BACKGROUND OF CONTINUOUS CASTING BILLET DEFECTS: FORMATION MECHANISMS AND FAST & EFFECTIVE DETECTION with 5 WHYS METHOD

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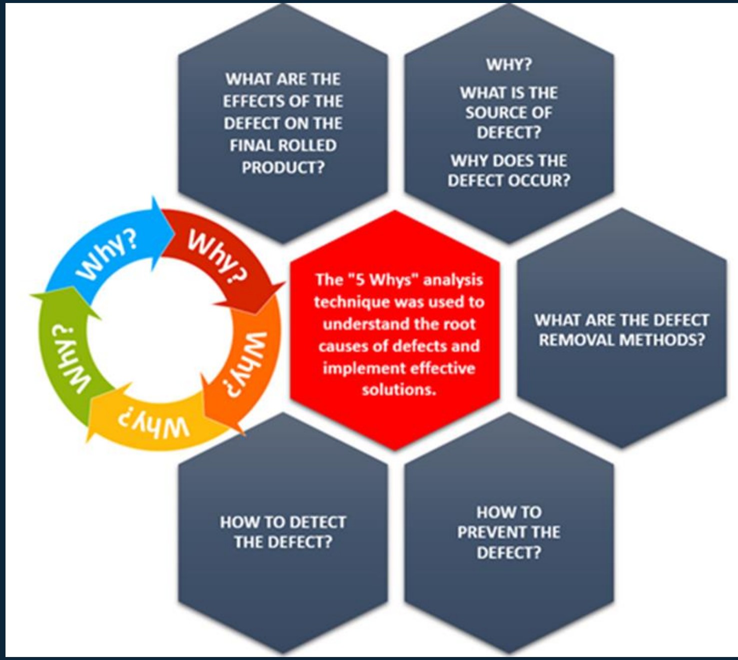
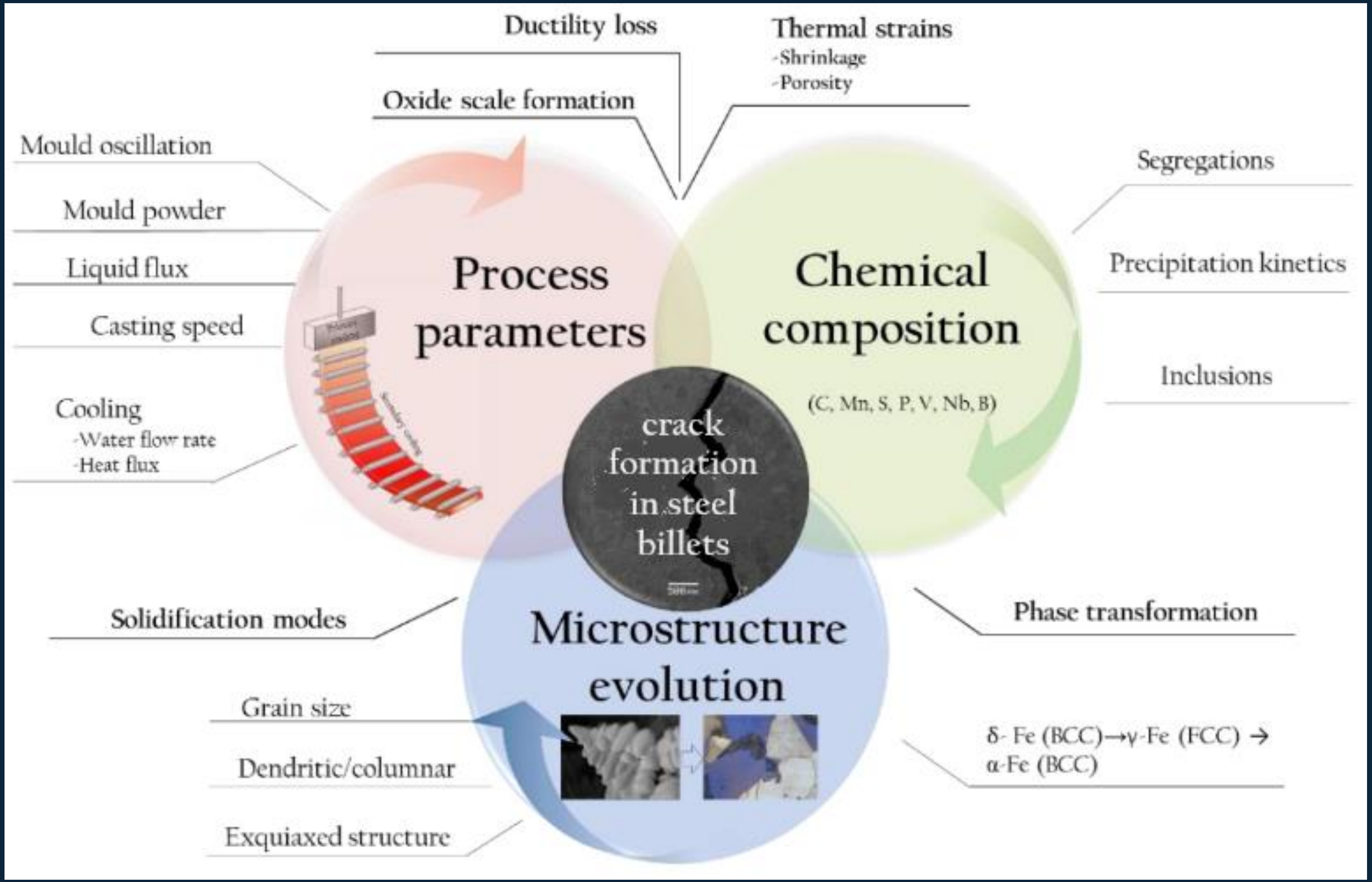
Challenge: In the Continuous Casting (CC) process, billets often suffer from defects like cracks and inclusions, which can severely impact product quality. Identifying the formation mechanisms of these defects and developing fast, effective detection methods are crucial for minimizing production losses and ensuring high-quality output.



