COMPARISON OF GLOBULARISATION BEHAVIOUR DURING REHEATING TREATMENT OF DIFFERENT PEARLITIC MICROSTRUCTURES

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The Aim of this work

Fully pearlitic steels present very interesting mechanical properties when weldability requirements are not too severe.

In order to reach very thin gauges after cold rolling (high cold reduction level), some intermediate annealing treatments are necessary to globularise the pearlite and therefore to facilitate the cold rolling operations.

A **reheating treatment after hot rolling** could be a cost saving way to modify the microstructure of as-rolled strips in order to facilitate the subsequent cold rolling operation.

The influence of this treatment on microstructure of pearlite and mechanical properties is the subject of this talk

The most commonly heat treatments found in industrial practice are summarised in Figure 1.

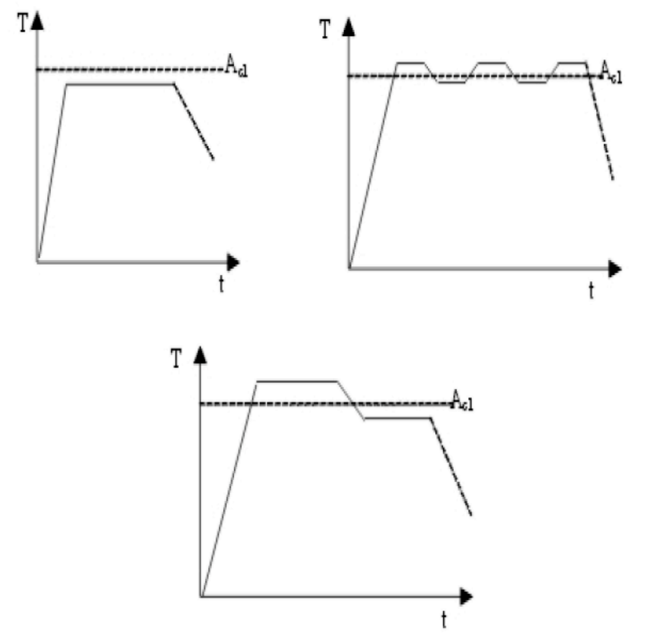


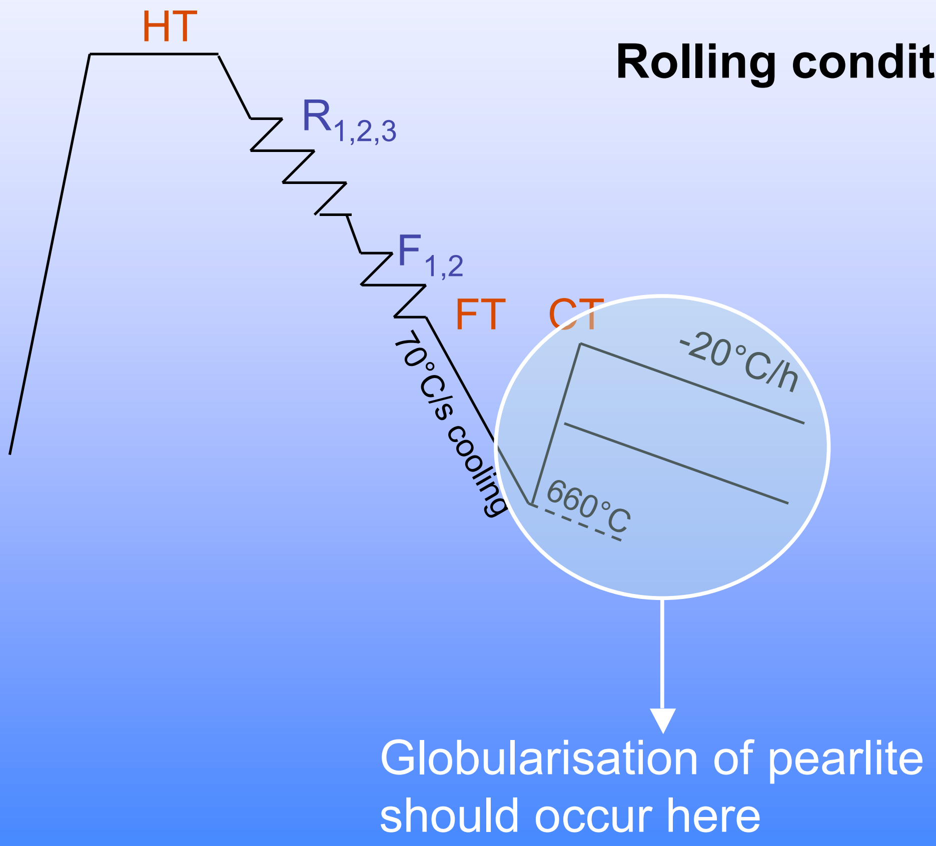
Figure 1: Globularisation treatments for steels

