Pearlite Monitoring in Steel Sheets by Laser UltraSonic Technique

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Short Summary: A new laser-ultrasonic technique based on the cementite (Fe3C) magnetic transition was developed to monitor the presence of pearlite in steel sheets. In contrast to off-line and destructive metallography techniques, this non-destructive 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 monitor austenite decomposition during cooling of steel plates but that do not give any information on the new phases formation.

PEARLITE MONITORING PRINCIPLE

UltraSonic (US) velocity measurements conducted during cooling on pure Cementite (Fe3C) show a clear and strong velocity drop around 200 Celcius (fig. 1). This velocity change is attributed to the magnetic transition of Cementite when crossing its 200 C Curie temperature T_c: above 200 C, Cementite is no longer magnetic while below 200 C it is ferro-magnetic. Moreover, measurements show also that the Cementite Curie temperature and velocity change both decrease with Mn alloying elements. As pure pearlite is composed by 89% of ferrite and 11% of Cementite, this magnetic transition of Cementite may be detected and monitored during cooling in steel sheets containing even a small amount of pearlite.

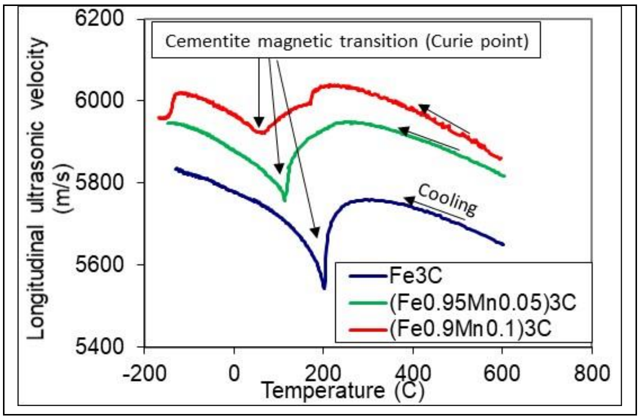

Fig.1: Measurement of ultrasonic velocity in pure Cementite (Fe3C) with different Manganese addition as a function of temperature during cooling.

To monitor pearlite fraction in the steel sheet material, a law of mixture combining pure ferrite and pure pearlite ultrasonic velocities is used:

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

V: US velocity measured on material (mixture of pearlite and ferrite).

$V_{ferrite}$ $V_{pearlite}$: US velocity measured respectively on pure ferrite and pure pearlite

$X_{pearlite}$: pearlite fraction.

The pearlite fraction is obtained by reversing the above equation.

PEARLITE MONITORING VALIDATION

To validate the above technique, ultrasonic velocity was measured during dilatometric tests at a 1 celcius/sec. cooling rate on steel grades with different Carbon contents. The chemistry of the different grades shown on table 1 produces different amounts of pearlite in the final material after cooling: from pure pearlite (100% pearlite – grade 1080) to almost pure ferrite (~0% of pearlite – grade 1008).

Table 1: Steel grades for technique validation/calibration

	C	Mn	Si	Cr	Mo	Al	% pearlite measured by metallography
1008	0.1	0.4	0	0	0	0	8%
1020	0.2	0.45	0	0	0	0	25%
1035	0.35	0.75	0	0	0	0	49%
1074	0.75	0.65	0	0	0	0	68%
1080	0.787	0.693	0.197	0.027	0.002	0.031	100%

For each grade, a clear deviation of velocity is observed during cooling when crossing the 200 C Cementite Curie temperature (fig.2-a): the higher the amount of pearlite is, the stronger the deviation is. For grades 1020, 1035 and 1074, pearlite fraction is determined by adjusting its value so that calculated and measured velocities match; grades 1008 and 1080 are used as reference for pure ferrite and pure pearlite respectively. With these adjustments, pearlite fraction obtained by the present laser ultrasonic technique is in good agreement with pearlite fraction from metallography (fig. 2-b), validating the technique. Figure 3 shows the velocity fittings for grades 1020 and 1074.