Formation Mechanisms of Defects

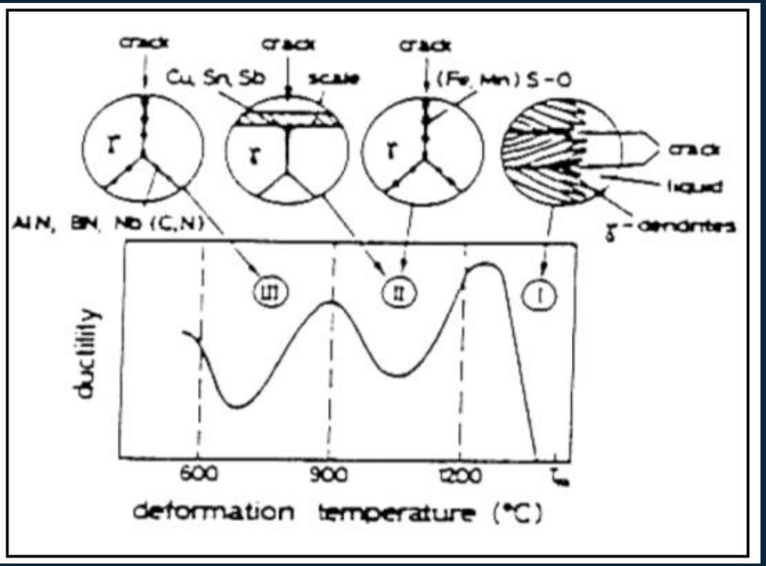


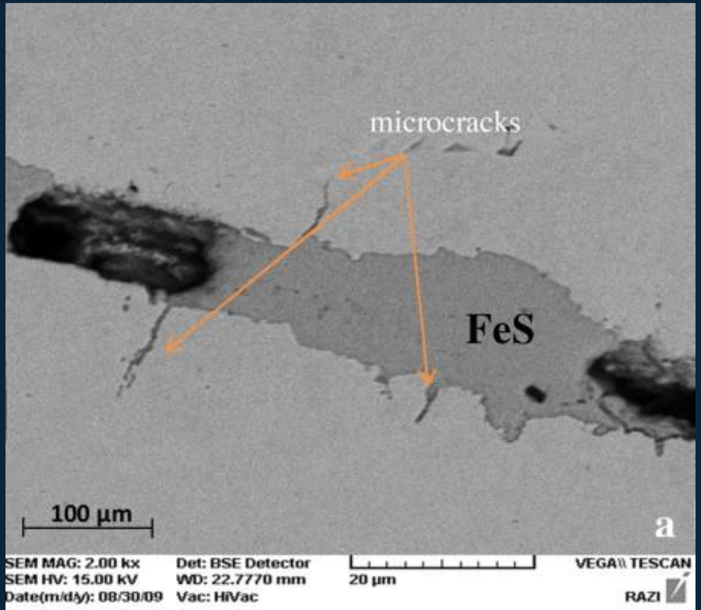
Understanding Defect Formation

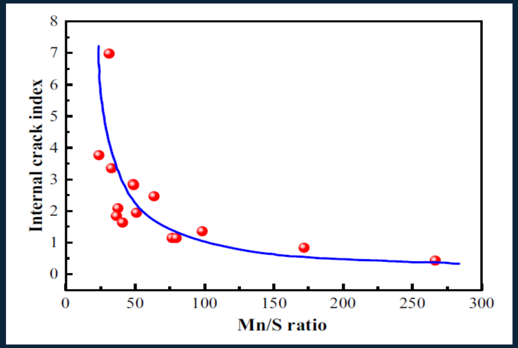
Longitudinal cracks form in the direction of steel extraction/flow.

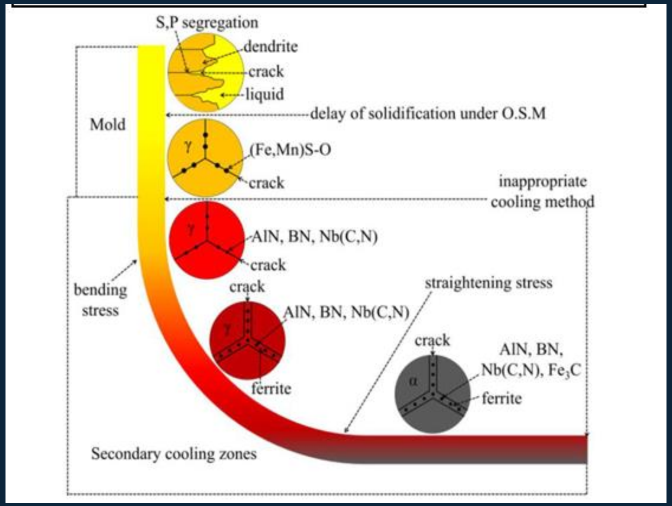
These cracks typically occur very close to the corners of the surface and are usually about 1-2 mm deep.

