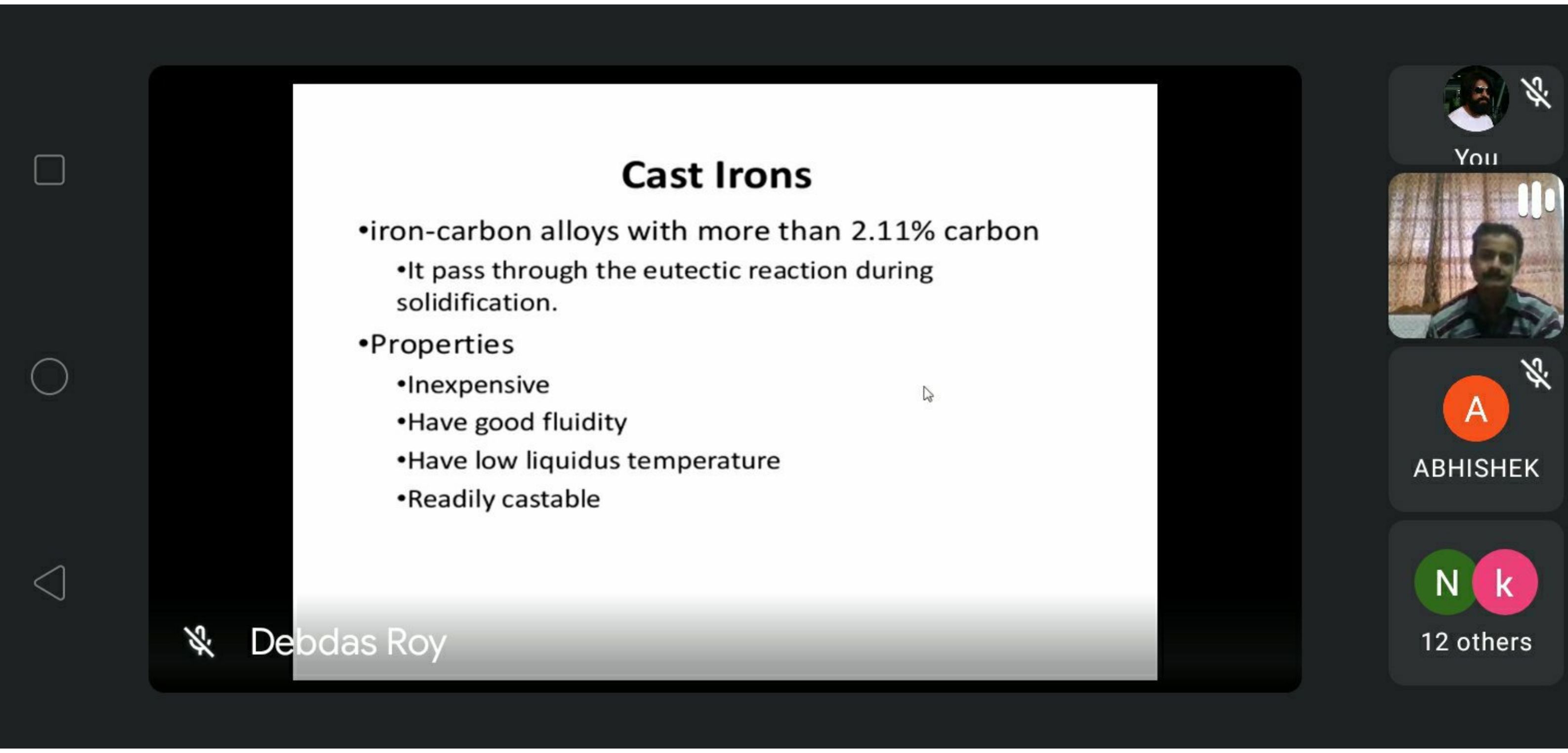

Cast Irons
•iron-carbon alloys with more than 2.11% carbon
•It pass through the eutectic reaction during solidification.
•Properties
•Inexpensive
•Have good fluidity
•Have low liquidus temperature
•Readily castable
Debdas Roy
You
ABHISHEK
12 others

Cast Irons

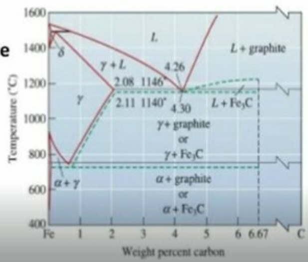
- typically cast iron contains 2–4% C and 0.5–3% Si
- Effect of Si
  - **reduces the amount of carbon contained in the eutectic. carbon equivalent (CE):**

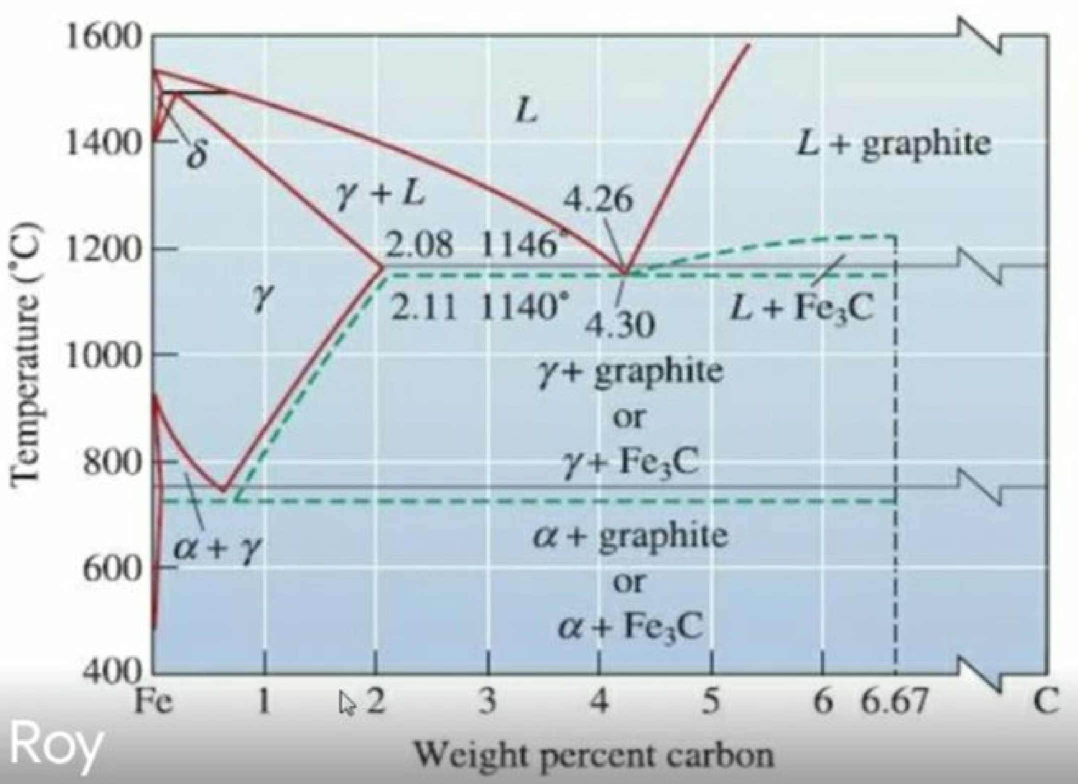
$$CE = \%C + \frac{1}{3}\%Si$$

  - **Enhances oxidation and corrosion resistance by forming a tight adhering surface oxide.**
  - **It is a *graphite stabilizing element.***
- **Eutectic Reaction in Cast Irons**
  - **Metastable phase diagram**

$$L \rightarrow \gamma + Fe_3C$$

  - **Stable rxn** $L \rightarrow \gamma + \text{graphite}$





1600
1400
1200
1000
800
600
400
Temperature (°C)
L
L + graphite
δ
γ + L
4.26
2.08 1146°
γ
2.11 1140°
4.30
L + Fe3C
γ+ graphite
or
γ+ Fe3C
α + γ
α + graphite
or
α + Fe3C
Fe
1
2
3
4
5
6 6.67
C
Weight percent carbon

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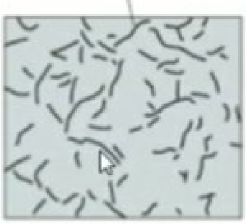
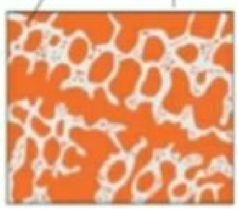
Cast Irons

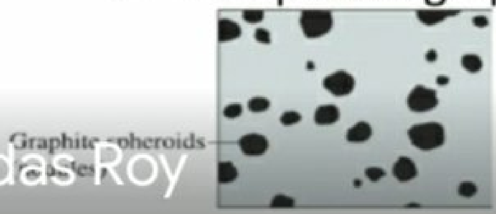
- *The microstructure of cast iron has two extremes*
  1. *Liquid* $\longrightarrow$ *austenite + Fe_3C (white cast iron)*
  2. *Liquid* $\longrightarrow$ *austenite + graphite (gray, ductile...)*
- *graphite formation is promoted by*
  - *Slow cooling*
  - *High C and Si content*
  - *Heavy or thick section size*
  - *Inoculation particles*
  - *Presence of S, P, Al, Ni, Sn, Mn, Cu, Cobilt, antimony*
- Formation of cementite (*Fe_3C*) is favored by
  - Fast cooling
  - Low C and Si contents
  - Thin sections
  - Alloying elements, titanium, vanadium, zirconium, chromium, manganese, and molybdenum

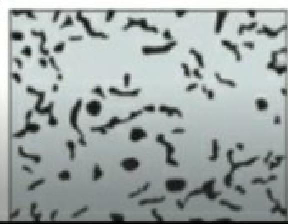
Types of Cast Iron

- Depending on chemical composition, cooling rate, types and amount of inoculants that are used we can have
  a. Gray iron
  b. White iron
  c. Malleable iron
  d. Ductile iron
  e. Compacted graphite iron









- **Gray cast iron**
  - The least expensive and most common type
  - Characterized by formation of graphite
  - Typical composition ranges from 2.5-4.0% C, 1.0-3.0% Si, and 0.4-1.0% Mn.
  - contains small, interconnected graphite flakes that cause low strength and ductility.
  - It is the most widely used cast iron
  - It is named for the dull gray color of the fractured surface.
  - The gray irons are specified by a class number of 20 to 80.
- Properties
  - high compressive strength,
  - good machinability,
  - good resistance to sliding wear,
  - good resistance to thermal fatigue,
  - good thermal conductivity, and
  - good vibration damping.

