Valcra Workshop

TRANSFORMATION STRESS CRACKS AT THE TERTIARY COOLING

5th March 2020

Process Department
Sidenor I+D

Valcra Workshop on the inffluence of S and Microalloyed elements on the Surface cracking of continuos Casting Billets

Transformation Stress Cracks at the tertiary cooling

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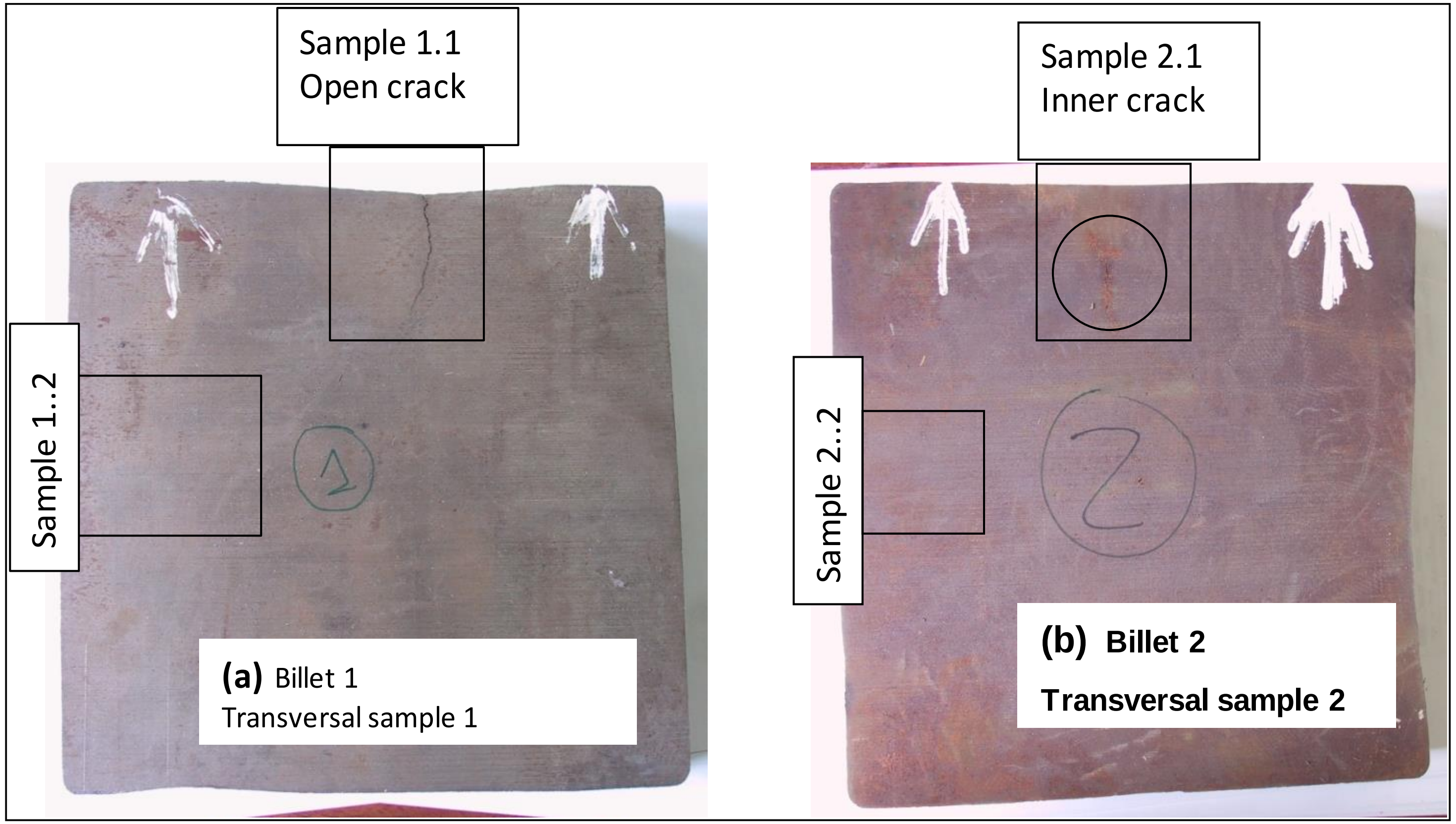
1. Introduction

- **Thermal stress cracks (TSC)**, also called perlitic transformation cracks, are frequently produced when casting microalloyed steels grades and steels with Pb or Bi.
- The increase in production rates in the CC process and the related increase of the casting speed, has also lead to the necessity of higher cooling rates in the cooling bed. This fact, together with the casting of more complex microalloyed steels have peaked the incidence of this defect when casting billets, blooms and slabs.
- Mn additions decrease the γ-α transformation temperature, additionally, microalloying elements precipitate along transformation temperature range leading to transformation cracks.

2. CHARACTERIZATION OF A HEAT PRESENTING TSC

2.Characterization of a Heat presenting TSC

- Thermal stress cracks (TSC) observed when casting a high Mn and high Cr steels grade.



- Most of them were inner cracks detected with ultrasounds.
- Others reached the Surface and lead to an open crack

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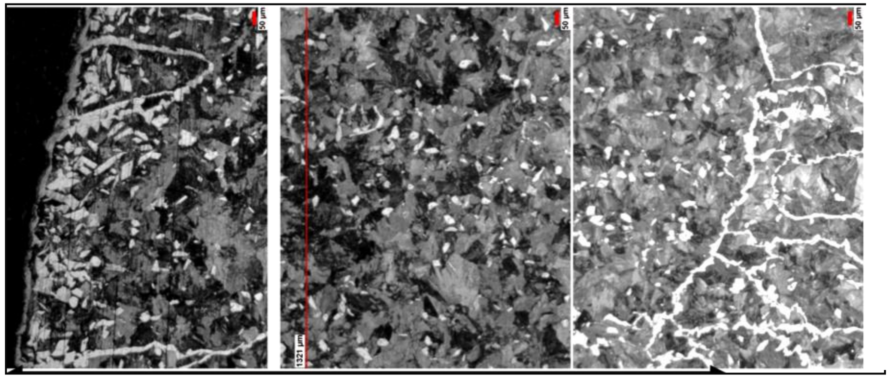
2. Characterization of a Heat presenting TSC

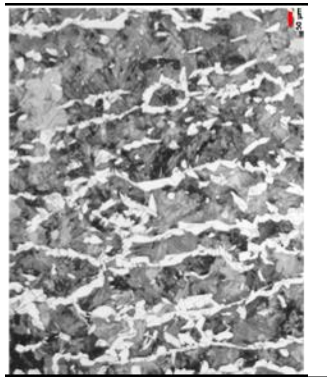
Metallographic studies

Craked Billet Face



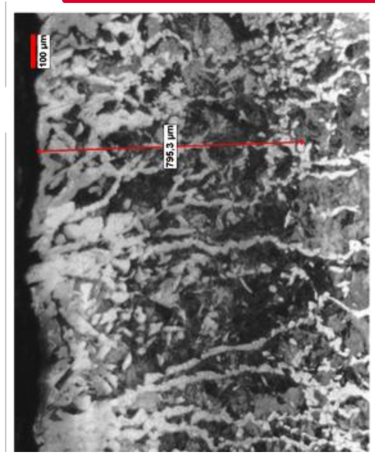
Big PGG
Low ferrite content

Microstructure change: 5mm

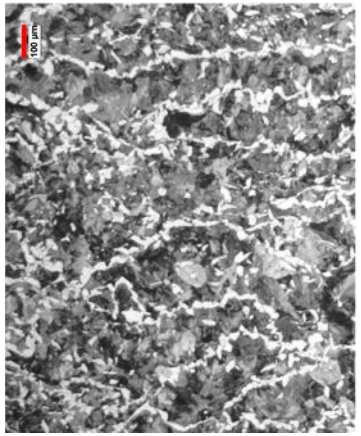


Interior

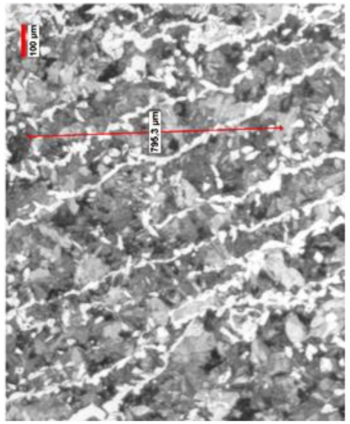
Non-Cracked Billet Face



Big PGG
Low ferrite content



Microstructure change: 3mm



Interior

Big Primary Gamma Grains (PGG) are normally related to billet reheatings at the mould.