Hot deformation of the pearlite microstructure before globularisation treatment is also reported [1,2]. Whatever the treatment applied, the globularised cementite in medium carbon steels provide then higher ductility, formability and machinability.

[1] R. Kaspar, W. Kapellner, and C. Lang. Hot deformation-enhanced globularization of pearlite. **Steel research**, (11):492–498, 1988.
[2] L. Storojeva, D. Ponge, R. Kaspar, and D. Raabe. Development of microstructure and texture of medium carbon steel during heavy warm deformation. **Acta materialia**, 52:2209–2220, 2004.

Our proposal:

We will consider Fe-C metallurgy with Mn≈0,7%, Si=0,2%, C≈0,5%



Rolling conditions :

HT : 1200°C
$R_{1,2,3}$: Roughing (to 1000°C)
F1 : 950°C
F2 : 900°C
FT : 860°C
CT : from 660 to 720°C
(kept below the intercritic domain)

The industrial interest of the study is clear, but ….

…. How the initial pearlitic microstructure affect the globularisation process?

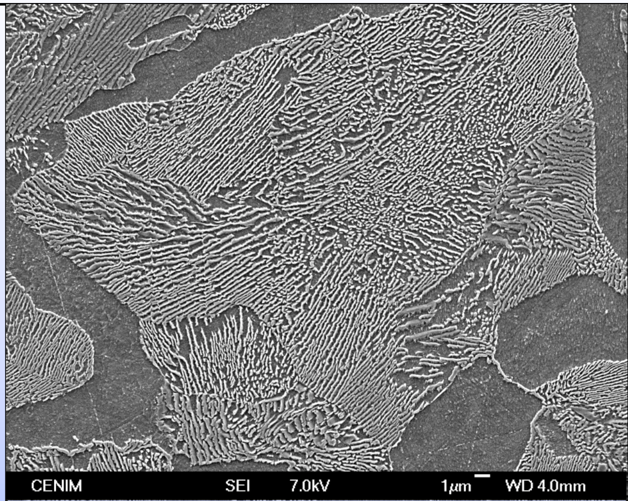
In order to study the influence of initial microstructure on pearlite globularisation, different thermomechanical and thermal treatments were applied to a 0.44 C, 0.73%Mn 0.18%Si weight per cent steel.

Pearlitic microstructures **generated**

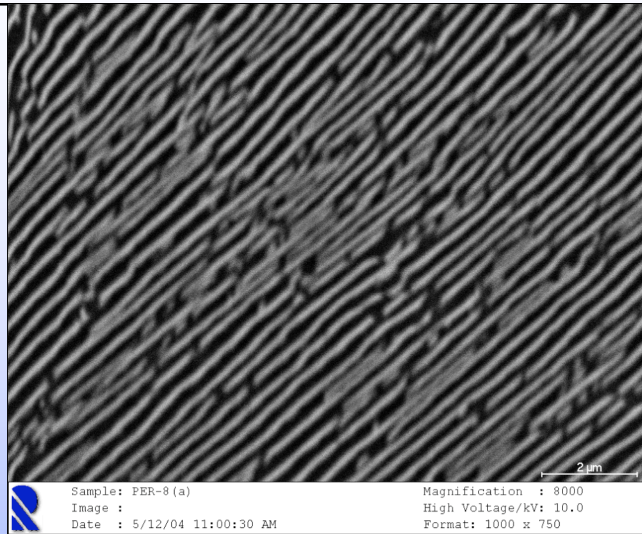
PER 1	•Austenitic hot rolling process with a finishing temperature of 850 ºC. •Seven passes were performed with a total reduction of 86%. •The steel was cooled down to 650 ºC at 35 ºC/s and then held in a furnace for 2 minutes in order to ensure a thermal homogeneity and the full transformation of the pearlite. After holding, the steel was air cooled.
PER 2	•Austenitisation at 1200ºC during 3 minutes and cooling to room temperature at 0.1ºC/s
PER 3	•Austenitisation at 1200ºC during 3 minutes and cooling to room temperature at 3 ºC/s
PER 4	•Austenitisation at 1200ºC for 15 minutes. •The sample was deformed in five steps with a final deformation temperature of 945 ºC. •Subsequently it was cooled down to 600 ºC at 50 ºC/s, held at this temperature for 20 seconds and quenched.