Gray CI

- **Application**;
  - Damping vibrational energy
    - Base structures for machines and heavy equipment
  - High resistance to wear.
  - High fluidity at casting temperature
    - Intricate shapes; Low casting shrinkage allowance.
      - (strength is not a primary consideration)
      - Tensile strength 120 – 300 MPa
    - Small cylinder blocks, cylinder heads, pistons, liners, clutch plates, transmission cases.
    - gears, flywheels, water pipes, engine cylinders, brake discs, Machinery beds

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GRAY IRON PRODUCTS SAMPLES

- **White cast iron**
  - is a hard, brittle alloy containing massive amounts of Fe_3C.
  - A fractured surface of this material appears white, hence the name.
  - Features promoting formation of cementite over graphite
    - A low carbon equivalent (1.8-3.6 %C, 0.5-1.9%Si, 0.25-0.8%Mn) and
    - Rapid cooling
- A group of highly alloyed white irons are used for their hardness and resistance to abrasive wear.

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White CI

- **Application:**
  - brake shoes, shot blasting nozzles, mill liners, crushers, pump impellers and other abrasion resistant parts.
  - wear-resistant surface, example, as rollers in rolling mills. Generally, white iron is used as an intermediary in the production of yet another cast iron, **malleable iron**
- White fracture surface
- No graphite, because carbon forms Fe_3C or more complex carbides
- Abrasion resistant
- Often alloyed

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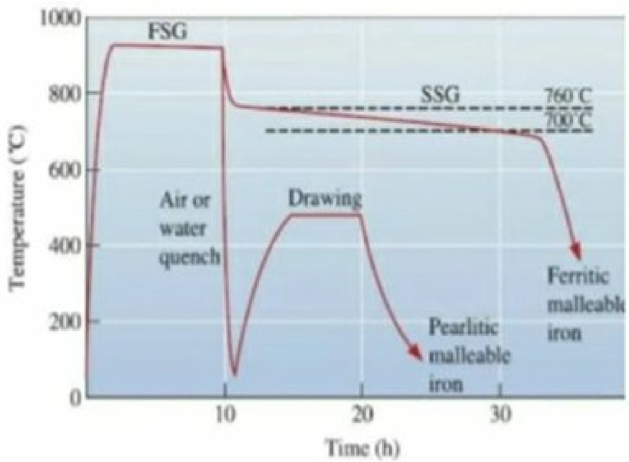
- **Malleable cast iron**
  - formed by the heat treatment (in range of 900°C) of unalloyed 3%C white cast iron (carbon equivalent 2.5%C, 1.5%Si)
  - the cementite dissociates into its component elements (graphite clumps, or nodules)
  - It exhibits better ductility than gray or white cast irons. It is also very machinable.
- The production steps
- **first stage graphitization:** cementite decomposes to the stable austenite and graphite phases
- **second stage graphitization:** slow cooling through eutectoid temperature to make *ferritic malleable iron*

- *when austenite is cooled in air or oil Pearlitic malleable iron is obtained (*pearlite or martensite.*)*
- **Drawing:** is a heat treatment that tempers the martensite or spheroidizes the pearlite.



Application

Connecting rods, transmission gears, and differential cases for the automotive industry, and also flanges, pipe fittings, and valve parts for railroad, marine, and other heavy-duty services

parts of power train of vehicles, bearing caps, steering gear housings, agricultural equipment, railroad equipment

- **Ductile or nodular cast iron**
  - contains spheroidal graphite particles.
  - produced by treating liquid iron with a carbon equivalent of near 4.3% with magnesium
- Steps
  - **Desulfurization**: CaO is used to remove sulfure and oxygen from the liquid.
  - **Nodulizing:** Mg in dilute form (MgFeSi alloy) is added, a residual of 0.03%Mg must be present after treatment in order for spheroidal graphite to grow
- **inoculation:** heterogeneous nucleation of the graphite is essential
- **Fading:** occurs by the gradual, nonviolent loss of Mg due to vaporization and/or reaction with oxygen

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Ductile or nodular cast iron

- **Application:**
  - **valves, pump bodies, crankshafts, high-strength gears (heavy duty gears) and machine, rollers, slides, die material having high strength and high ductility.**
- Inoculation with Ce or Mg or both causes graphite to form as spherulites, rather than flakes
- Also known as spheroidal graphite (SG), and nodular graphite iron
- Far better ductility than grey cast iron

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- **Compacted graphite cast iron:** contains rounded but interconnected graphite also produced during solidification
- intermediate between flakes and spheres with numerous rounded rods of graphite that are interconnected to the nucleus of the eutectic cell.
- **vermicular graphite:** forms when ductile iron fades
- permits strengths and ductilities that exceed those of gray cast iron, but allows the iron to retain good thermal conductivity and vibration damping properties.

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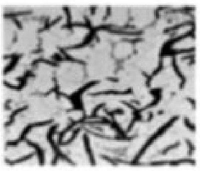
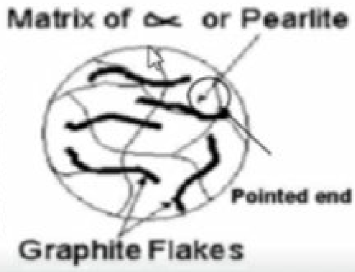
The mechanical characteristic of Gray cast Irons - summary

- **Less hard and brittle**
- **Very weak in tension due to the pointed and sharp end of graphite flakes, where the failure of component initiated at this point.**
- **Good during compression which graphite acts as a cushion or sponge that could absorb the compression energy.**
- Low shrinkage in mould due to formation of graphite flakes.
- Good dry bearing qualities due to graphite.

THE MICRISTRUCTURE OF GREY CAST IRON





GREY CAST IRON PRODUCTS

Sprockets

Park Bench

Manhole Covers with Frames

Gas Burners

White Cast Irons - summary

- The composition of Carbon and Silicon contents for white cast irons are in range between 2.5 to 4.0% and less than 1.0% respectively.
- With a rapid cooling rate most of the carbon in the cast irons consist of pearlite and cementite (Fe_3C).
- The mechanical characteristic of White cast Irons are as follows:
  - Relatively very hard, brittle and not weldable compared to gray cast iron, since it is obtained from rapid cooling process.
  - When it's annealed, it becomes malleable cast iron.
- A fracture surface of these alloy has a white appearance and it is called white cast iron.
- <u>Typical Uses</u>:

  Necessitate a very hard and wear resistance surface such as rollers in rolling mills, railroads wheel.

THE MICRISTRUCTURE OF WHITE CAST IRON

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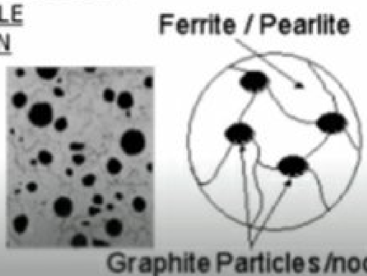
Ductile (Nodular) Cast Irons - summary

- **Ductile cast iron, which is sometimes called nodular or spheroidal graphite cast iron. It gets this name because its carbon is in the shape of small spheres, not flakes.**
- **Magnesium or cerium is added to the iron before casting occurs. The effect of these material is to prevent the formation of graphite flakes during the slow cooling of the iron.**
- **The structures of the cast irons is mainly pearlite with nodules of graphite.**
- **A heat treatment process can be applied to a pearlite nodular iron to give a microstructure of graphite nodules in ferrite. The ferrite structure is more ductile but has less tensile strength than the pearlite form. It's also weldable.**

- **<u>Typical Uses</u>:**
  Valves, pump bodies, gears crankshafts, and other machine components.

TEE pipe

<u>THE MICRISTRUCTURE OF DUCTILE CAST IRON</u>



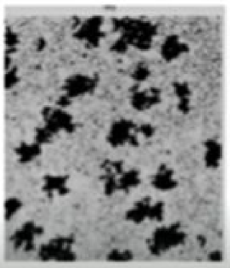
Malleable Cast Irons - summary

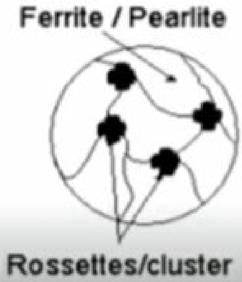
- **Malleable cast iron is produced by the heat treatment of white cast irons.**
- **Heating white iron at temperatures 800 c to 900 c for 50 hours in a neutral atmosphere (to prevent oxidation) causes a decomposition of the cementite, forming graphite in the form of clusters/ rossettes surrounded by a ferrite or pearlite matrix depending on cooling rate.**
- **The mechanical characteristic of malleable cast iron is similar to nodular cast iron and give higher strength and more ductility and malleability. The silicon content is low.**

MALLEABLE CAST IRON PRODUCTS

CLAMPS

THE MICRISTRUCTURE OF MALLEABLE CAST IRON





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Effect of alloying elemets

General Characteristics of White Cast Irons

- White Cast Irons contain **Chromium to prevent formation of Graphite** upon solidification and to ensure stability of the carbide phase.
- Usually, **Nickel, Molybdenum, and/or Copper** are alloyed to prevent to the **formation of Pearlite** when a matrix of **Martensite is desired**.
- Fall into three major groups:
- Nickel Chromium White Irons: containing 3-5%Ni, 1-4%Cr. Identified by the name Ni-Hard 1-4
- The chromium-molybdenum irons (high chromium irons): 11-23%Cr, 3%Mo, and sometimes additionally alloyed w/ Ni or Cu.
- 25-28%Cr White Irons: contain other alloying additions of Molybdenum and/or Nickel up to 1.5%