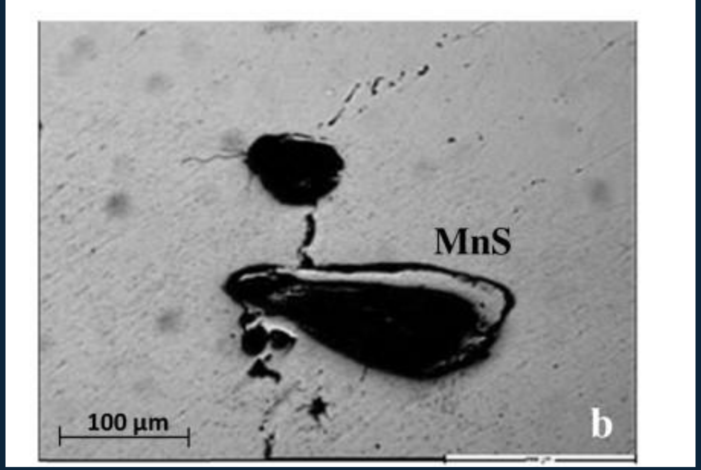
Influence of Steel Chemistry

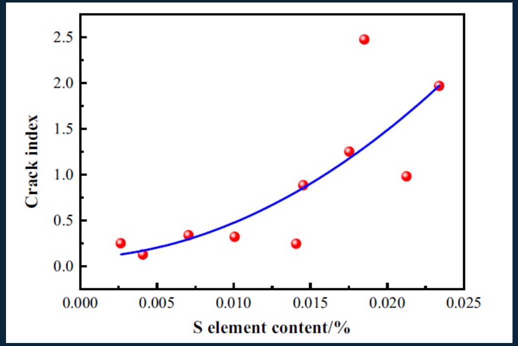


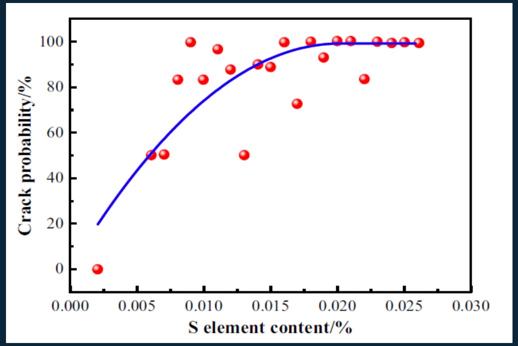


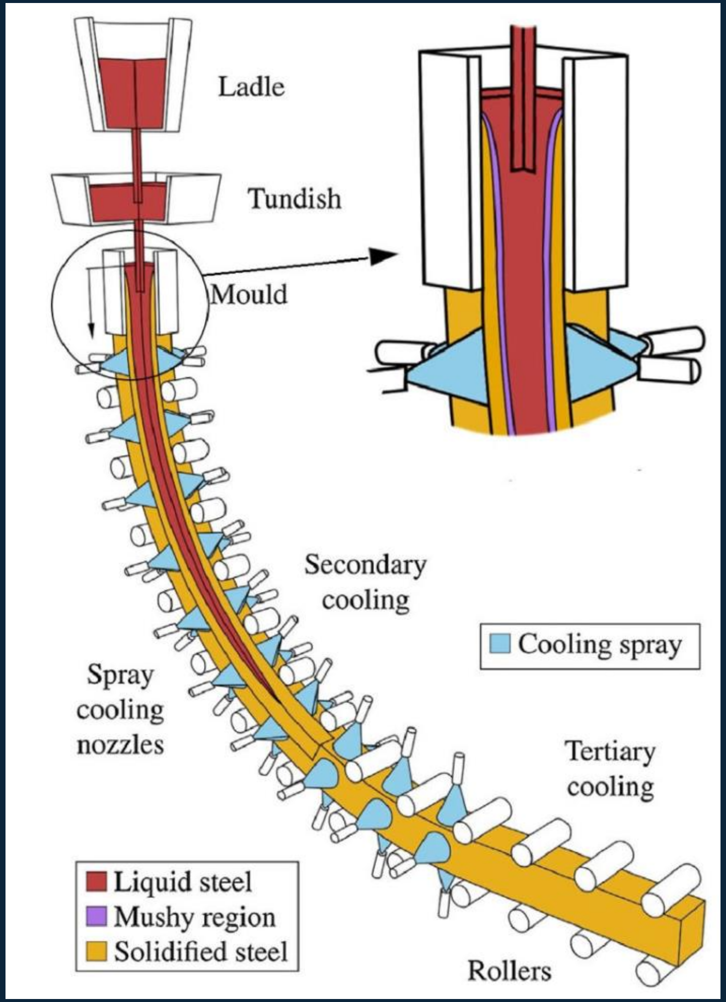