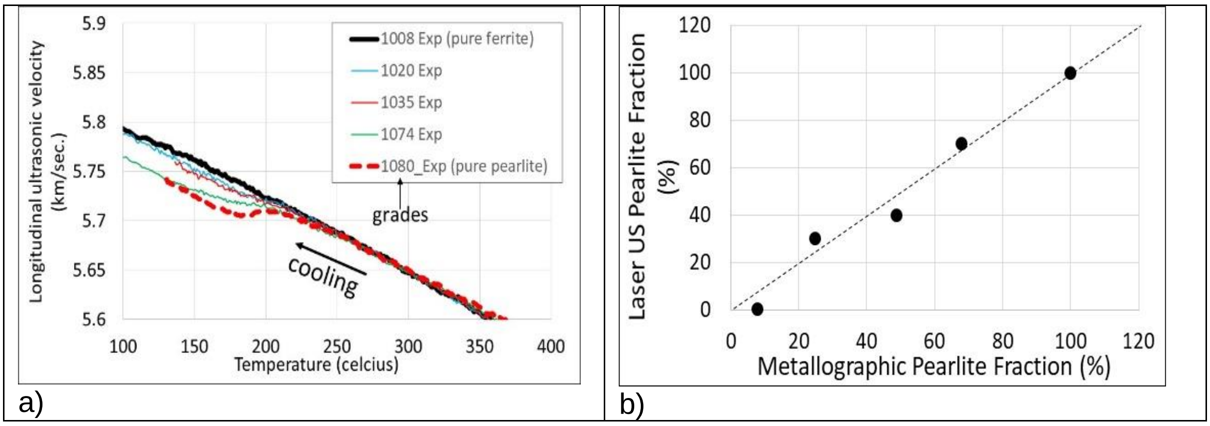

Fig.2: a) Measurement of laser ultrasonic velocity in different steel grades containing various amounts of pearlite. b) Pearlite fraction deduced from laser ultrasonic measurements (present method) versus pearlite fraction obtained by metallography.

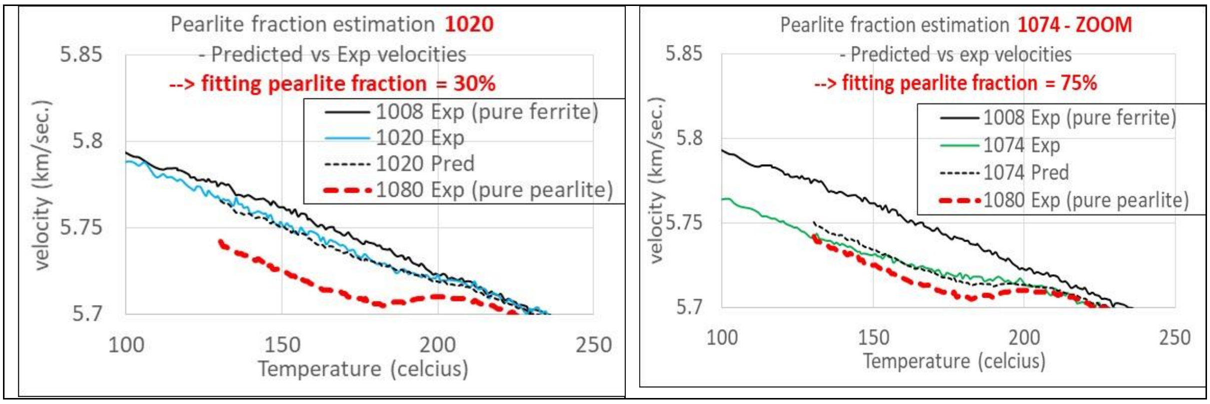

Fig.3: Measured versus predicted velocity (eq.1) for grades 1020 and 1074 using reference pure ferrite (1008) and pure pearlite (1080) velocities (grade 1035 prediction not shown)