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# Pearlite Monitoring in Steel Sheets by Laser Ultrasonic Technique

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# Objectives



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Monitor **Pearlite formation** during cooling of steel grades using the **magnetic transition of cementite** (Pearlite ~ 89% ferrite + 11% cementite)

## Experimental conditions

- Materials selection

### *Chemical composition (Weight %)*

	C	Mn	Si	Cr	Mo	Al
1008	0.1	0.4	0	0	0	0
1020	0.2	0.45	0	0	0	0
1035	0.35	0.75	0	0	0	0
1074	0.75	0.65	0	0	0	0
1080	0.787	0.693	0.197	0.027	0.002	0.031

~ pure ferrite/low Carb.  
~0% pearlite

~ pure Pearlite  
=100% pearlite  
~ 11% Cementite



# Theory:

## Carbon content & Cementite: Mixing rule

- **Basic parameters:**

**Pure cementite:** 6.67 wt% carbon (Fe<sub>3</sub>C: 25 at%)

**Pure ferrite:** 0.02 wt% carbon (max solubility)

**Pure pearlite:** 0.76 wt% carbon (see phase diagram)

- For any 2 components:

$$f_o = xf_1 + (1 - x)f_2$$

then:

$$x = \frac{f_o - f_2}{f_1 - f_2}$$

- Therefore:

**Pure pearlite:** **11% cementite**, 89% ferrite

**Grade 1080:** 0.75 - 0.88 wt% carbon (almost pure pearlite)

**Grade DP780:** 0.136 wt% carbon  
16% pearlite, 84% ferrite  
**1.7% cementite**, 98.3% ferrite



# Experimental Conditions

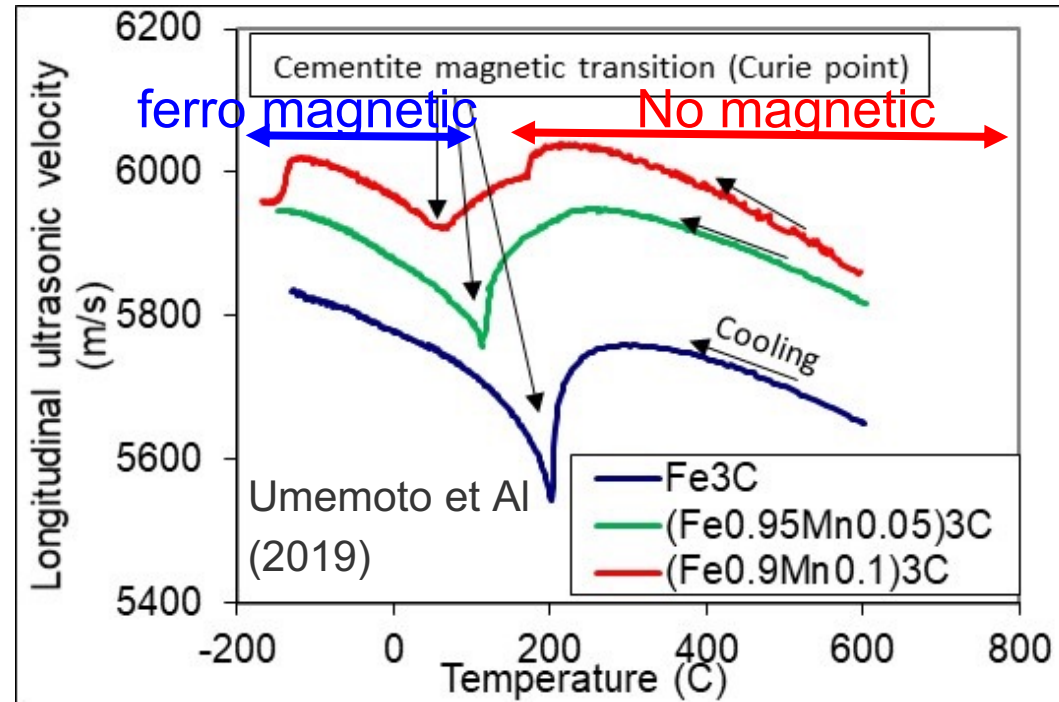
# Experimental Results

## Laser Ultrasonic Velocity Tests

Gleeble 3500 &  
Laser Ultrasound



## Measured Ultrasonic Velocity in Pure Cementite



→ Influence of Mn on Magnetic transition

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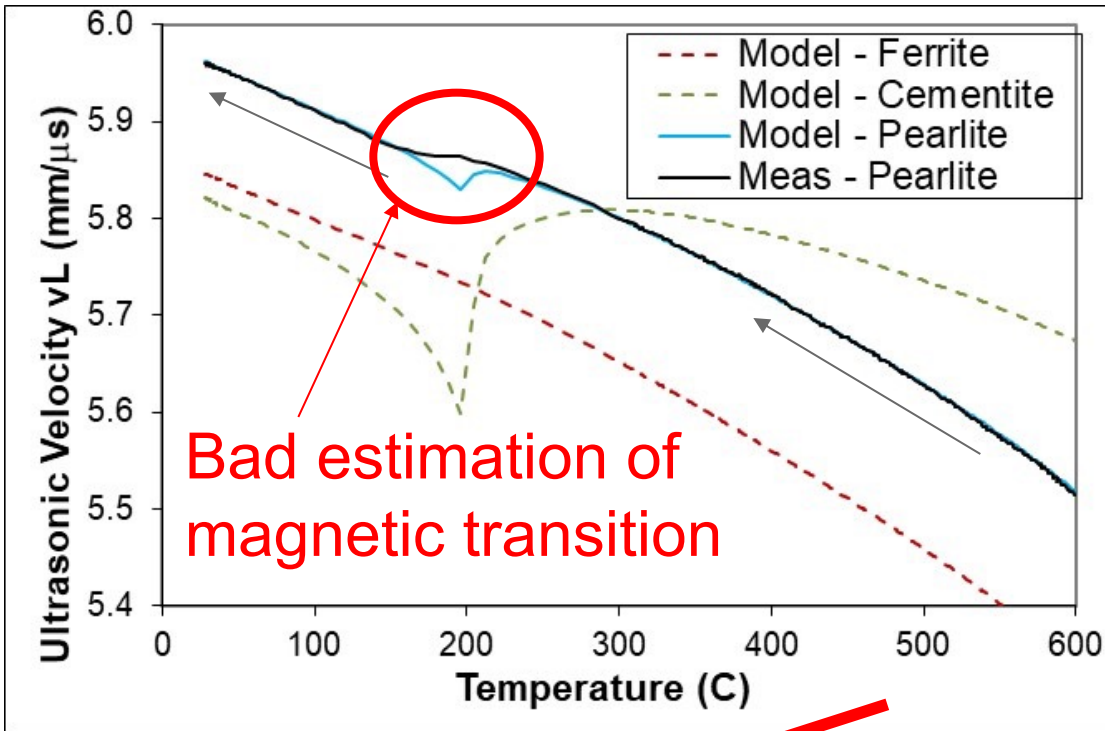


# Pearlite Monitoring Principle: 1<sup>st</sup> method

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- Measured Ultrasonic Velocity in Pure Cementite

## Grade 1080



Bad estimation of magnetic transition

Unrealistic estimation of cementite fraction

~~Law of mixture on ultrasonic velocity~~

~~$$V = X_{cem} \cdot V_{cem} + (1 - X_{cem}) \cdot V_{\alpha}$$~~

?

?