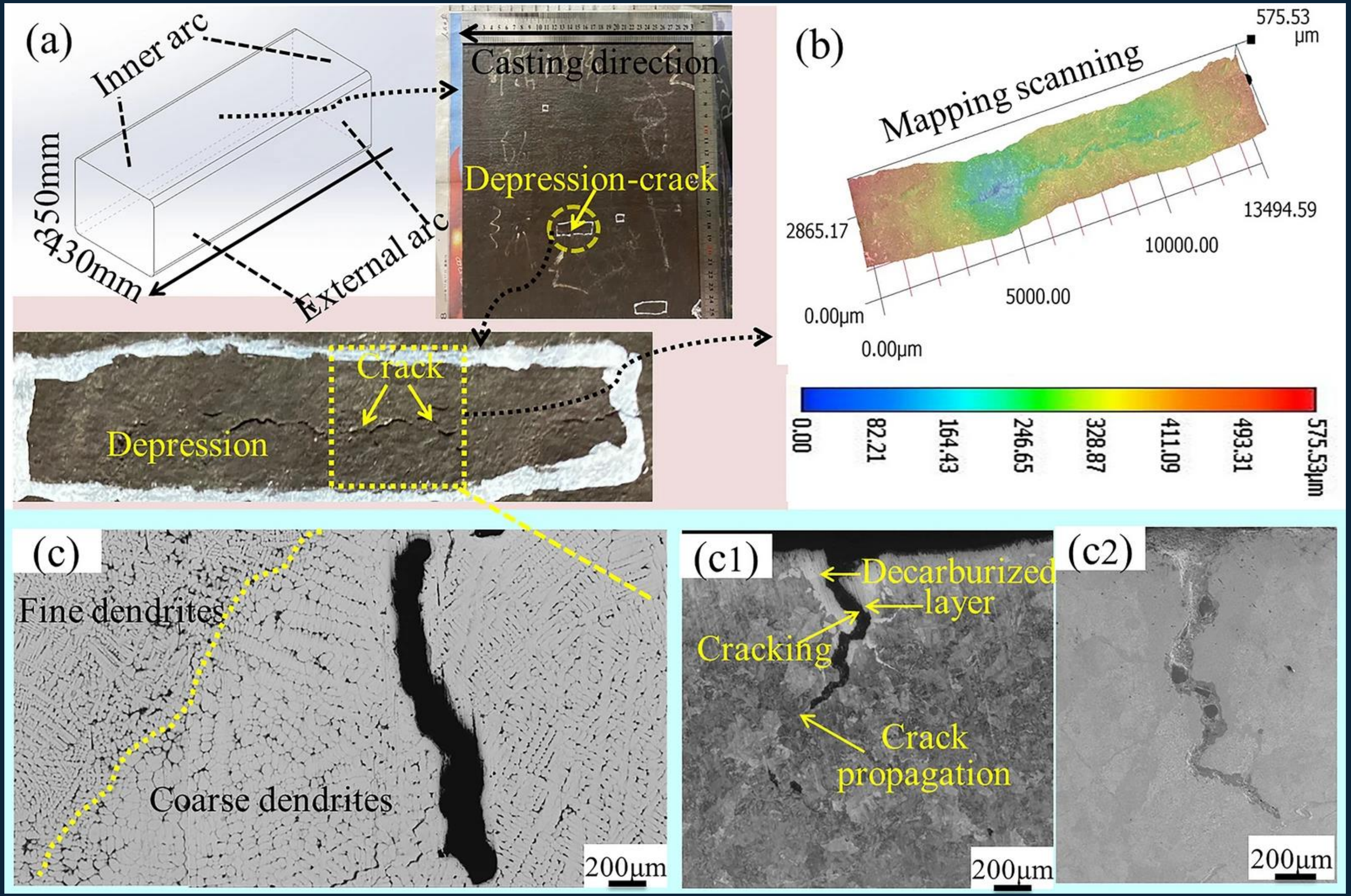








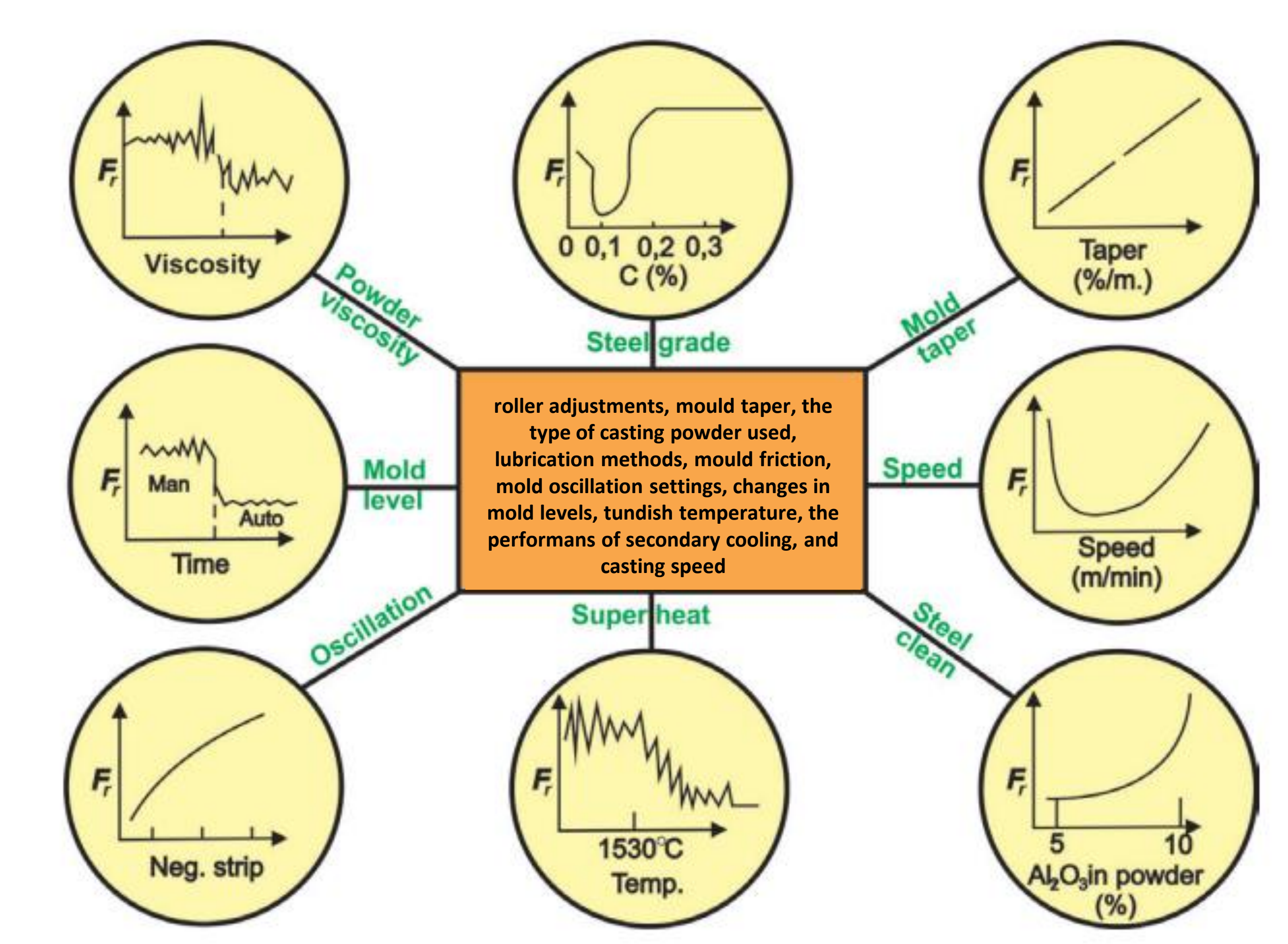




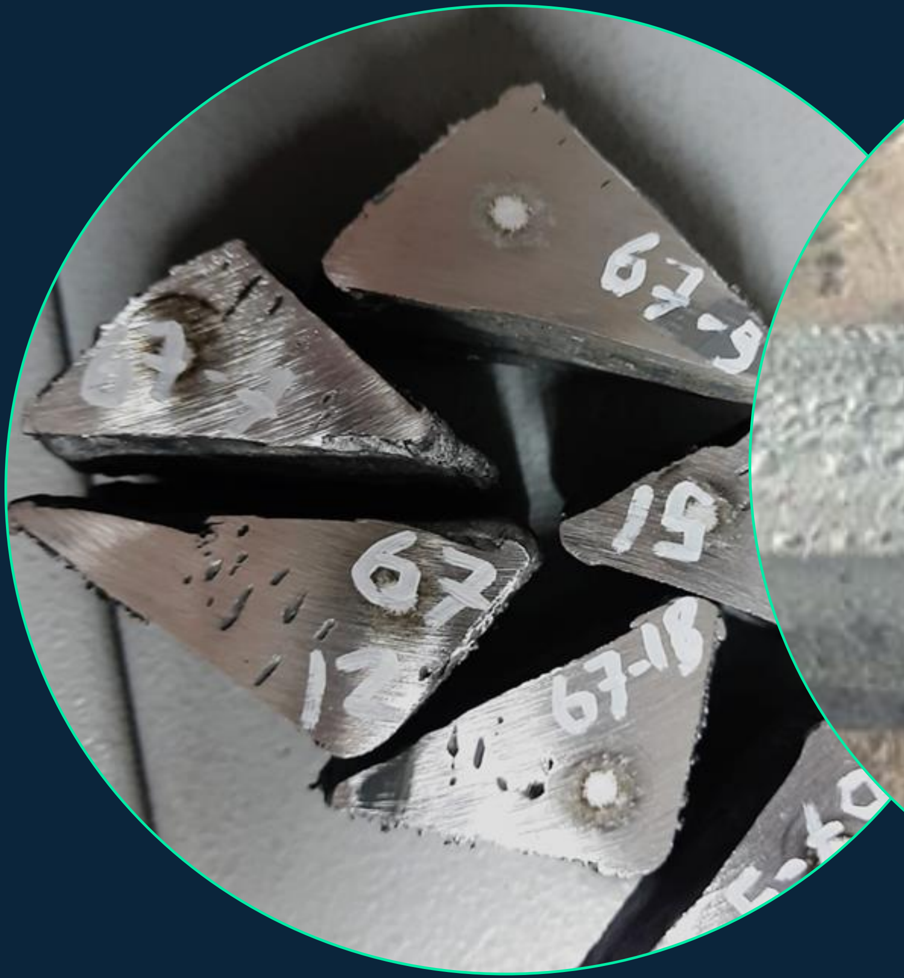
Characteristics of surface cracks in the bloom: (a) Macroscopic of surface depression-type crack, (b) 3D depth of field of depressions, (c) Dendrite of crack surface, (c1) OM from longitudinal cross section of crack, (c2) SEM from longitudinal cross section of crack