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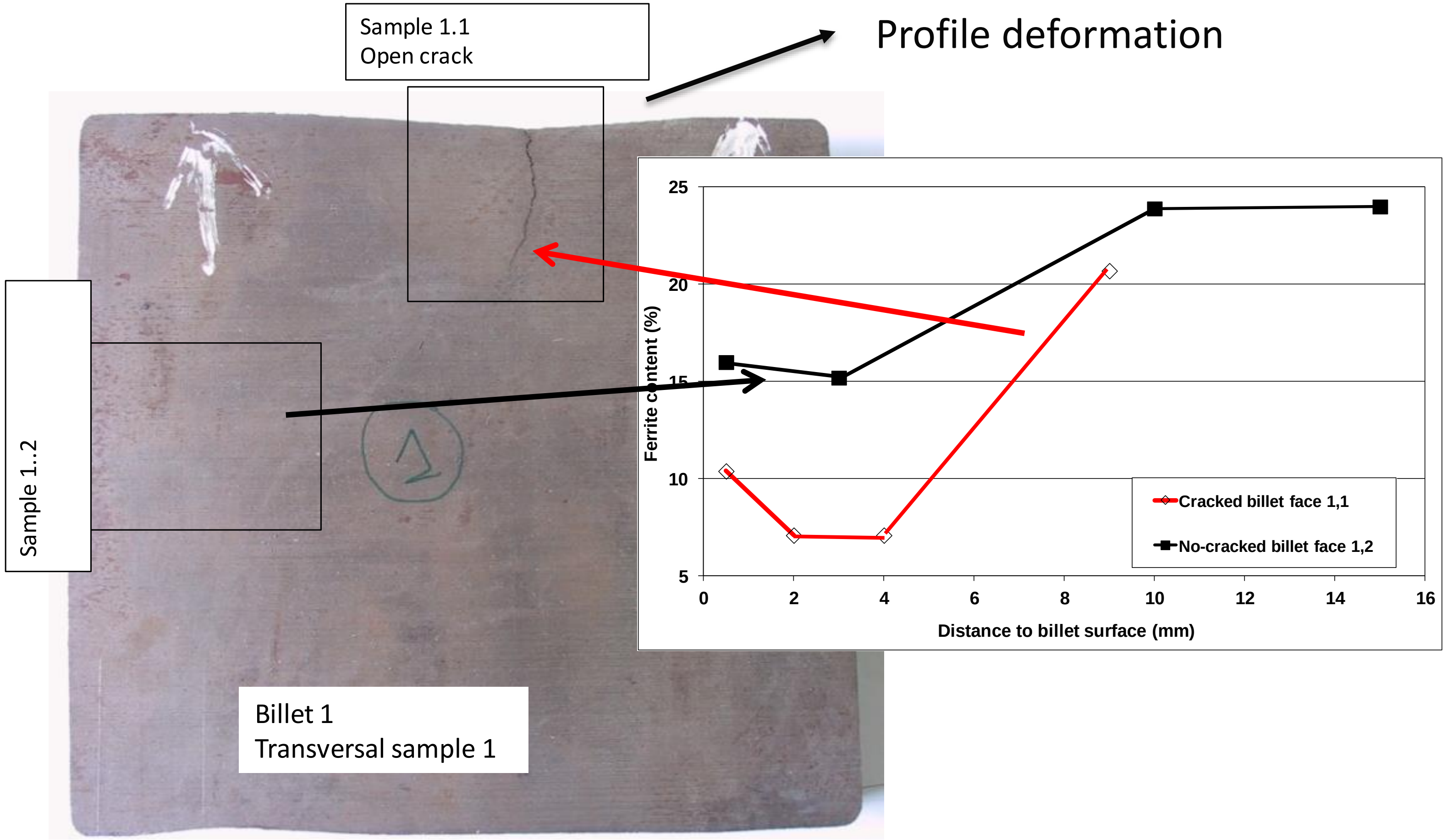
2. Characterization of a Heating presenting TSC

- **Ferrite Content** as a function of surface distance: the cracked Billet Surface presents a lower ferrite content.



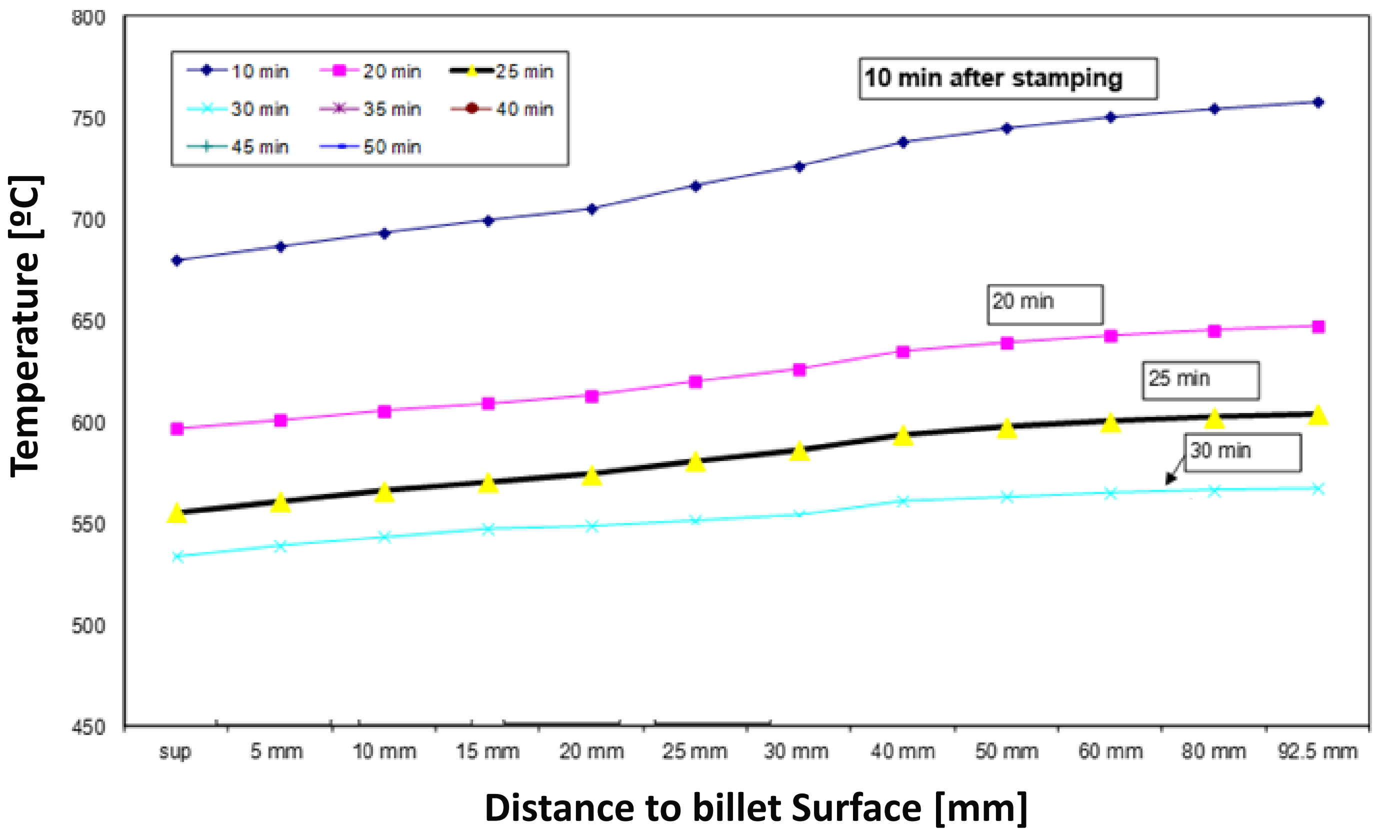
- When transformation begins ferrite precipitates at grain boundaries.
- Big Primary Gamma grains entails less Ferrite precipitation therefore the inner grain precipitates to perlite.

