hoti hai ya storm hota hai vah easily hum dekh sakte hain appreciate kar sakte hain but vah aasani se measure nahi kar sakte hum sirf relatively baat kar sakte hain usi tarah se hardness ki hum baat karte hain to jo table ka maine example diya tha conversion ka vo

aap is book ko refer karke dekh sakte hain The Hardness of Metals to is part mein humne hardness ke baare mein dekha hardness ka importance humne dekha hardness ke different measuring techniques dekhi aur last mein humne hardness ke kuch conversions dekhe next part mein hum padhenge impact testing ke baare mein abhi ke liye rukta hoon dhanyawad