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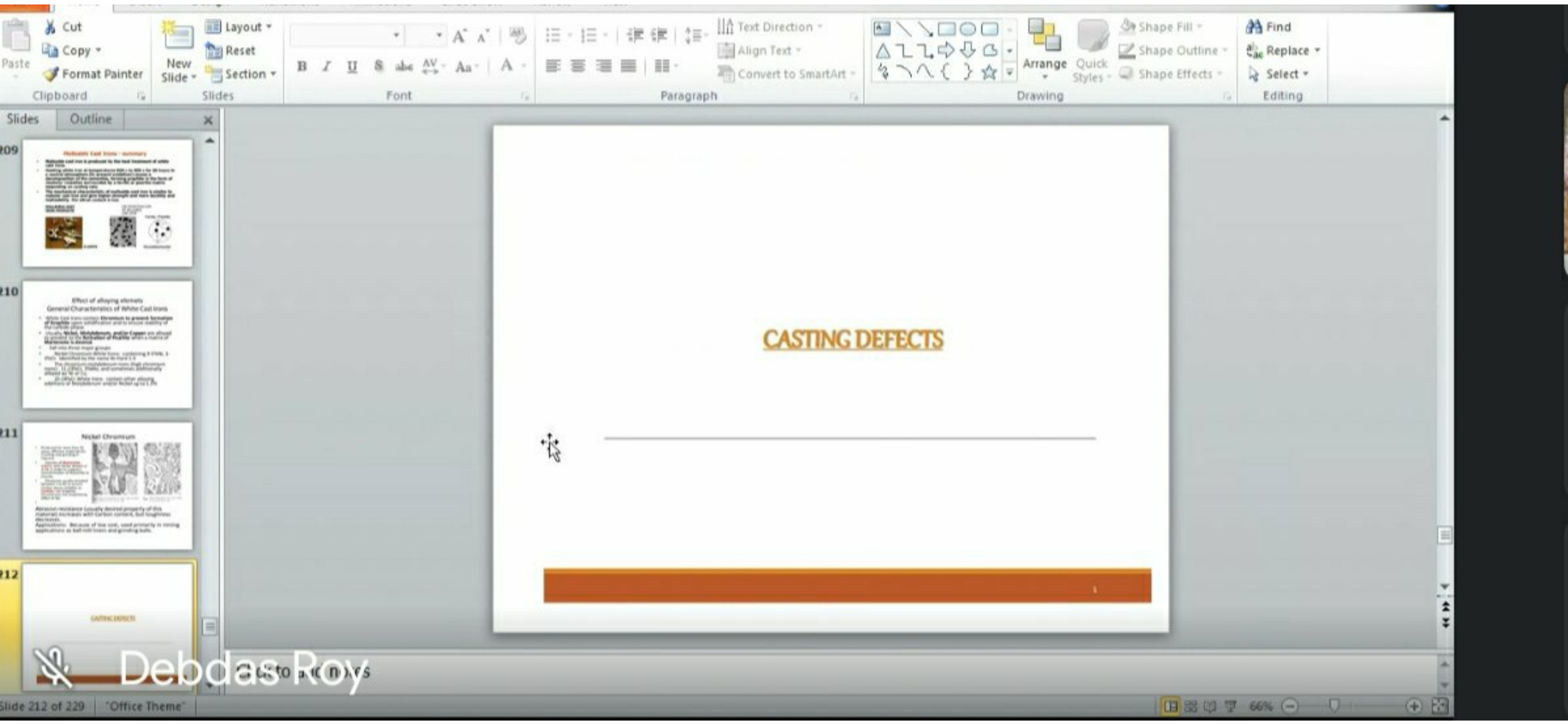
Nickel Chromium

- Produced for more than 50 years, effective materials for crushing and grinding in industry.
- Consists of **Martensite matrix,** with Nickel alloyed at 3-5% in order to suppress transformation of Austenite to Pearlite.
- Chromium usually included between 1.4-4% to ensure Carbon phase solidifies to **Carbide**, not Graphite. (Counteracts the Graphitizing effect of Ni)
-

Fig.5 Typical microstructure of class I type A nickel-chromium white cast iron. 340x

Fig.6 Typical microstructure of class I type D nickel-chromium white cast iron. 340x

Abrasion resistance (usually desired property of this material) increases with Carbon content, but toughness decreases.
Applications: Because of low cost, used primarily in mining applications as ball mill liners and grinding balls.


CASTING DEFECTS
Debdas Roy
Slide 212 of 229
"Office Theme"
Cut
Copy
Format Painter
Paste
Clipboard
New Slide
Layout
Reset
Section
Slides
Font
Paragraph
Text Direction
Align Text
Convert to SmartArt
Drawing
Arrange
Quick Styles
Shape Fill
Shape Outline
Shape Effects
Find
Replace
Select
Editing
Slides
Outline
Effect of alloying elements
General Characteristics of White Cast Irons
Nickel Chromium
66%

MISMATCH

- The casting that does not match at the parting line is known as Mismatch or Mould shift.

- **Causes :**
  - Worn out or bent clamping pins.
  - Misalignment of two halves of pattern.
  - Improper location & support of core.
  - Faulty core boxes.
  - Loose dowels.

- **Remedies :**
  - Increase strength of mould & core.
  - Provide adequate support to core.
  - Proper alignment of two halves of the pattern.
  - Proper clamping of mould box.
  - Repair or replace dowels & pin causing mismatch.