3. STUDY OF THERMAL AND METALLURGICAL MECHANISIMS PRODUCING TSC

3. Study of Thermal and Metallurgical mechanisims producing TSC

1. Temperature distribution inside the billet

- Distemp, Sidenor home made continuous solidification program, has been used in order to study temperature distribution inside the billet as a function of time since billet stamping.



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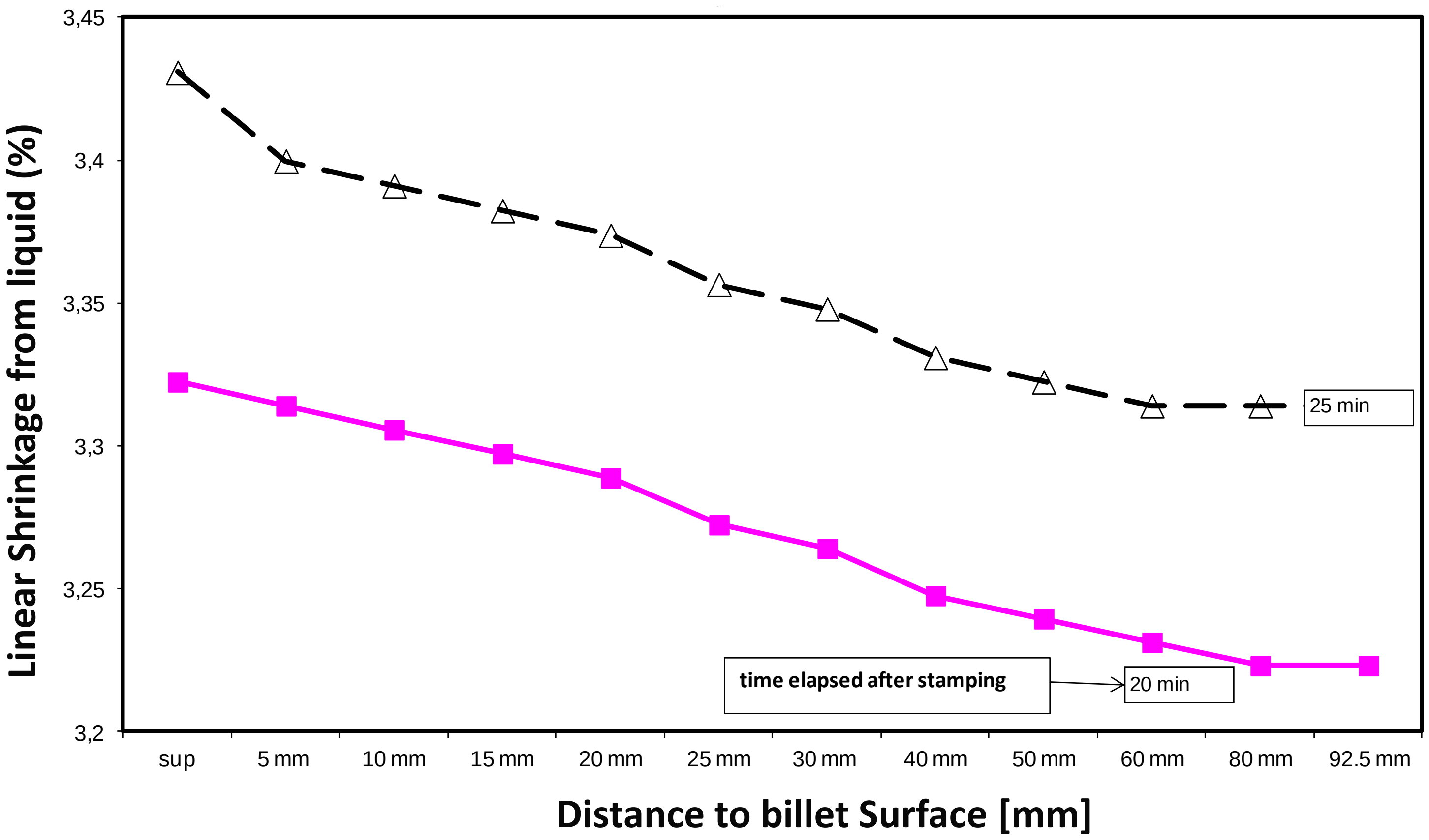
3. Study of Thermal and Metallurgical mechanisims producing TSC

1. Temperature distribution inside the billet

- Linear shrinkage evolution as a function of the distance to billet surface for two different times after billet stamping. Shrinkage calculated with the IDS program.



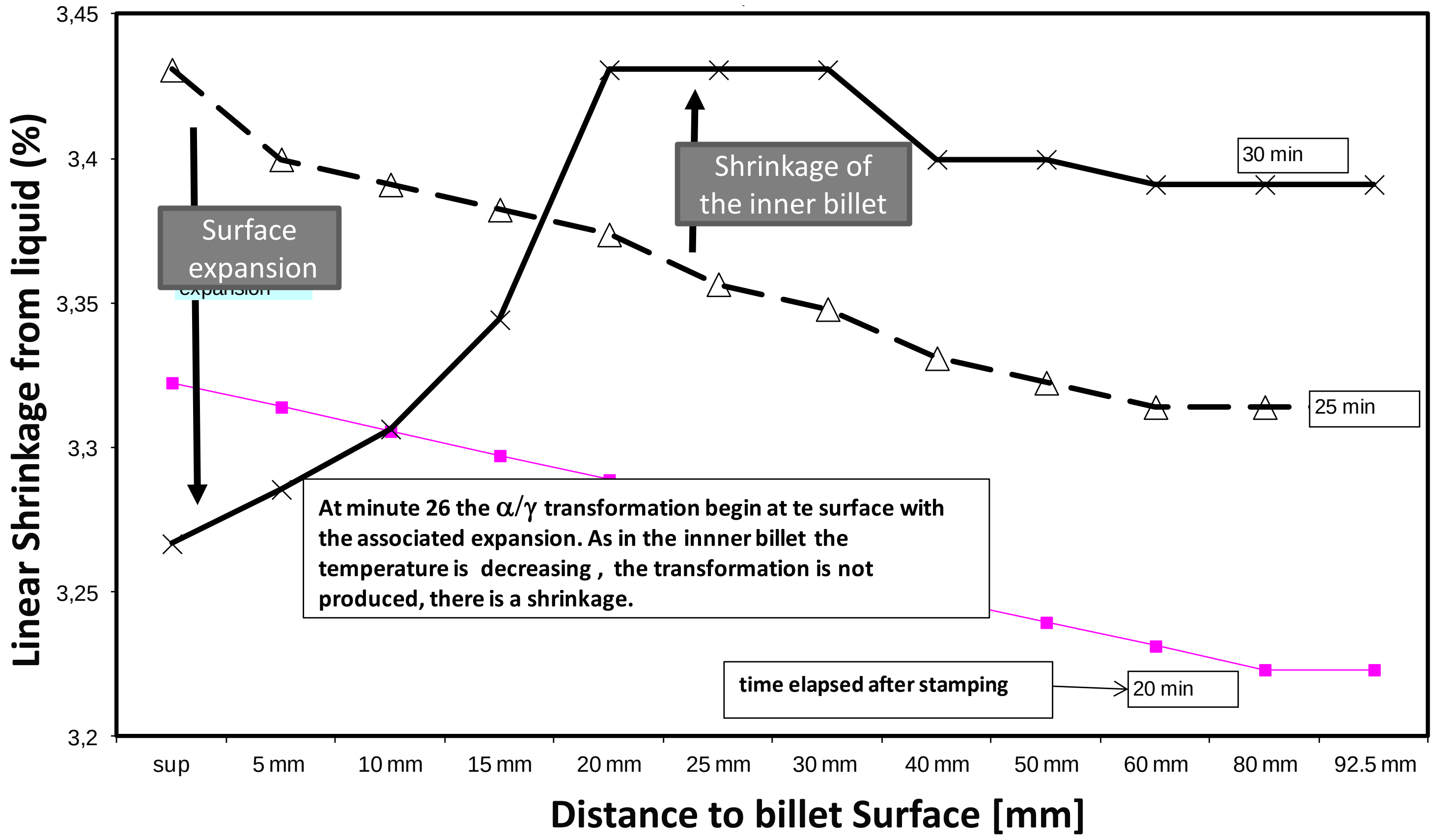
As time progress and the temperature decreases, the shrinkage increases.