$$X_{cem} = \frac{V - V_{\alpha}}{V_{cem} - V_{\alpha}} \sim 0.18$$

**Bulk Cementite ≠ Cementite in pearlite waves ?**

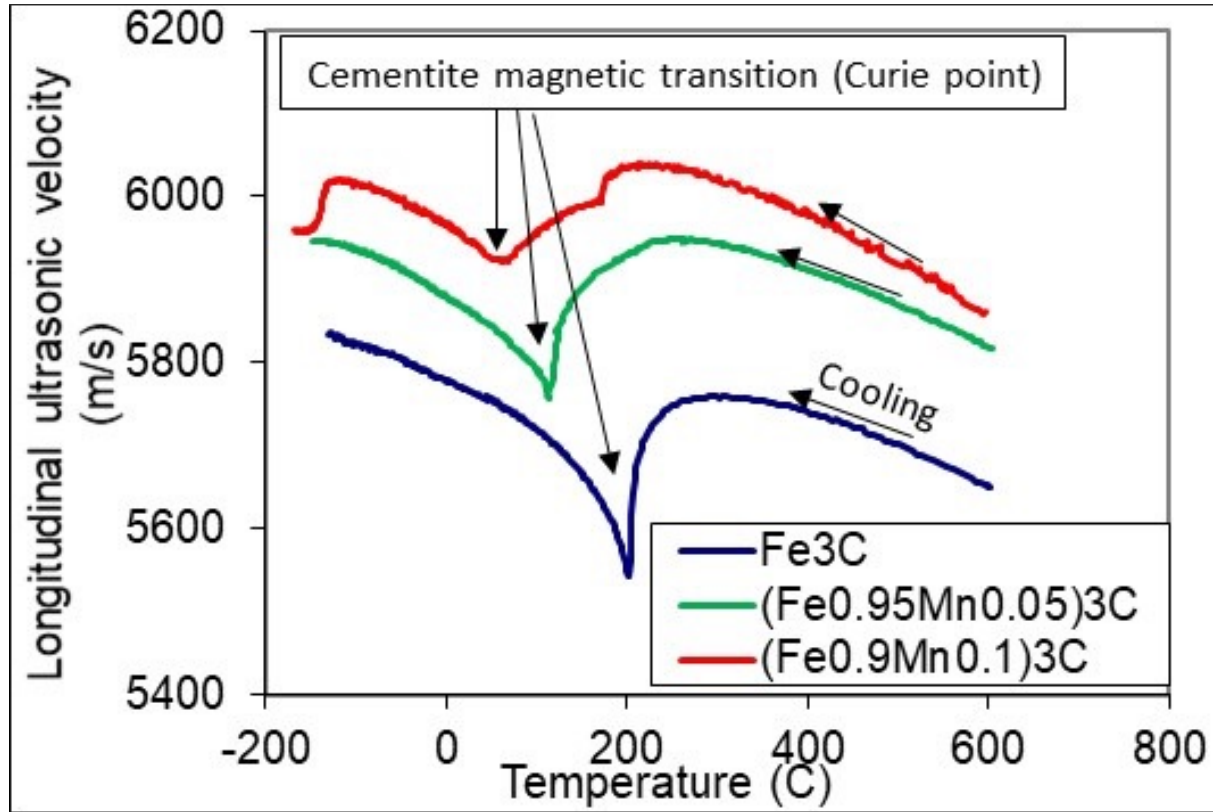
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# Pearlite Monitoring Principle: 2<sup>nd</sup> method

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- Measured Ultrasonic Velocity in Pure Cementite



Umemoto et Al  
(2019)

## Law of mixture on ultrasonic velocity

$$V = V_{\text{ferrite}} \cdot (1 - X_{\text{pearlite}}) + V_{\text{pearlite}} \cdot X_{\text{pearlite}}$$