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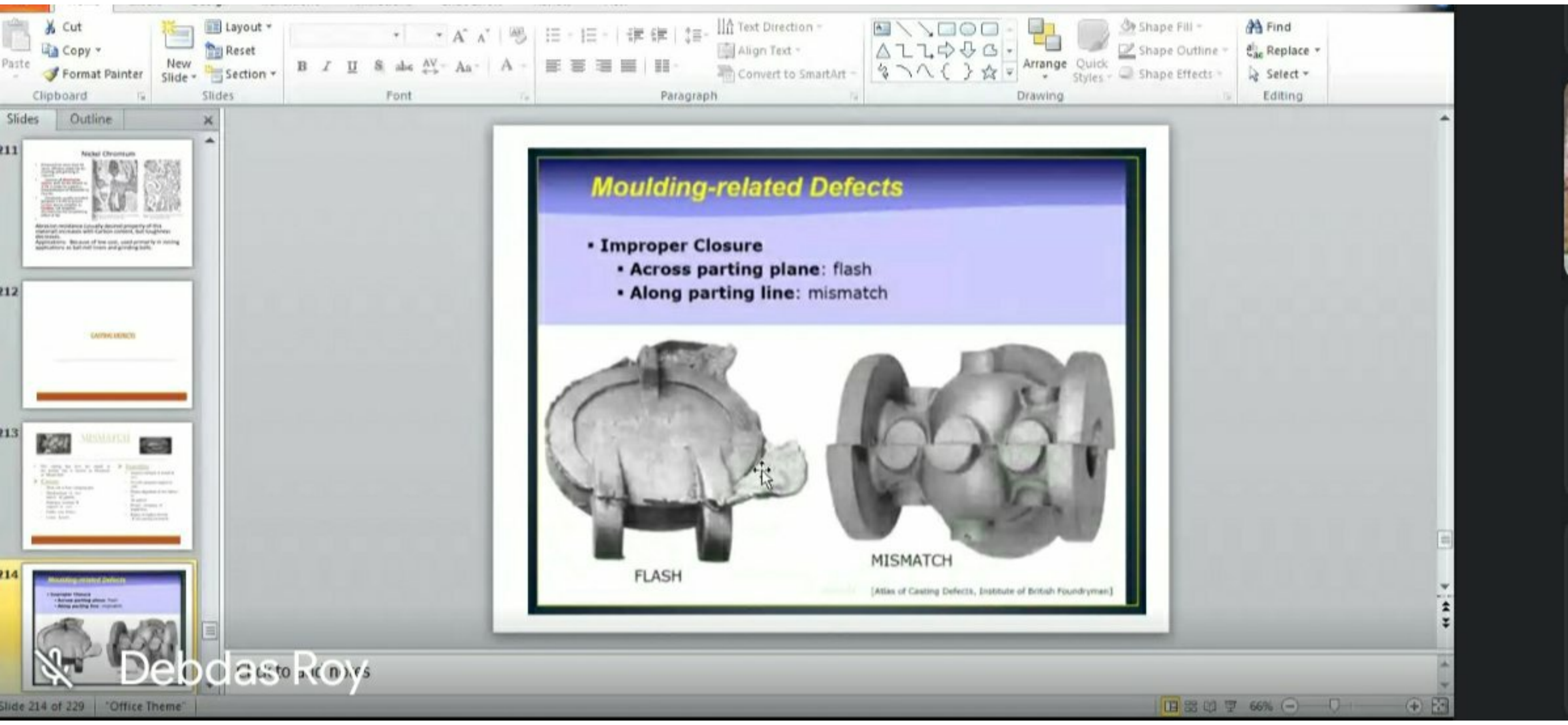
Moulding-related Defects
• Improper Closure
• Across parting plane: flash
• Along parting line: mismatch
FLASH
MISMATCH
[Atlas of Casting Defects, Institute of British Foundryman]
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Slide 214 of 229
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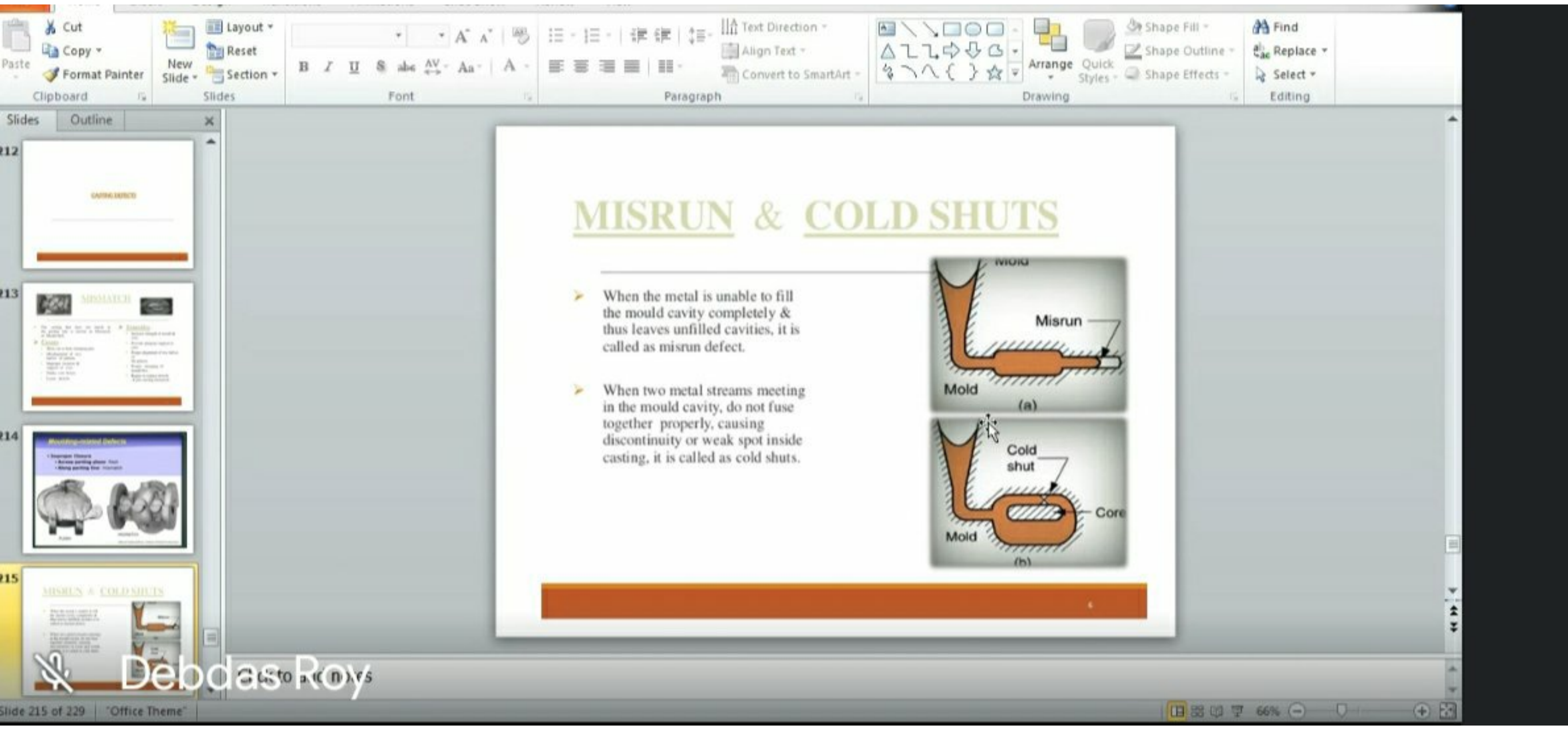
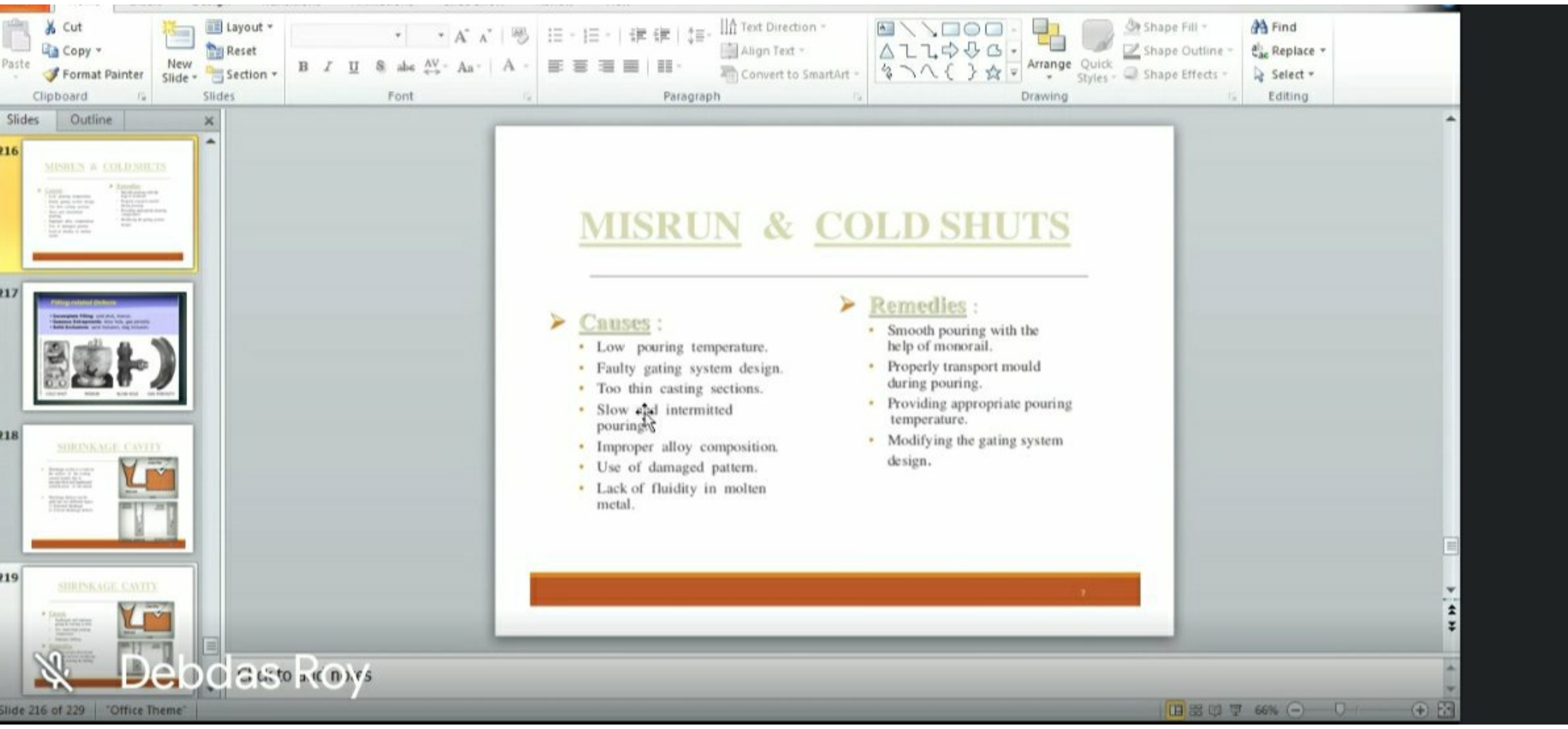

MISRUN & COLD SHUTS
When the metal is unable to fill the mould cavity completely & thus leaves unfilled cavities, it is called as misrun defect.
When two metal streams meeting in the mould cavity, do not fuse together properly, causing discontinuity or weak spot inside casting, it is called as cold shuts.
Misrun
Mold
(a)
Cold shut
Core
Mold
Debdas Roy
Slide 215 of 229
"Office Theme"


MISRUN & COLD SHUTS
Causes :
Low pouring temperature.
Faulty gating system design.
Too thin casting sections.
Slow and intermitted pouring.
Improper alloy composition.
Use of damaged pattern.
Lack of fluidity in molten metal.
Remedies :
Smooth pouring with the help of monorail.
Properly transport mould during pouring.
Providing appropriate pouring temperature.
Modifying the gating system design.
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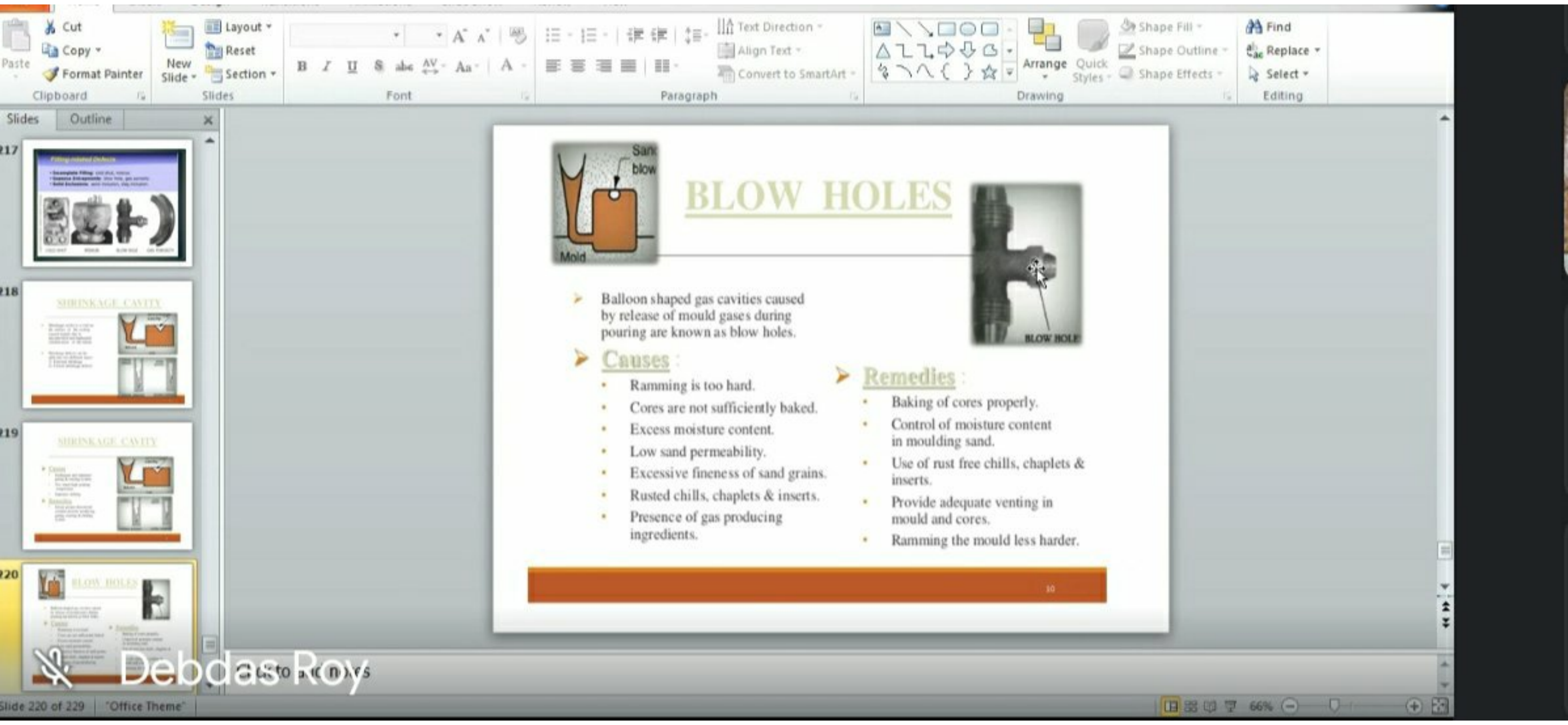
Slide 216 of 229