https://link.springer.com/article/10.1007/s11663-023-02911-4/figures/2

Influence of Process Parameters & Microstructure Evolution



- Prevention
  - Metallurgical measures
    - Decrease precipitation start temperature
    - Improve hot ductility
    - Decrease oscillation mark depth
    - Control residuals (network cracks)
  - Operating measures
    - Increase casting speed
  - Mold –related measures
    - Improve lubrication (oil/mold powder)
    - Decrease oscillation mark depth
  - Secondary cooling
    - Decrease specific water flowrate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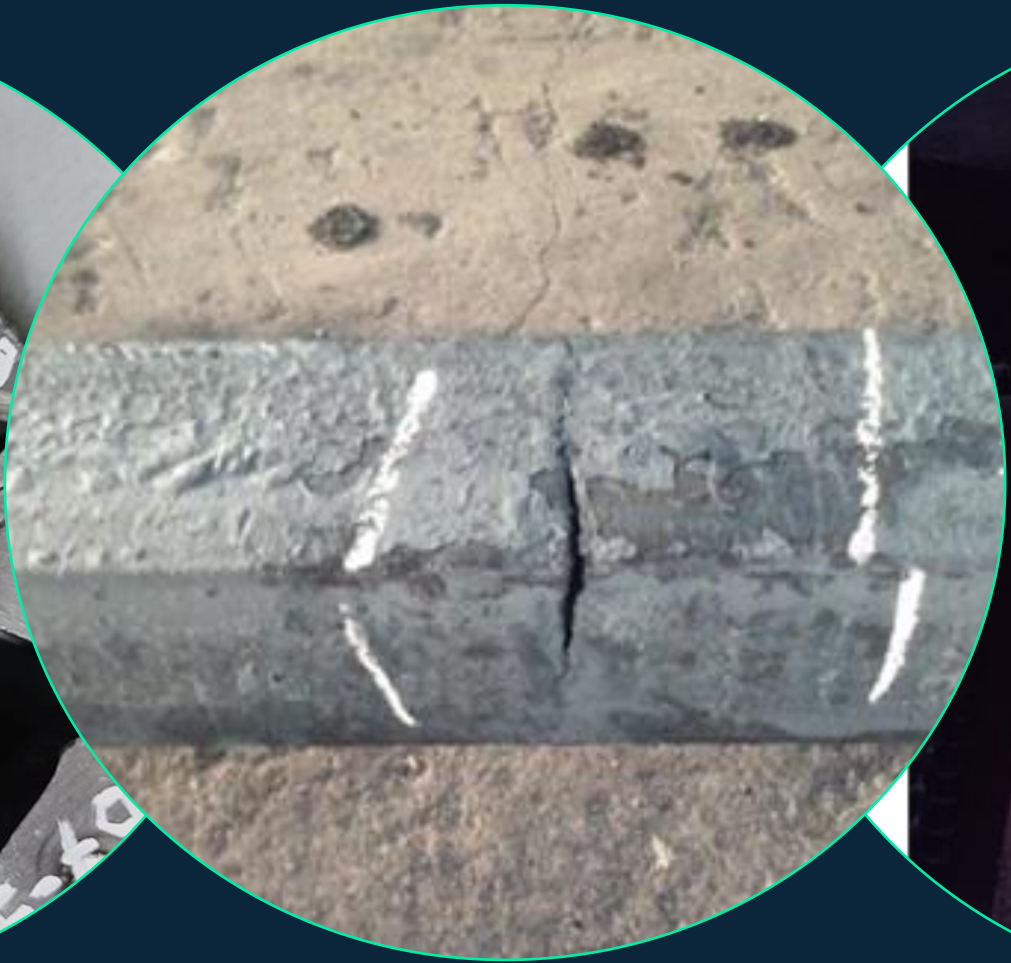
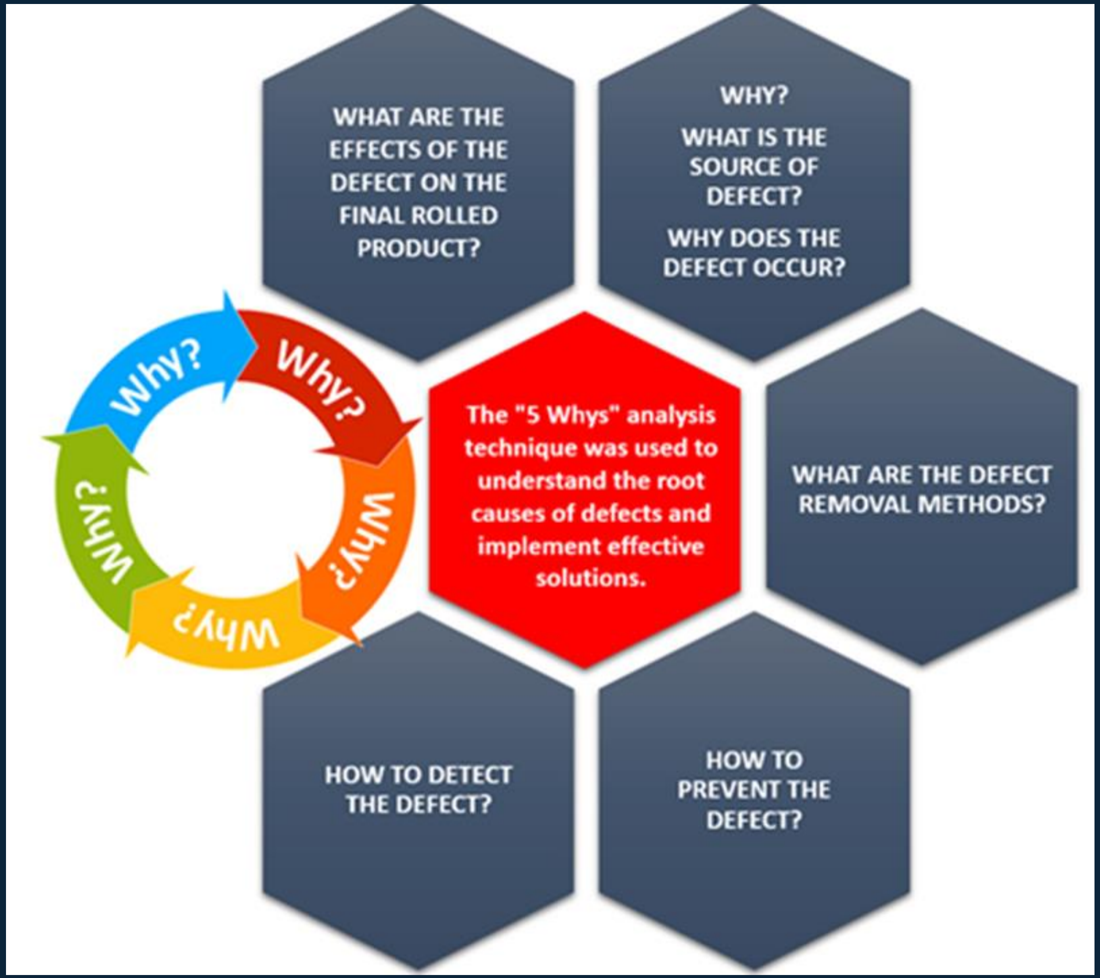