Pearlitic microstructures **generated**

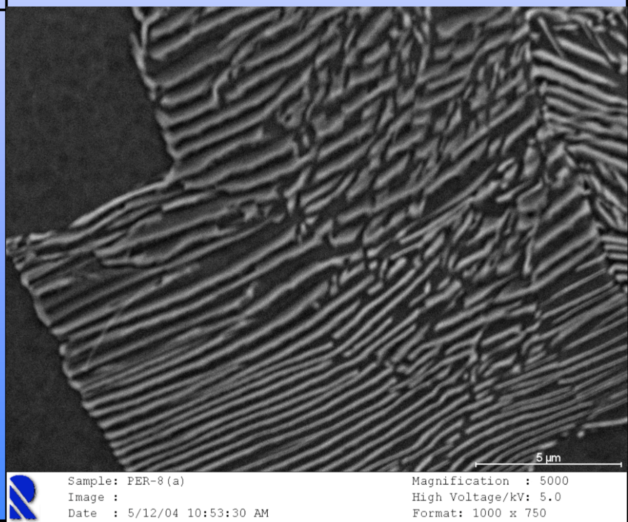
PER 1



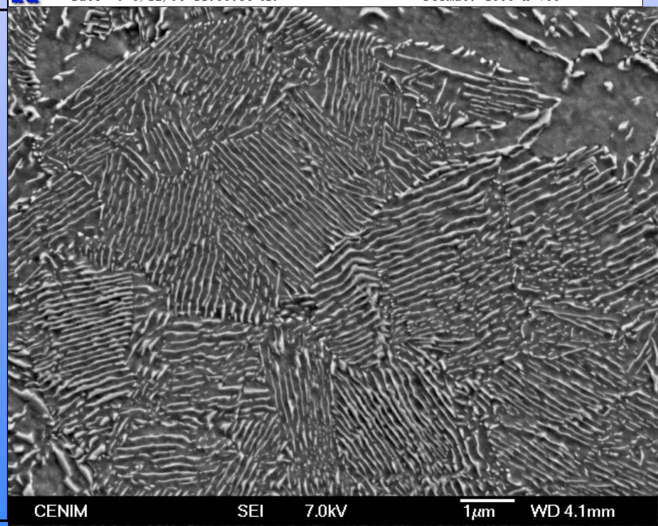
PER 3



PER 2



PER 4



Pearlitic microstructures **generated**

TABLE I. Pearlite characterisation

Sample	% Pearlite	Interlamellar spacing (µm)	Hv (1Kg)
PER3: 1200ºC, 180s + cooling at. 0.1ºC/s	89	0.24±0.07	202±12
PER2: 1200ºC, 180s + cooling at. 3ºC/s	97	0.17±0.03	259±14
PER1: Hot rolling+ 650ºC, 2min	71	0.23±0.06	220±10
PER4: Hot Torsion + 600ºC, 10s	100	0.13±0.03	281±2

Globularisation Heat Treatment **proposed**

Simulation of the industrial heat treatment after hot rolling by **Isothermal Heat Treatment**.

Samples were reheated at **650ºC** and **700ºC** during **1.5h** in order to promote the softening by pearlite globularisation.

Vickers hardness measurements and SEM micrographs were performed on reheated samples.

Factor used to determine **degree of globularisation**:

Tian and Kraft have reported a limit value of F=1 which indicates that the whole of cementite particles are spherical in shape [3,4].

$$F = \frac{2N_L^2}{3\pi V_c N_A}$$

The actual calculation of the F values is performed in terms of the quantities NL (number of interceptions with cementite particle profiles per unit length of test line), Vc (volume fraction of cementite) and NA (number of cementite particle profiles per unit area on the plane of observation)

[3] Y. L. Tian and R. W. Kraft, **Metallurgical transactions**, **18A** (1987) 1359.
[4] Y. L. Tian and W. Kraft, **Metallurgical transactions**, **18A** (1987) 1403.