3. Study of Thermal and Metallurgical mechanisims producing TSC

2. Transformation influence: Volume changes

- 26 minutes after the stamping, a 1% volume expansion related with the γ/α transformation changes the shrinkage pattern.

- Nevertheless, even for a 30 minutes time, untransformed inner billet continues to shrinks due to decreasing temperatures.



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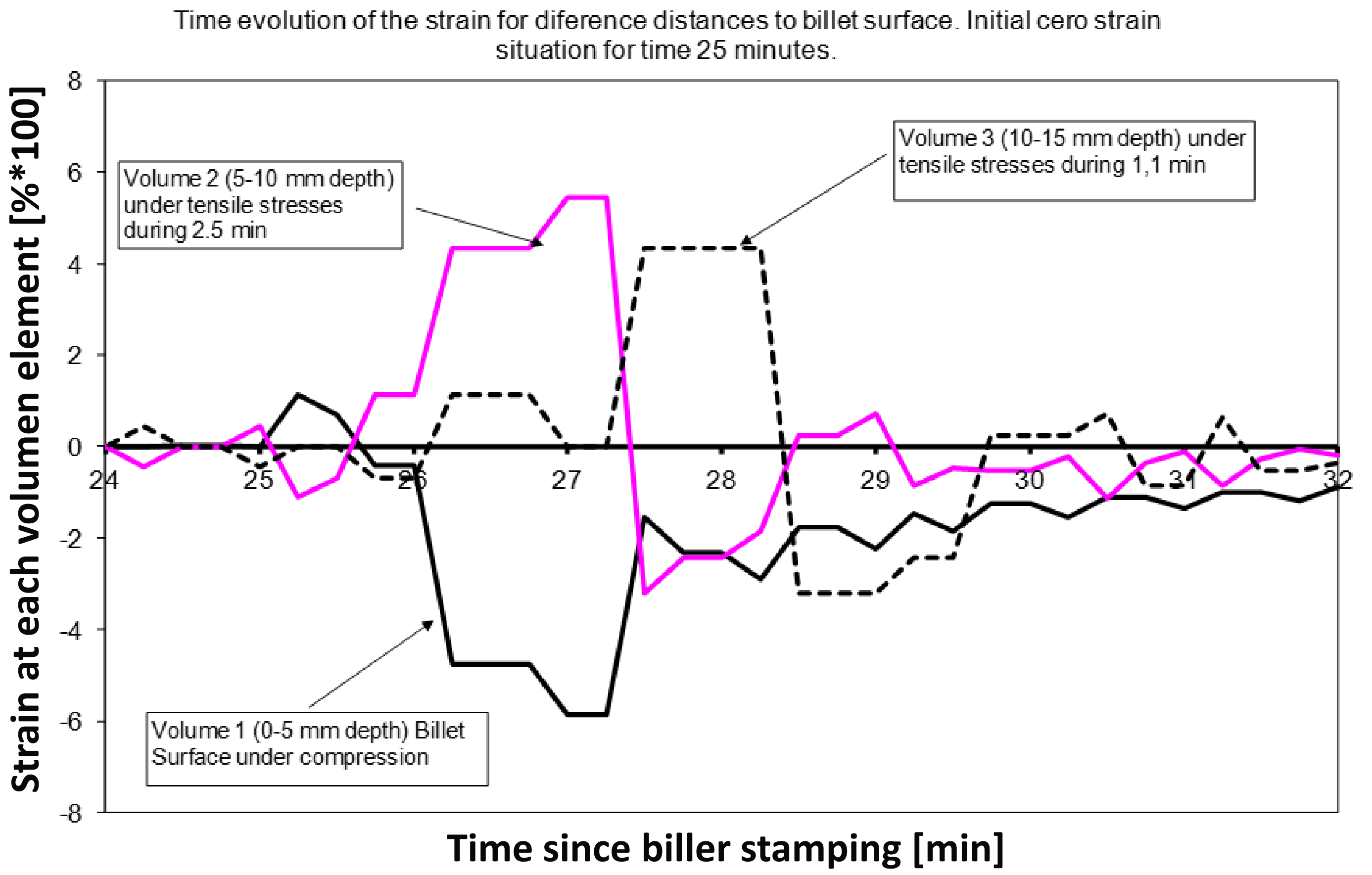
3. Study of Thermal and Metallurgical mechanisims producing TSC

2. Transformation influence: Stress associated

- Numerical calculations estimate the stresses produced during the γ-α transformation in the cooling bed and clarify the mechanism which led to the formation of TSC



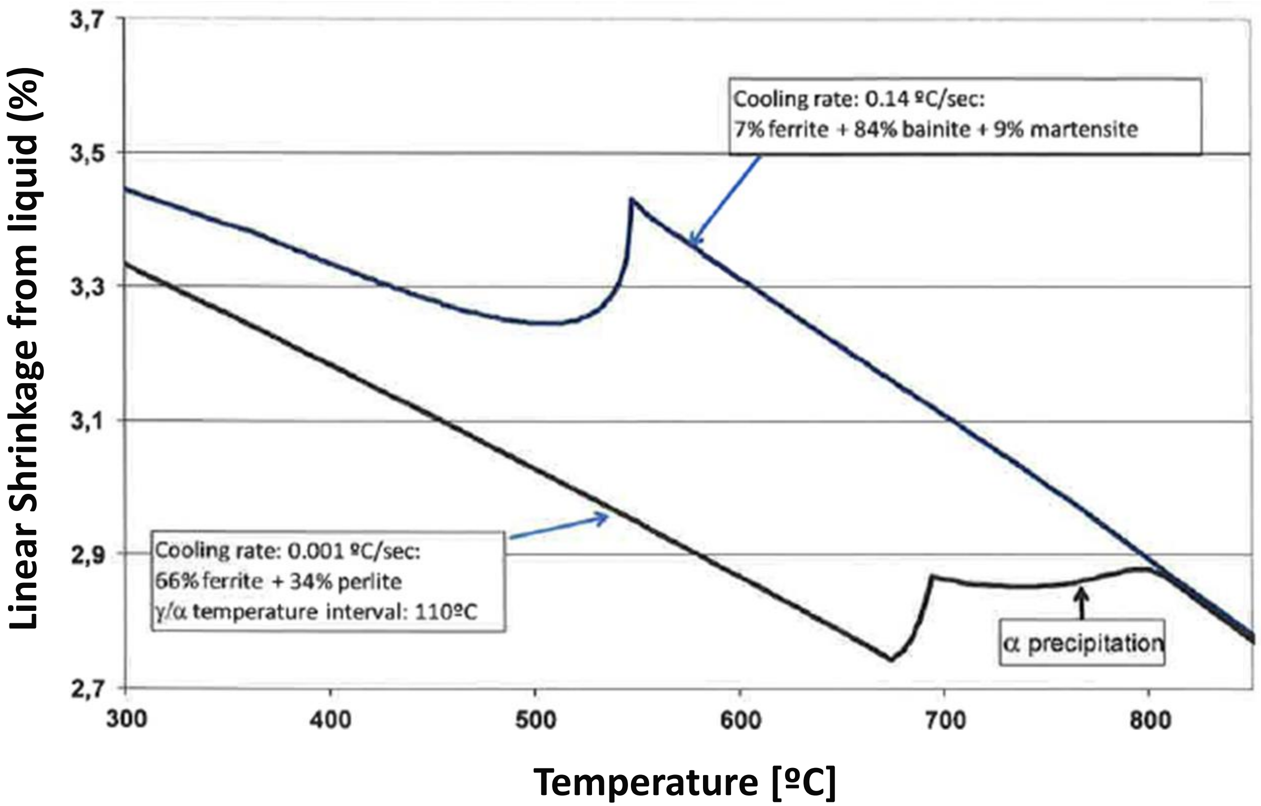
The model considers the expansions and shrinkages that are produced at different distance to billet surface. The billet stamping after billet torch cutting has been take as a cero strain reference time. When transformation begins differences in the strain among volumes is observed.