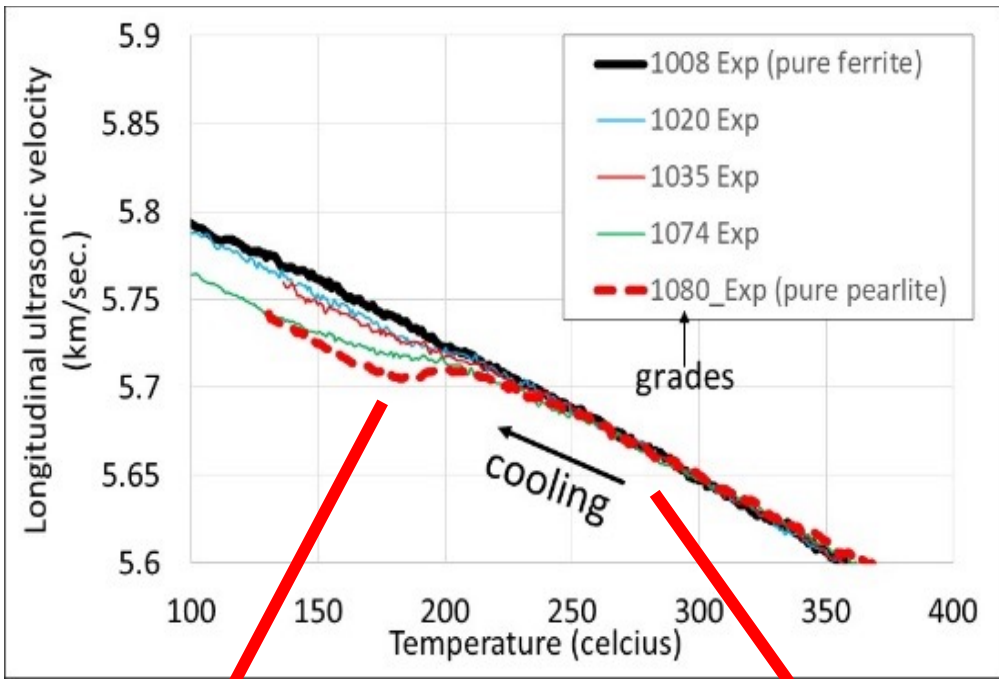
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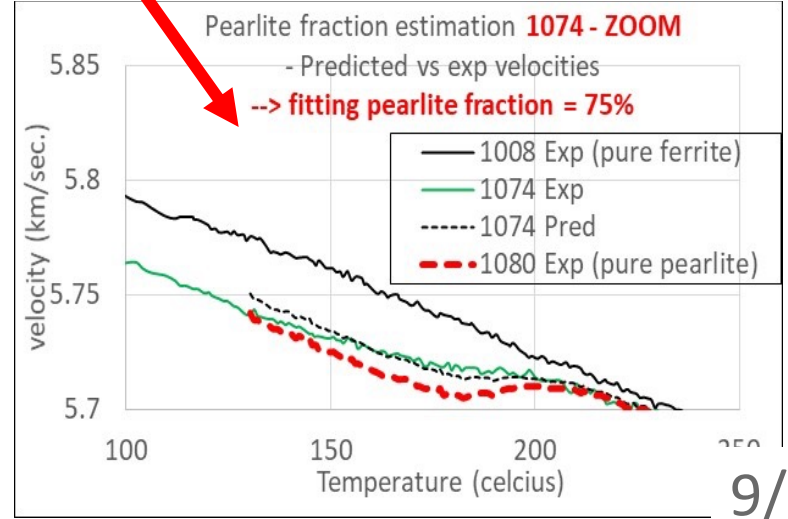
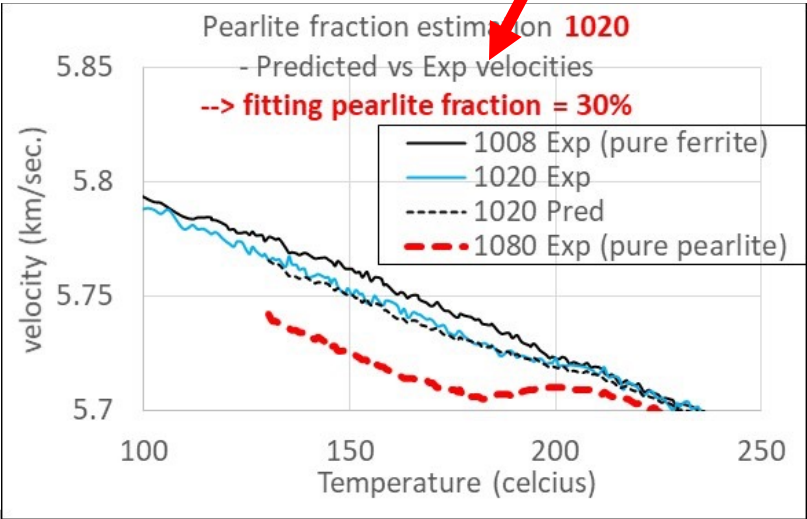
$$X_{\text{pearlite}} = \frac{V - V_{\alpha}}{V_{\text{pearlite}} - V_{\alpha}}$$