BLOW HOLES
Mold
Balloon shaped gas cavities caused by release of mould gases during pouring are known as blow holes.
Causes :
Ramming is too hard.
Cores are not sufficiently baked.
Excess moisture content.
Low sand permeability.
Excessive fineness of sand grains.
Rusted chills, chaplets & inserts.
Presence of gas producing ingredients.
Remedies :
Baking of cores properly.
Control of moisture content in moulding sand.
Use of rust free chills, chaplets & inserts.
Provide adequate venting in mould and cores.
Ramming the mould less harder.
BLOW HOLE
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Slide 220 of 229
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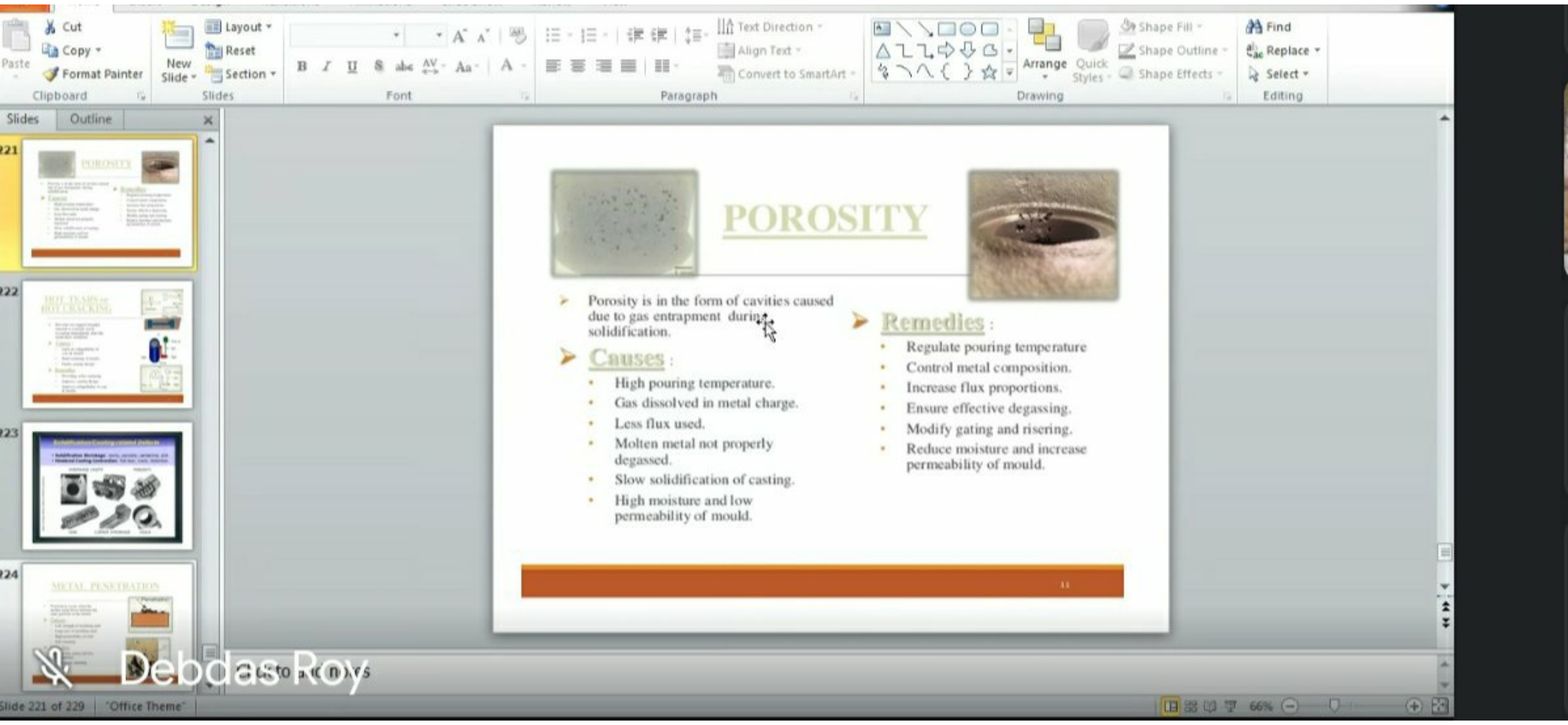
POROSITY
Porosity is in the form of cavities caused due to gas entrapment during solidification.
Causes :
High pouring temperature.
Gas dissolved in metal charge.
Less flux used.
Molten metal not properly degassed.