The tensile strain is progressing inwards as the transformation proceeds. The production of those strains inside the billet may explain the presence of internal cracking.

3. Study of Thermal and Metallurgical mechanisims producing TSC

3. Cooling rate influence

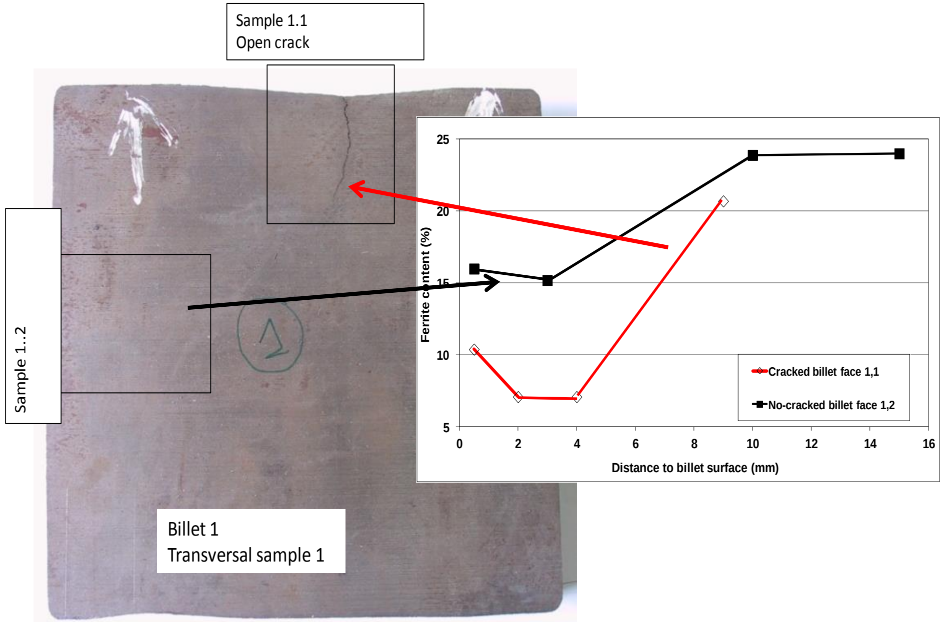
- On the other hand, the phases which are produced during transformation depends on the cooling rate, and also the expansion produced. The figure shows that a high cooling rate gives place t a sudden expansion. However for a low cooling rate the expansion produced is lower.

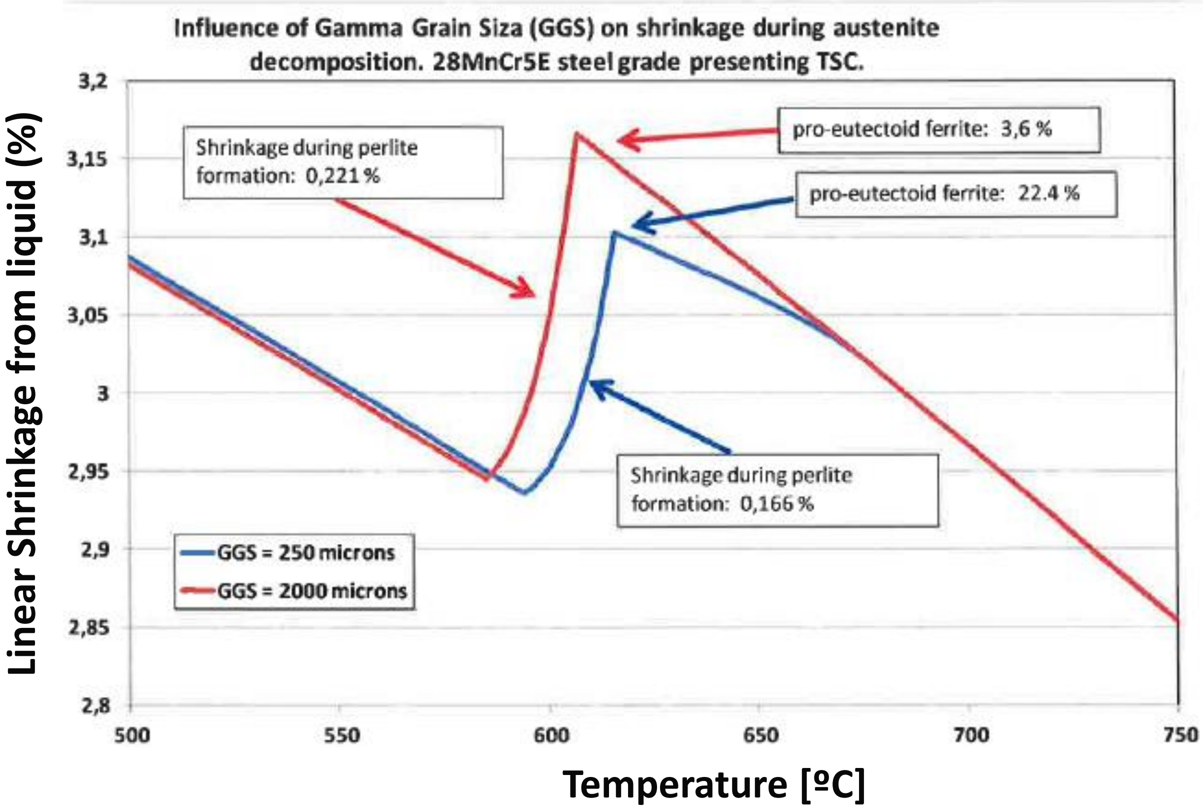


3. Study of Thermal and Metallurgical mechanisims producing TSC

4. Primary Gamma Grains Size (PGGS) influence

- As previously presented, the cracked Billet Surface presents a lower ferrite content.
- IDS calculations shows the variation of the expansion associated with the transformation as a function of the PGGS.