# 2<sup>nd</sup> method Pearlite Monitoring: → Pearlite fraction from calibrated US Velocity



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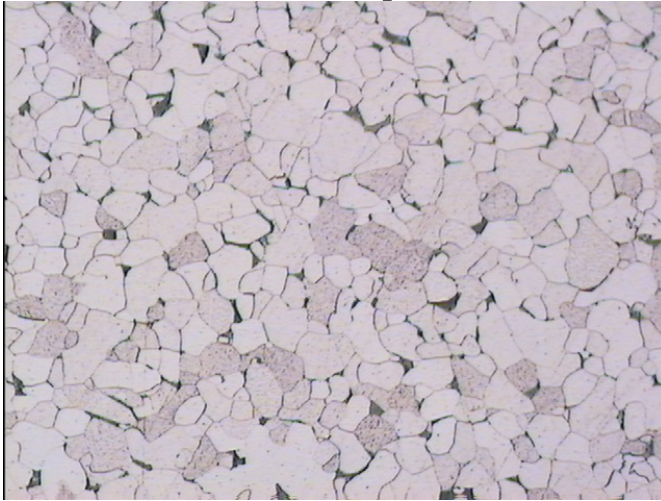


# 2<sup>nd</sup> method Pearlite Monitoring Validation: Pearlite fraction from metallography

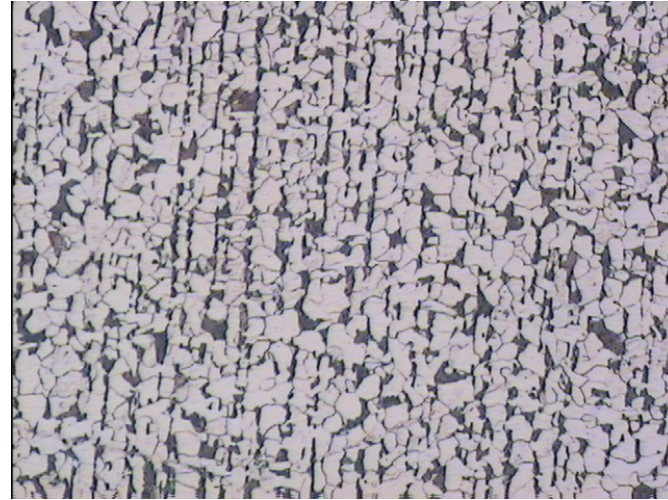


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1008: ~8% pearlite



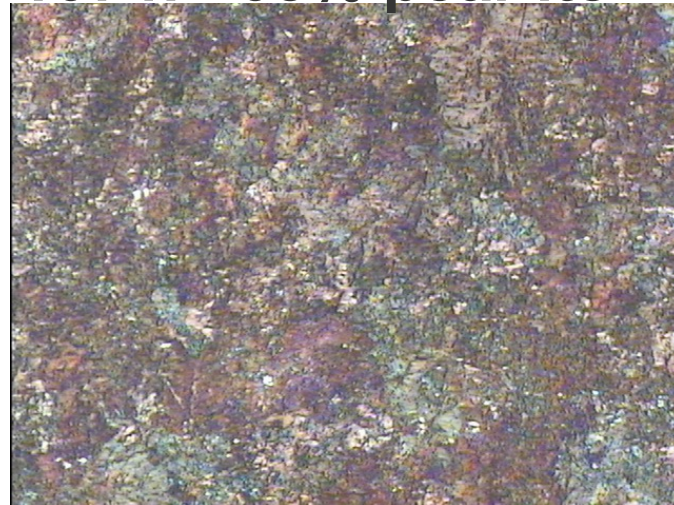
1020: ~25% pearlite



1035: ~49% pearlite



1074: ~68% pearlite

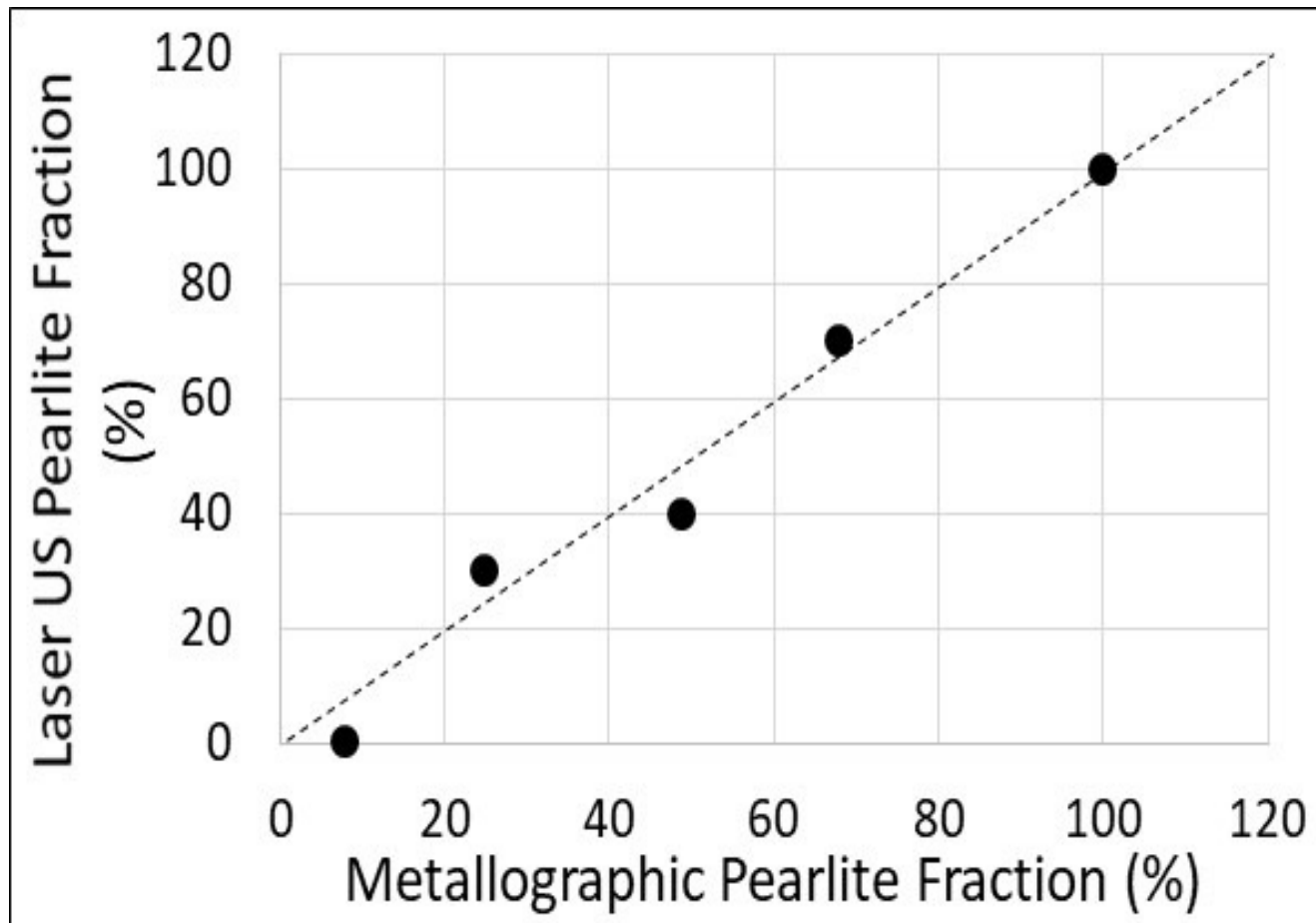


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# 2<sup>nd</sup> method Pearlite Monitoring Validation: Pearlite fraction metallo vs Laser US



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# Conclusion

- A new laser-ultrasonic technique based on the cementite ( $\text{Fe}_3\text{C}$ ) magnetic transition can monitor pearlite fraction in steel sheets.

In contrast to off-line and destructive metallography techniques, this technique **determines in real time during cooling in which proportion austenite was decomposed in pearlite.**

The technique is therefore **complementary to other non-destructive techniques** such as the laser **ultrasonic velocity technique or the magnetic techniques** that do not give any information on the new phases formation.

- The technique needs to be further evaluated on other grades