Slow solidification of casting.
High moisture and low permeability of mould.
Remedies :
Regulate pouring temperature
Control metal composition.
Increase flux proportions.
Ensure effective degassing.
Modify gating and risering.
Reduce moisture and increase permeability of mould.
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Slide 221 of 229
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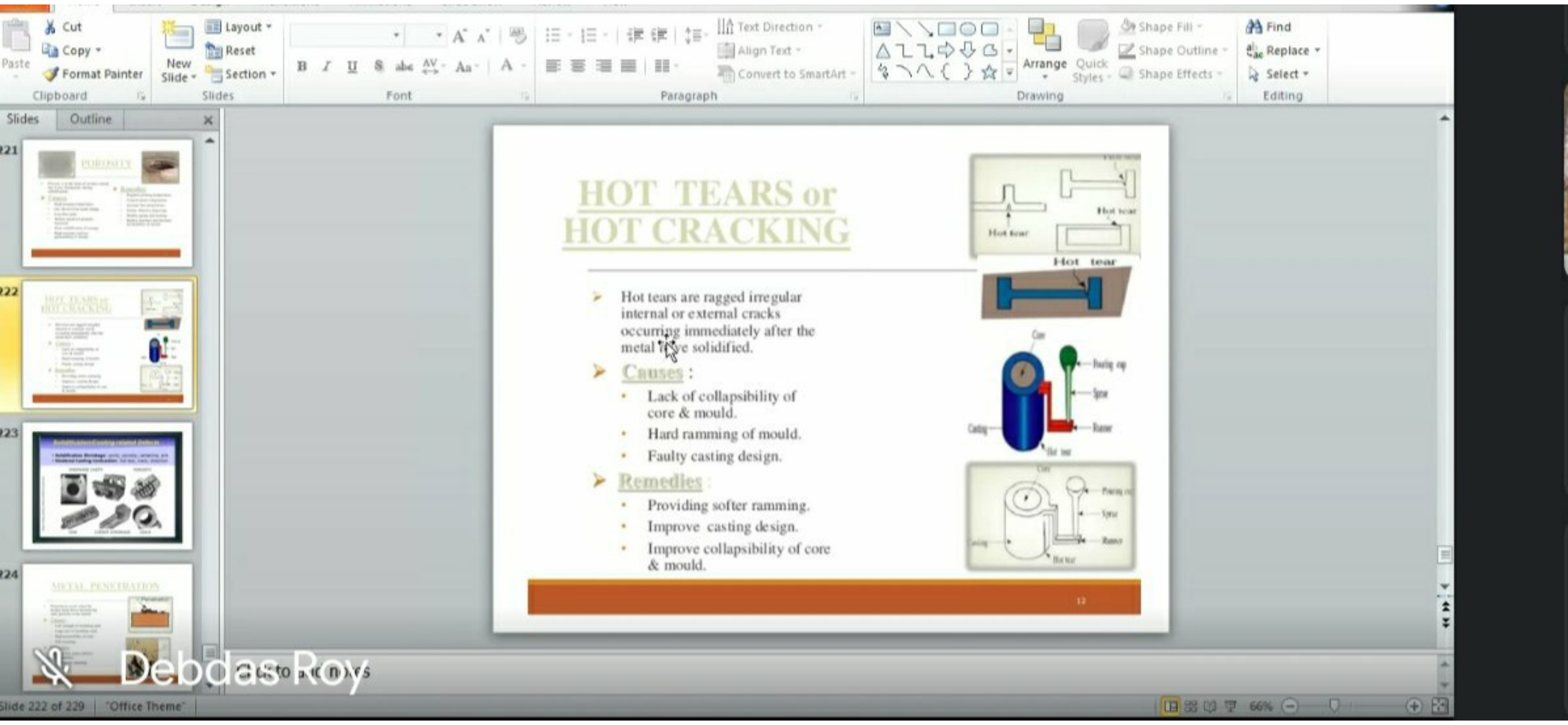
HOT TEARS or HOT CRACKING
Hot tears are ragged irregular internal or external cracks occurring immediately after the metal have solidified.
Causes :
Lack of collapsibility of core & mould.
Hard ramming of mould.
Faulty casting design.
Remedies :
Providing softer ramming.
Improve casting design.
Improve collapsibility of core & mould.
Hot tear
Hot tear
Hot tear
Core
Pouring cup
Sprue
Runner
Casting
Slide 222 of 229
"Office Theme"
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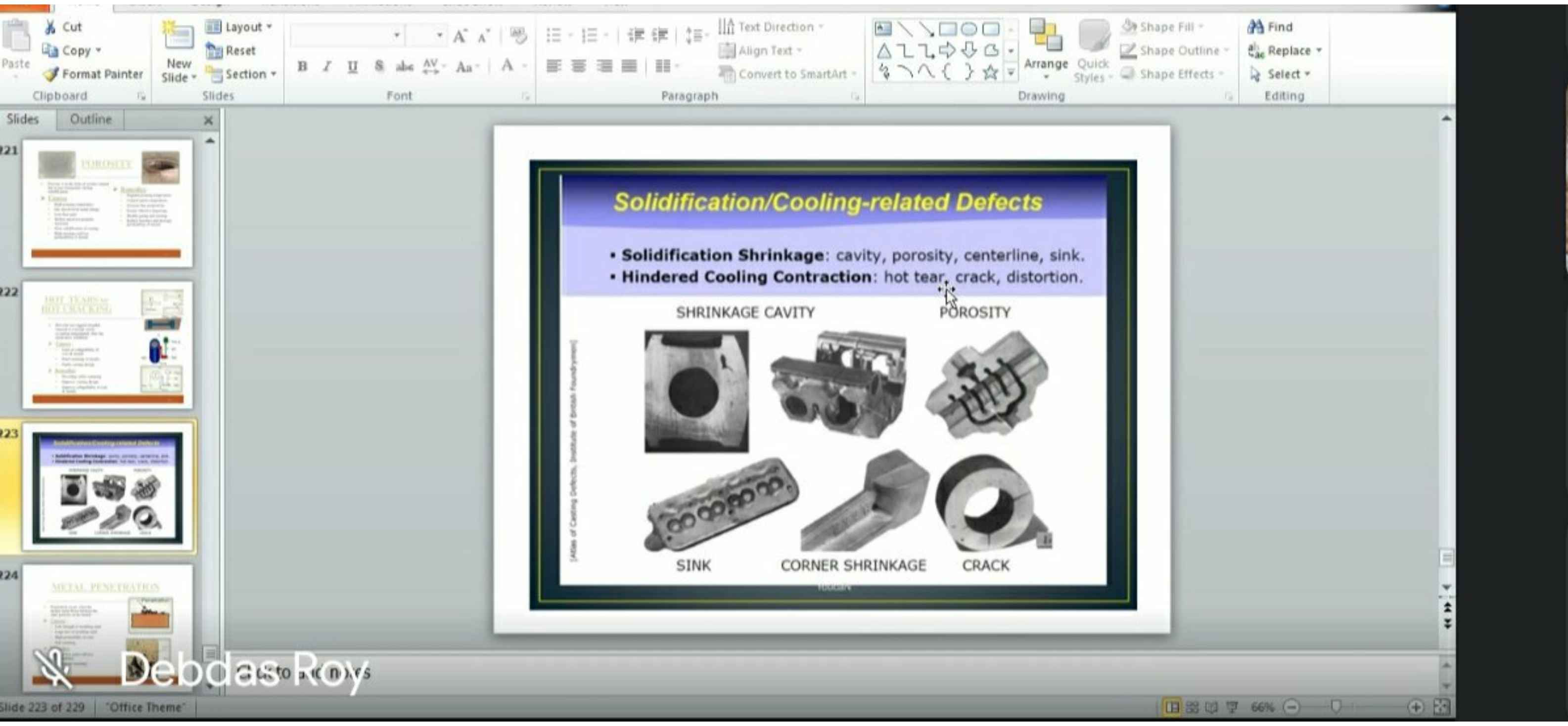