PGGS ↑ % Ferrite ↓ Expansion ↑

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4. TSC SUSCEPTIBLE COMPOSITIONS

4. TSC Susceptible Compositions

- Pb
  - Worsening when Cr↑, Mn ↑
- Bi
  - Worsening when Cr↑, Mn ↑
- Nb
- Mn High – V High
- Mn médium-High – Cr High – S High
- Mn High – **B High** Cr High (37MnBCr7S)
- Cr High – **Al*N Hgh**
- High C> 0,35 – **High B** (38B3E)
- 16MnCrBEF (Mn,Cr,B)

5. CONCLUSIONS

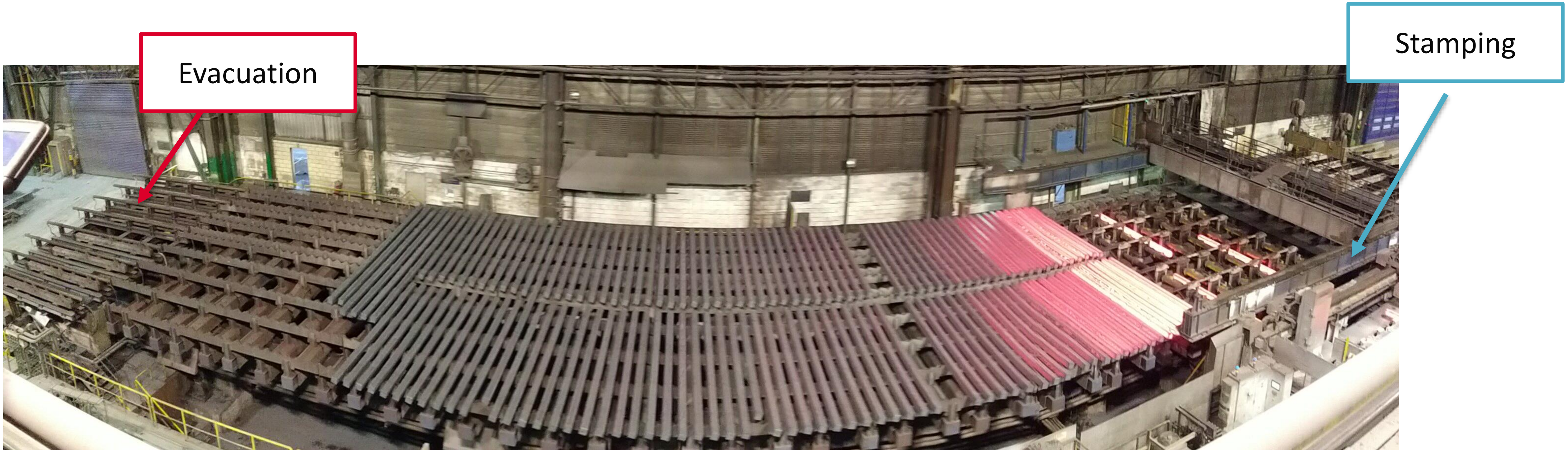
5. Conclusions

- Transformation stress cracks are generally internal
- Perlitic transformation cracks formation is influenced by
  - The cooling rate
  - Steel composition
    - Microalloyed elements precipitates leading to matrix hardening. When transformation tensile stresses are produce during the transformation, there will be a high strain concentration at the austenite grain boundaries which will produce cracking
    - As the amount of pertilic phase increases, the related expansion during transformation does too.
  - Primary Gamma Grain Size

6. SIDENOR TERTIARY COOLING CHARACTERIZATION

6. Sidenor Tertiary Cooling Characterization

- As previously discussed, in order to avoid STC an optimum cooling is of a paramount importance. The main objective is to assure that the γ-α transformation actually takes place at the cooling bed, where the thermal conditions are stable.
- At Sidenor, the conditions in the walking bed cooling have been studied for different steel grades and casting conditions, in order to determine if any critical situation may appear and might lead to stress cracks.



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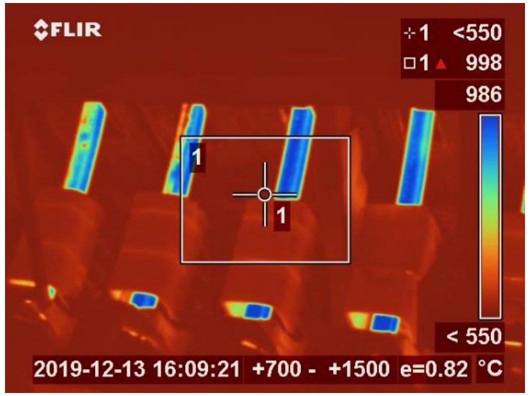
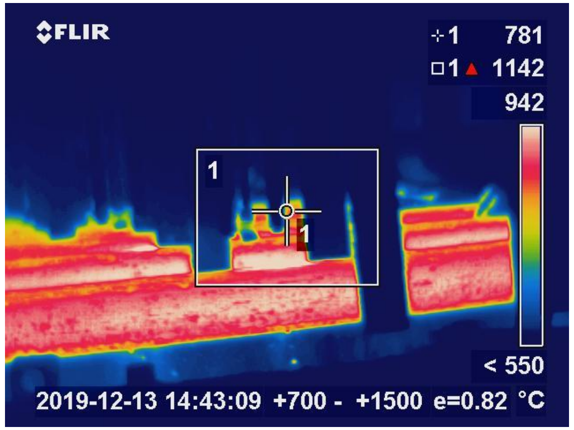
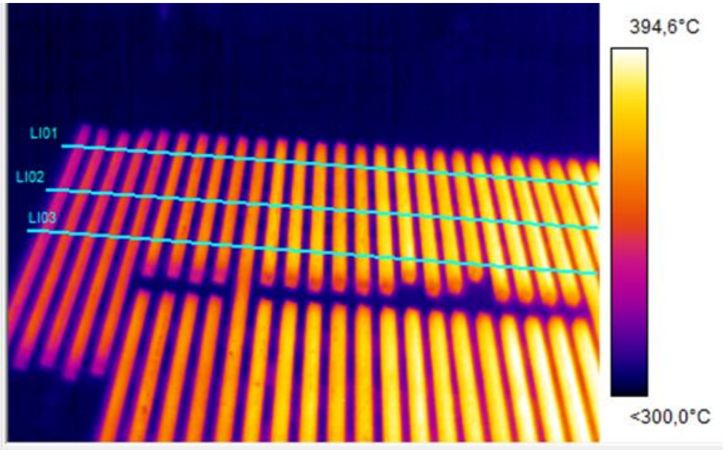
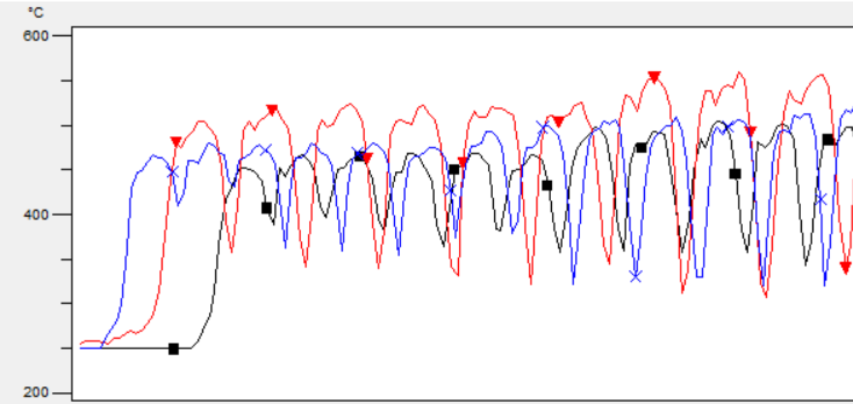
6. Sidenor Tertiary Cooling Characterization

- Firstly during casting, several temperatures are measured on the strand and in the cooling bed.