The 5 Whys Method for Root - Cause Analysis

1. **Why** did the crack form?
2. **Why** was the cooling uneven?
3. **Why** weren’t the mold conditions optimized?
4. **Why** was there a lapse in real-time monitoring?
5. **Why** wasn’t the steel chemical composition not properly adjusted?

The "5 Whys" analysis technique was used to understand the root causes of defects and implement effective solutions.



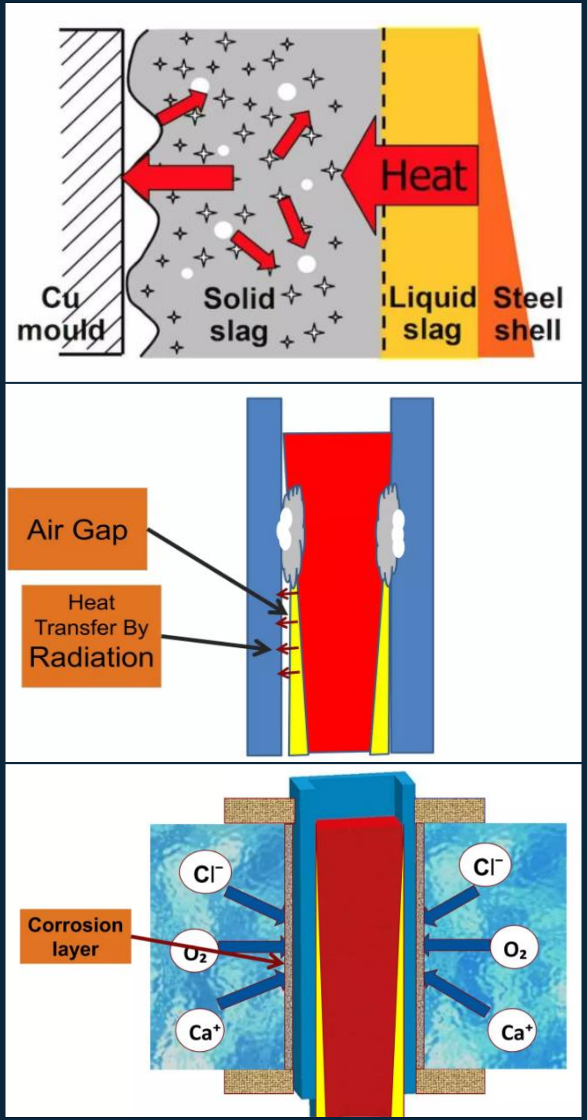
Benefits of Using the 5 Whys Method

Analysis of Transverse and Corner Crack with 5 Why method

WHY? WHAT IS THE SOURCE OF DEFECT? WHY DOES THE DEFECT OCCUR?	HOW TO PREVENT THE DEFECT?	HOW TO DETECT THE DEFECT?	WHAT ARE THE DEFECT REMOVAL METHODS?	WHAT ARE THE EFFECTS OF THE DEFECT ON THE FINAL ROLLED PRODUCT?
- Incorrect oscillation settings. - Solidifying liquid steel getting caught on irregularities inside the mold. - Deformation of the mold (excessive tapering, wall wear). - Very high steel temperature. - Non-uniform secondary cooling water. - Severe localized cooling of the strand. - Incorrect mold lubrication. - Dirty inner surface of the mold.	- Calibration (centering) of the mold with the "S" curve. - Absence of scratches and wear on the mold surface. - Appropriate liquid steel temperature. - Keeping unwanted elements (S, Sn, Cu, Zn, Pb) in the steel under control.	- It is very difficult to detect defects during casting. Only large cracks can be identified. - Grinding in a direction parallel to the cracks can easily reveal the defect. - Inspection performed after acid etching the surface provides very good results.	- If transverse surface cracks occur in one cast, this defect persists throughout the entire casting. - If the cracks are not deep, the entire semi-finished surface and corners should be cleaned by grinding or scarfing. If the cracks are deep, the semi-finished product is scrapped.	- Transverse billet cracks cause large cracks on the surface of the rolled product. - On bar products, cracks appear jagged, like a saw blade. - Large cracks can lead to significant rolling problems and may result in the billet breaking or snapping during rolling.

Fast and Effective Detection Strategies

WHY? WHAT IS THE SOURCE OF DEFECT? WHY DOES THE DEFECT OCCUR?	HOW TO PREVENT THE DEFECT?	HOW TO DETECT THE DEFECT?	WHAT ARE THE DEFECT REMOVAL METHODS?	WHAT ARE THE EFFECTS OF THE DEFECT ON THE FINAL ROLLED PRODUCT?
• Excessive slag in the steel and slag adhesion between the mold and the first shell/billet, • Low tundish level and slag leaking into the mould. • Insufficiency/excess of lubrication, • Excessive use of casting powder, • Steel/slag adhesion at the mouth of the mold, • Mold deformation, • Mold cooling water not at appropriate flow rate, • Casting temperature is too high, • High casting speed, • High casting speed due to zirconia nozzle expansion. • Casting flow does not flow into the mold center, • 1st and 2nd stage waters not having the appropriate flow rate (ring and collector) • Improper selection or clogging of the 1st and 2nd cooling water jets.	