Solidification/Cooling-related Defects
• Solidification Shrinkage: cavity, porosity, centerline, sink.
• Hindered Cooling Contraction: hot tear, crack, distortion.
SHRINKAGE CAVITY
POROSITY
SINK
CORNER SHRINKAGE
CRACK
Slide 223 of 229
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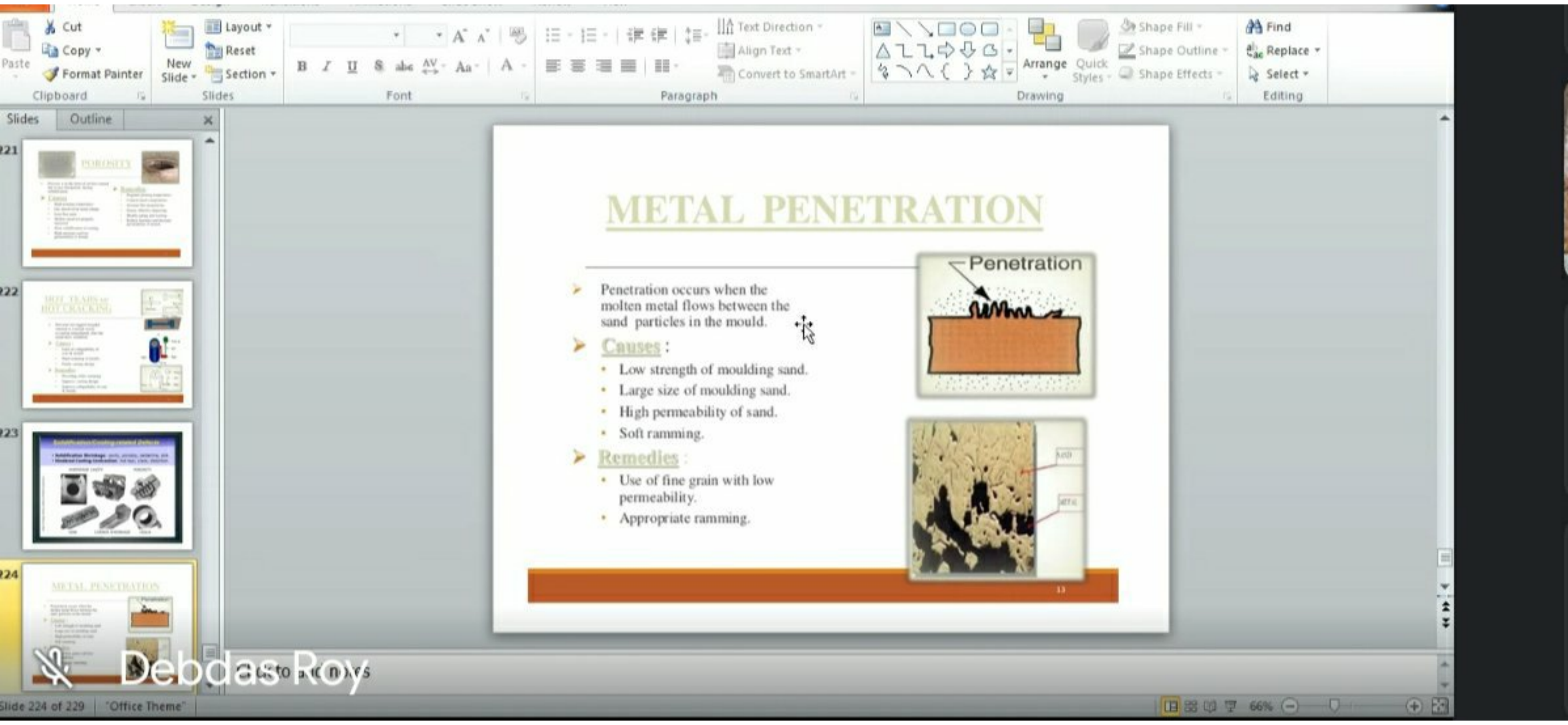
METAL PENETRATION
Penetration occurs when the molten metal flows between the sand particles in the mould.
Causes :
Low strength of moulding sand.
Large size of moulding sand.
High permeability of sand.
Soft ramming.
Remedies :
Use of fine grain with low permeability.
Appropriate ramming.
Penetration
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Slide 224 of 229
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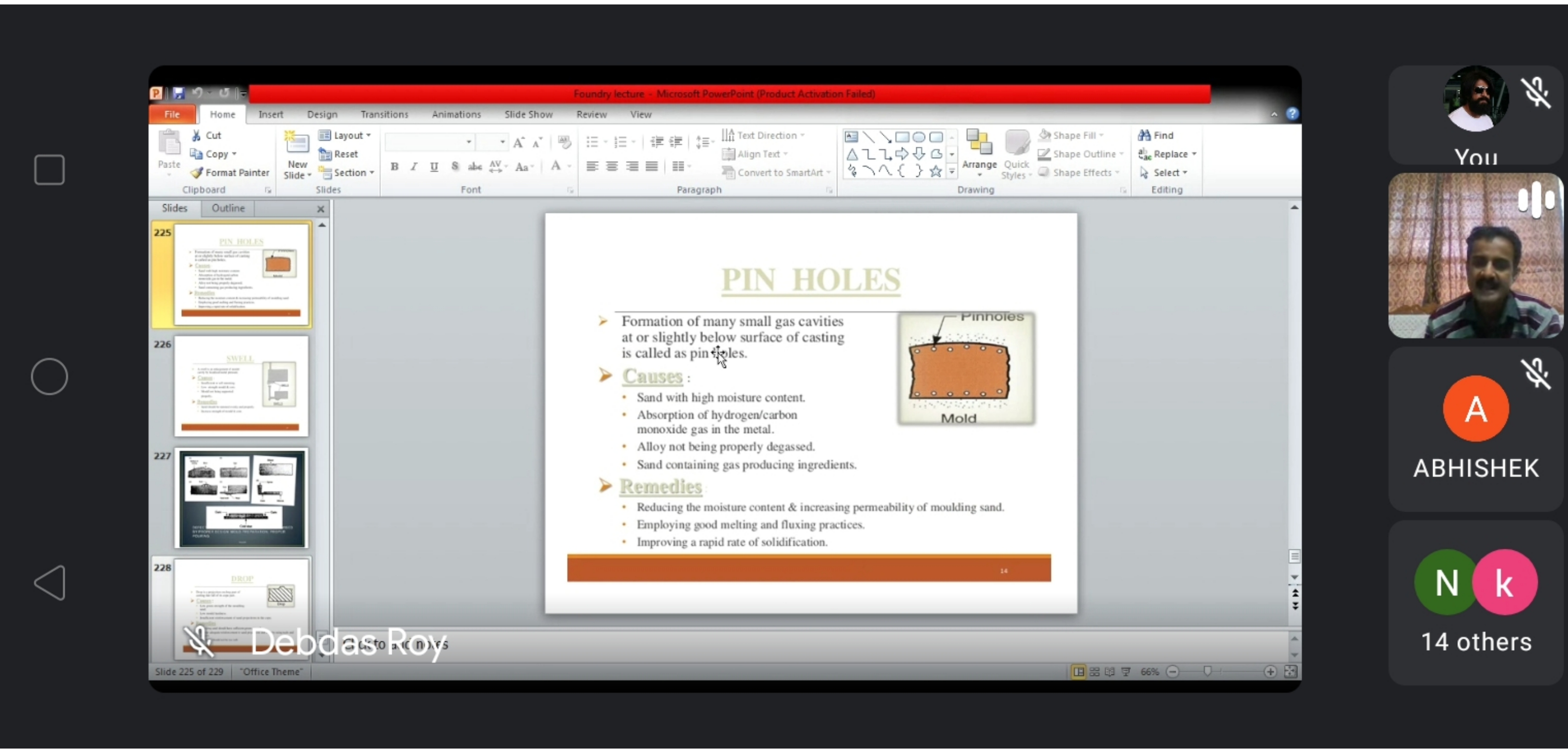
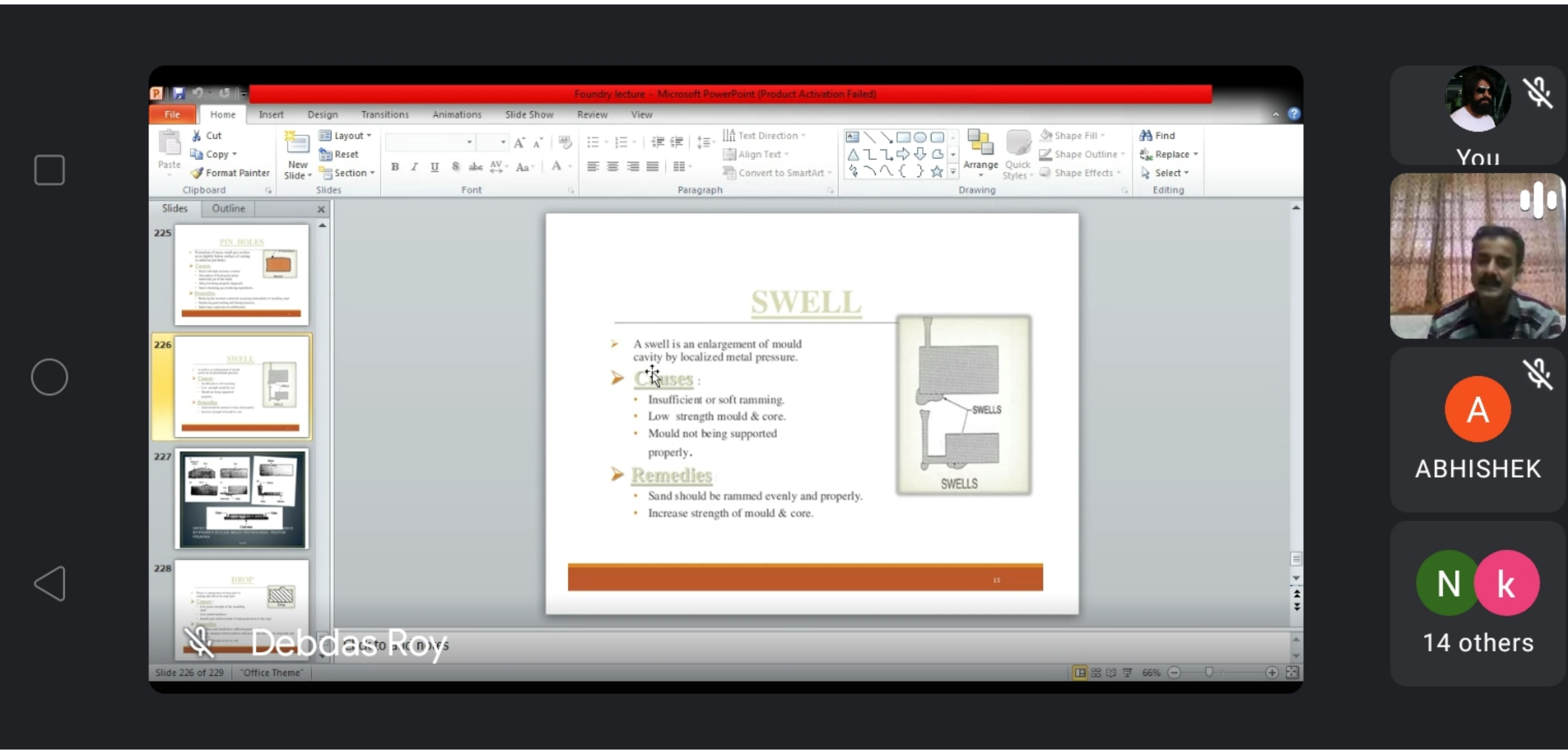
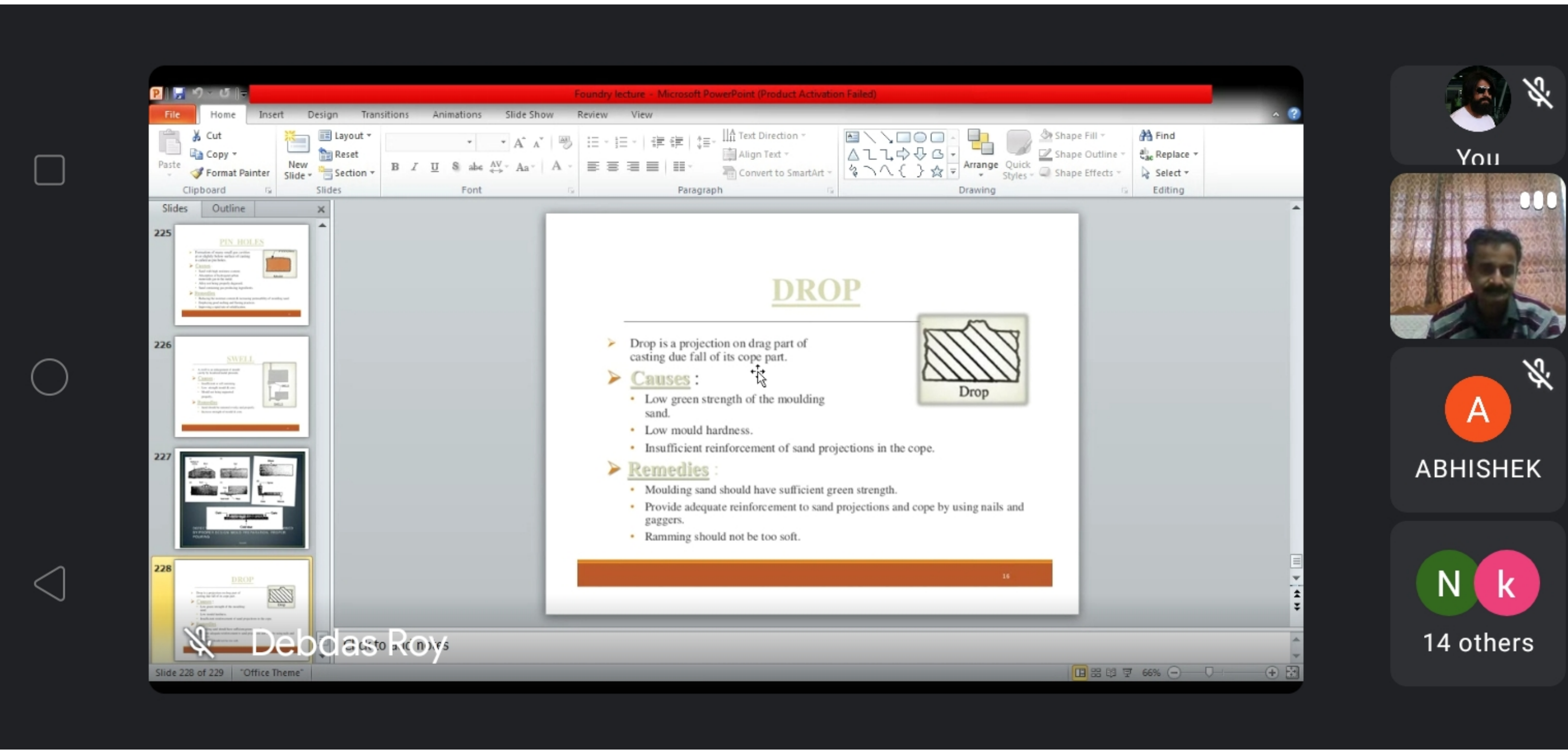
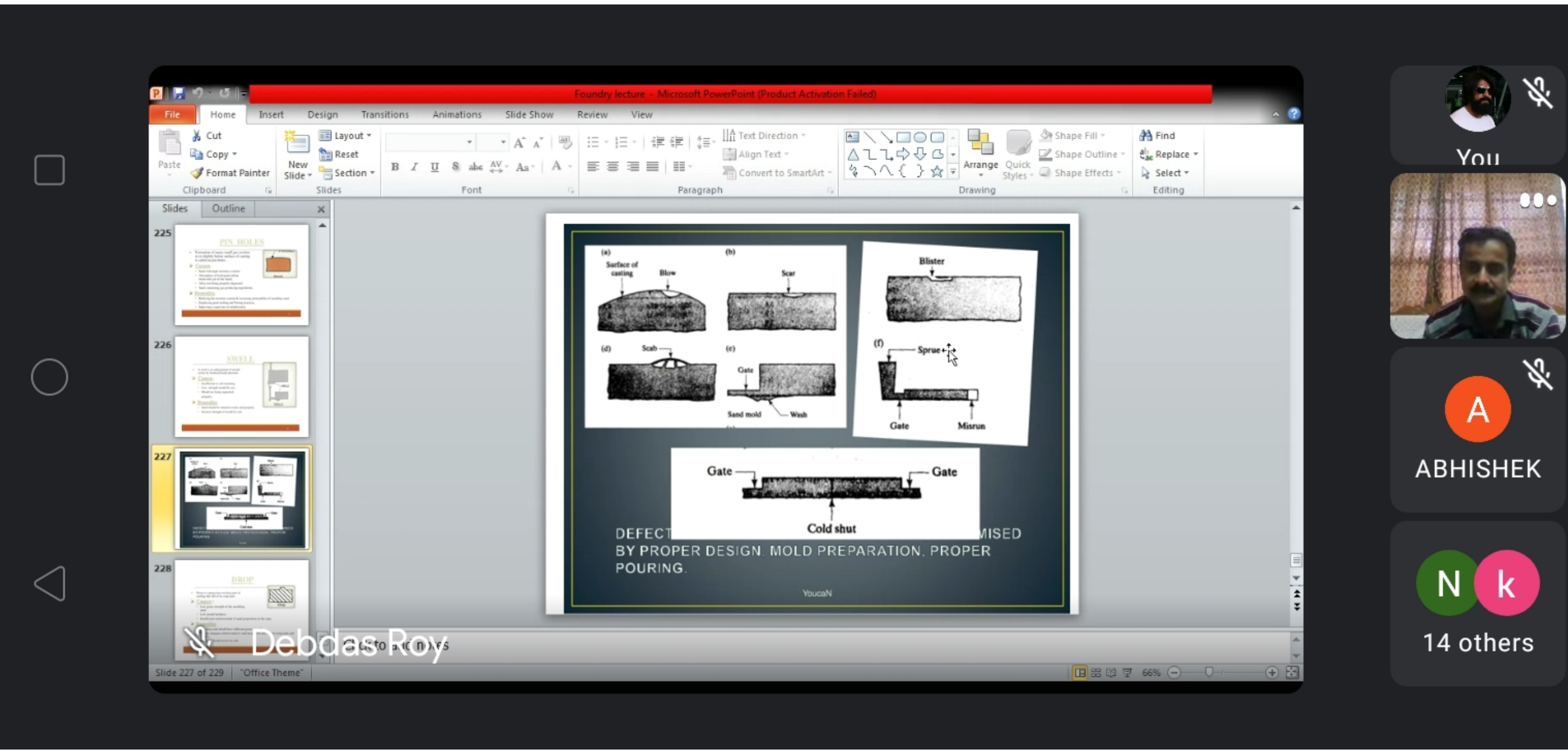