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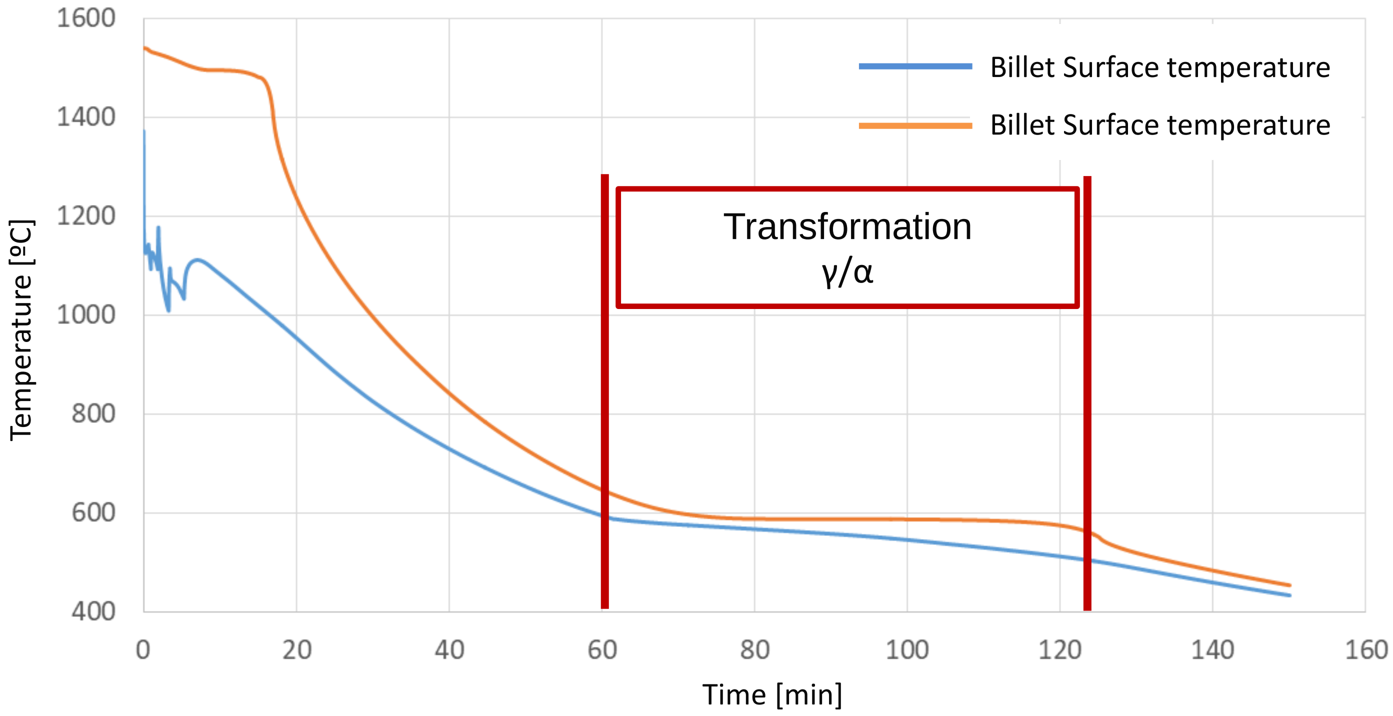
6. Tertiary Cooling Characterization

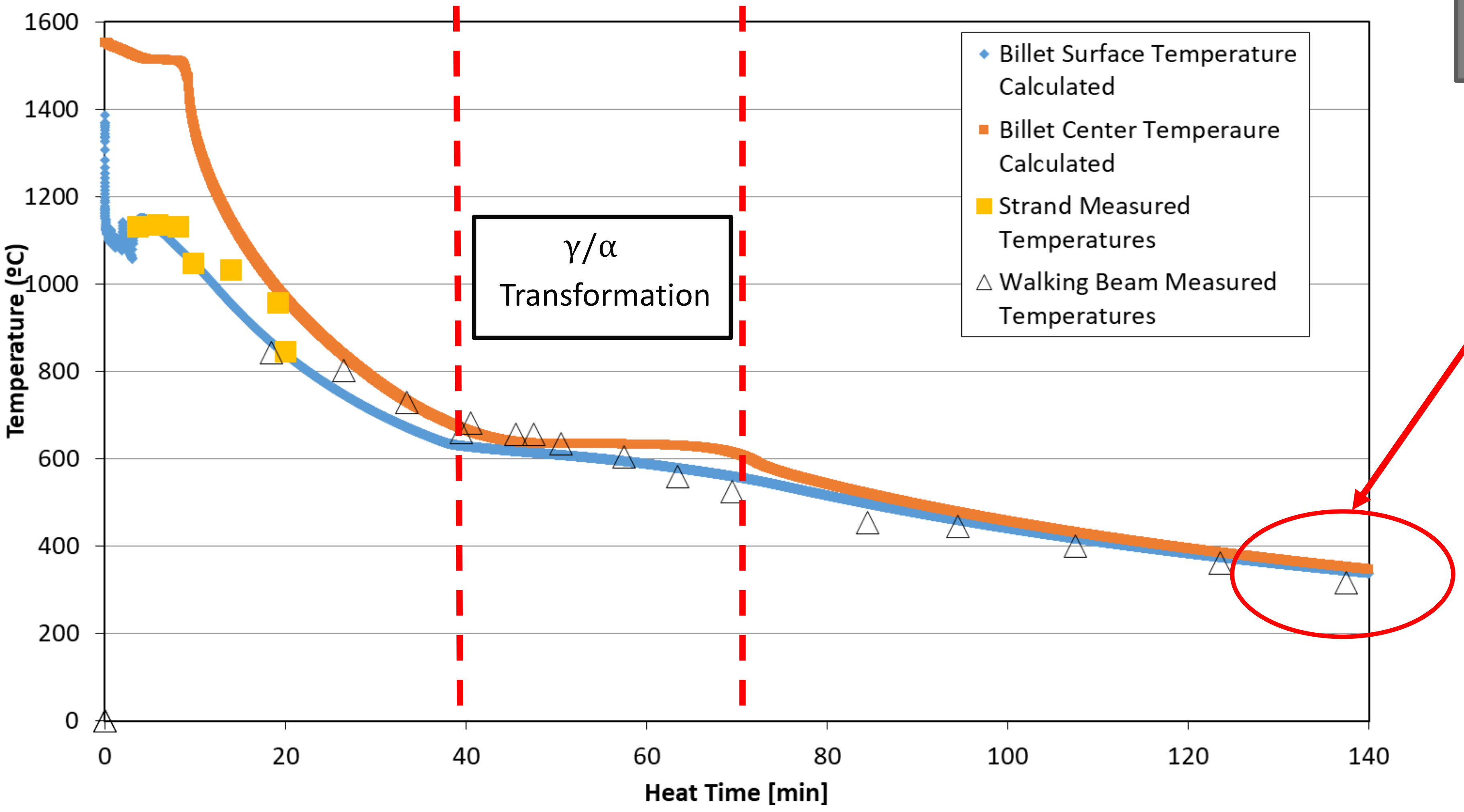
- Simultaneously, the time elapsed between each event is recorded, in order to obtain the tracking of each billet along the process. Consequently, the billet temperature evolution from the mould to the end of the tertiary cooling is known.



- Afterwards, Distemp simulations are performed and fitted with experimental results to be able to simulate the temperature distribution in the billet.
- As a consequence, we can determine when does the transformation takes place and we can verify if the transformation has finished before the billet is evacuated from the cooling bed.

6. Tertiary Cooling Characterization

Example: 16MnCr5E



Casting Conditions:
Casting Speed=1,75m/min
5 Strands Casting

Time that takes the billet to te evacuation for these heat conditions. Far from the transformation time.

Transformation takes place inside the cooling bed, far away from critical situations.