Removing slag from the mold, - Removing slag from the tundish, - Skimming the mold, - Maintaining Mn/Si ratio ≥ 3 and Al content < 0.005, - Limiting the amount of S that causes hot brittleness in the material, - Changing the mold, - Adjusting the proper mold cooling water flow rate, - Correctly controlling the casting temperature and speed, - Properly aligning the zircon mold, - Selecting and appropriately using suitable water sprinklers and nozzles, - Designing the spray cooling area so that the cooling intensity decreases from top to bottom, - Adjusting the secondary cooling water flow rate properly, keeping the water pressure high.	- The defect resulting from bleeding is easily visible during casting. - An explosion can cause the loss of the strand, leading to a severe burst. - An explosion can also cause serious damage to the machine.	- The defect necessitates grinding or material removal, often leading to the rejection of the billet.	- This defect can cause various serious surface flaws. - Material defects such as wavy edges, transverse cracks in the middle, edge cracks, and alligatoring, split ends cracks.



A breakout in the continuous casting process can be caused by several factors

Conclusion and Recommendations

In conclusion, the Continuous Casting (CC) process, despite its technological advancements and strict adherence to operational norms, remains prone to defects that affect the final quality of steel billets. Key factors influencing defect formation include the chemical composition of steel, process control parameters, and microstructure development during solidification. By applying methods such as the "5 Whys" analysis, we can better understand the root causes of defects and implement strategies to reduce their occurrence. Continuous monitoring and improvement of the CC process are essential to produce high-quality billets and minimize waste and operational losses.

- **Optimization of Chemical Composition:** Adjust and monitor elements like phosphorus, sulfur, and copper to reduce their negative impact on billet quality.
- **Process Parameter Control:** Maintain optimal casting temperatures, mold tapering, and cooling practices to avoid cracks and other defects.
- **Use of Advanced Detection Methods:** Implement real-time monitoring and advanced detection technologies to identify potential defects early in the production process.
- **Regular Equipment Maintenance:** Ensure that mold conditions, oscillation settings, and roller alignments are frequently checked and calibrated to reduce mechanical stresses on the billets.
- **Training and Skill Development:** Equip operators with the knowledge and skills to promptly respond to changes in production conditions, ensuring better defect management.

These steps can significantly improve the overall efficiency and quality of the Continuous Casting process.

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Thank you for your attention. I'm now open to any questions that you may have.