Foundry lecture - Microsoft PowerPoint (Product Activation Failed)
PIN HOLES
Formation of many small gas cavities at or slightly below surface of casting is called as pin holes.
Pinholes
Mold
Causes :
Sand with high moisture content.
Absorption of hydrogen/carbon monoxide gas in the metal.
Alloy not being properly degassed.
Sand containing gas producing ingredients.
Remedies
Reducing the moisture content & increasing permeability of moulding sand.
Employing good melting and fluxing practices.
Improving a rapid rate of solidification.
14
Slide 225 of 229
Debdas Roy
You
ABHISHEK
14 others



Foundry lecture - Microsoft PowerPoint (Product Activation Failed)
SWELL
A swell is an enlargement of mould cavity by localized metal pressure.
Causes :
Insufficient or soft ramming.
Low strength mould & core.
Mould not being supported properly.
Remedies
Sand should be rammed evenly and properly.
Increase strength of mould & core.
SWELLS
SWELLS
Slide 226 of 229
"Office Theme"
Debdas Roy
You
ABHISHEK
14 others



DROP
Drop is a projection on drag part of casting due fall of its cope part.
Causes :
Low green strength of the moulding sand.
Low mould hardness.
Insufficient reinforcement of sand projections in the cope.
Remedies :
Moulding sand should have sufficient green strength.
Provide adequate reinforcement to sand projections and cope by using nails and gaggers.
Ramming should not be too soft.
Drop
16
Foundry lecture - Microsoft PowerPoint (Product Activation Failed)
Slide 228 of 229
Debdas Roy
You
ABHISHEK
14 others


Foundry lecture - Microsoft PowerPoint (Product Activation Failed)
File
Home
Insert
Design
Transitions
Animations
Slide Show
Review
View
Surface of casting
Blow
Scar
Blister
Scab
Gate
Sand mold
Wash
Sprue
Gate
Misrun
Gate
Gate
Cold shut
DEFECT
MISED
BY PROPER DESIGN. MOLD PREPARATION. PROPER POURING.
Slide 227 of 229
"Office Theme"
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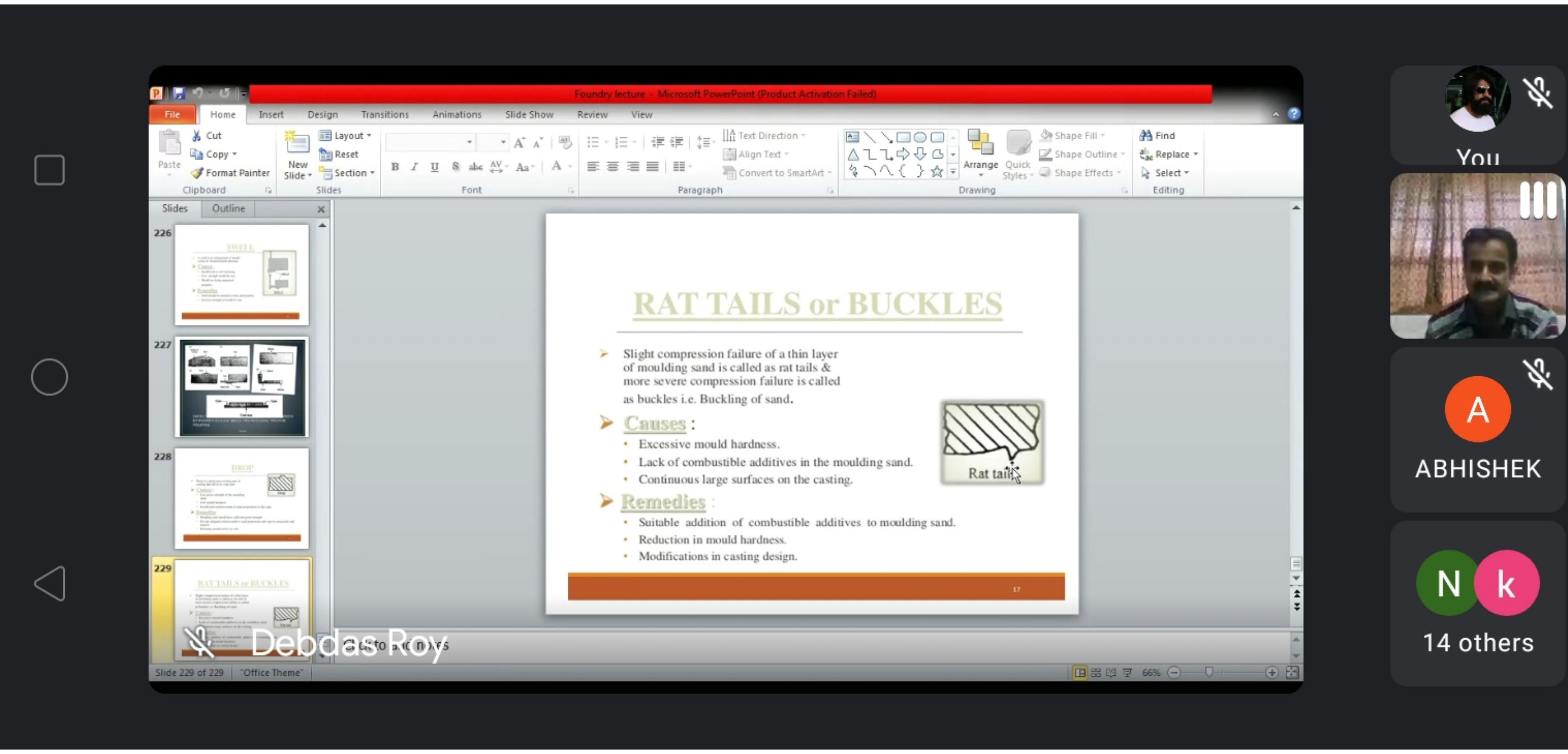
You
ABHISHEK
14 others



RAT TAILS or BUCKLES
Slight compression failure of a thin layer of moulding sand is called as rat tails & more severe compression failure is called as buckles i.e. Buckling of sand.
Causes :
Excessive mould hardness.
Lack of combustible additives in the moulding sand.
Continuous large surfaces on the casting.
Remedies :
Suitable addition of combustible additives to moulding sand.
Reduction in mould hardness.
Modifications in casting design.
Rat tail
17
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ABHISHEK
14 others
You