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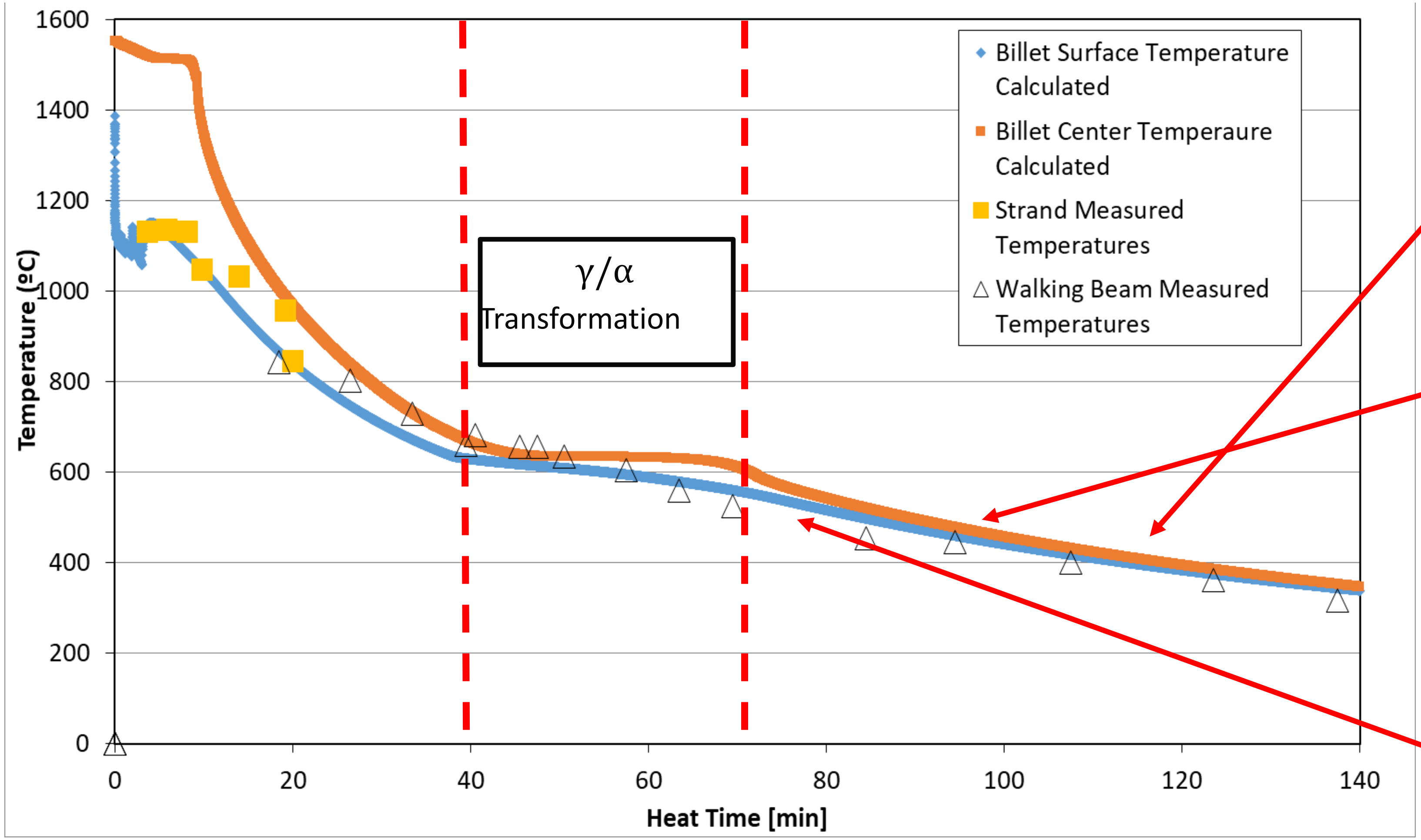
6. Tertiary Cooling Characterization

Example: 16MnCr5E



Casting time for different casting conditions

If both heats would have cast 5 strands at 1,75m/min: **118 min**

If both heats would have cast 6 strands at 1,75m/min: **96 min**

If both heats would have cast 6 strands at 1,85m/min: **72 min**

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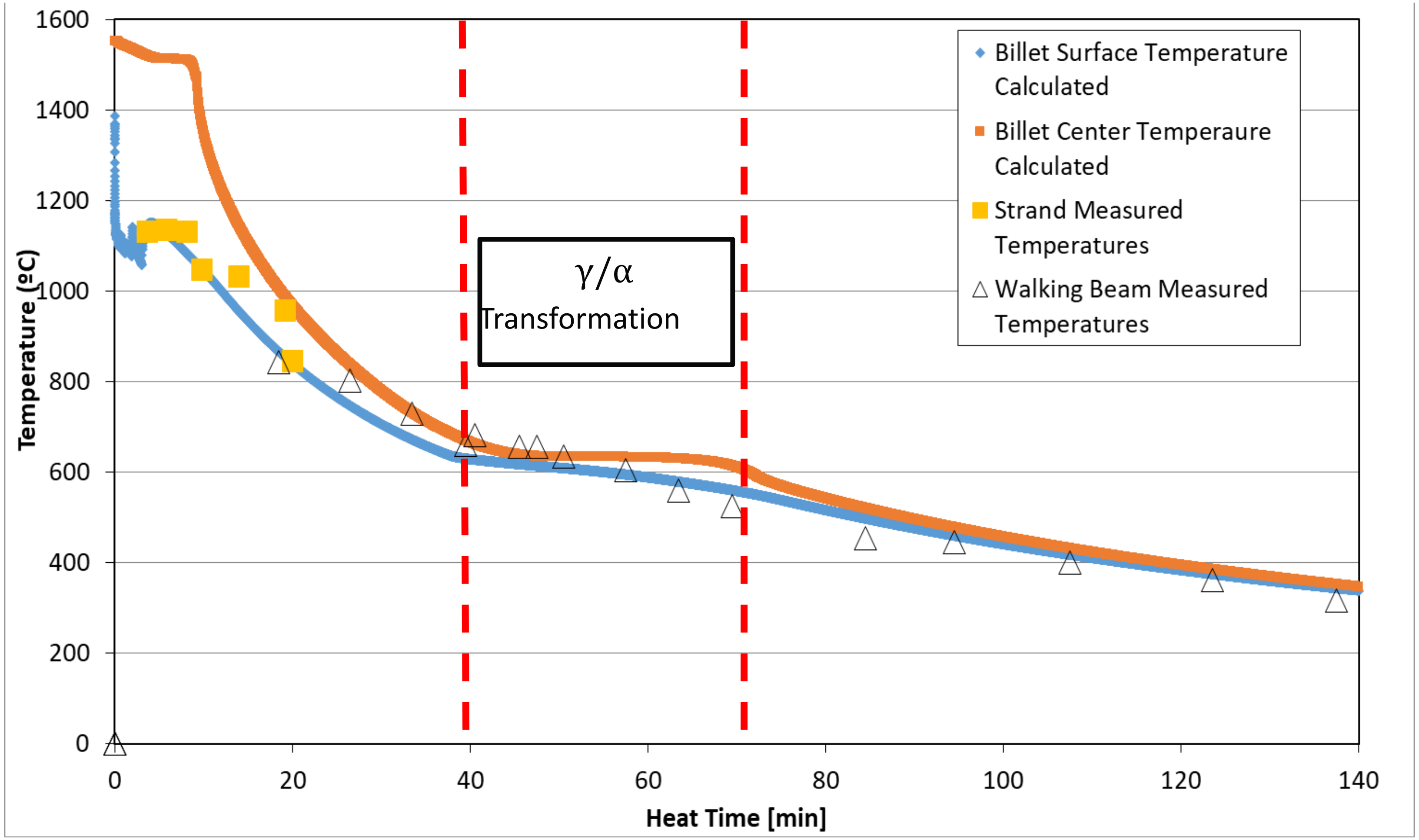
6. Tertiary Cooling Characterization

Example: 16MnCr5E



Conclusions:

- The actual billet cooling depends on the casting conditions of the heating, and on the conditions of the following ones.
- Steel grades which γ-α transformation takes place at low temperaturas should be studied.
- If the γ-α transformation has not been completed, the heat should remain in the cooling bed avoiding critical situations.

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