Globularisation Heat Treatment: **Results**

TABLE II. Samples characterization after reheat treatments

Sample	Reheated: 650ºC, 1.5h		Reheated: 700ºC, 1.5h		Hardness drop (%)	
	Hv (1kg)	F	Hv (1kg)	F	650ºC,1.5h	700ºC,1.5h
PER3: 1250ºC, 180s + cooling at. 0.1ºC/s	196±6	2.2±1.3	190±18	1.9±0.6	3	6
PER2: 1250ºC, 180s + cooling at. 3ºC/s	211±3	2.3±0.6	202±13	1.3±0.5	19	22
PER1: Hot rolling+ 650ºC, 2min	212±8	2.5±0.6	210±13	2.3±1.5	4	5
PER4: Hot Torsion + 600ºC, 10s	234±7	1.2±0.2	210±1	1±0.2	18	25

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TABLE II. Samples characterization after reheat treatments

Sample	Reheated: 650ºC, 1.5h		Reheated: 700ºC, 1.5h		Hardness drop (%)	
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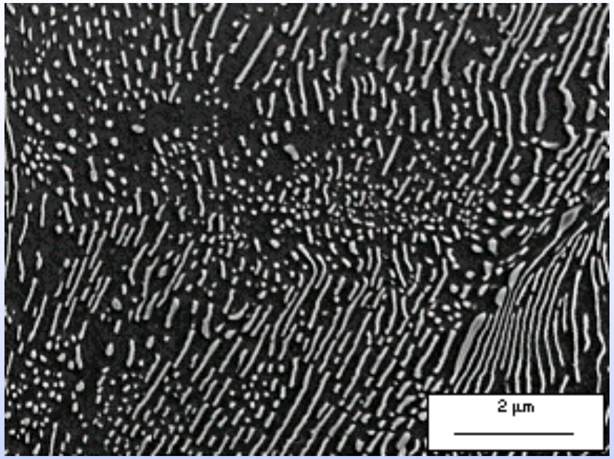
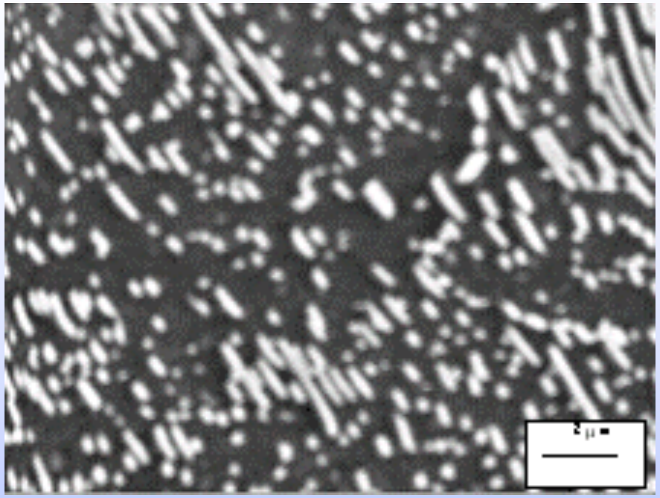
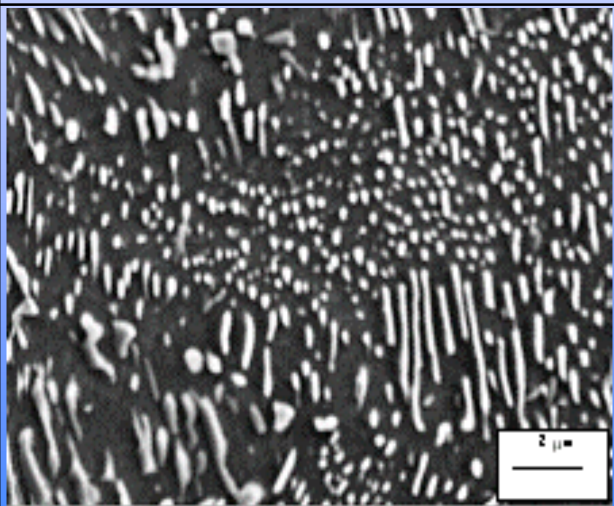
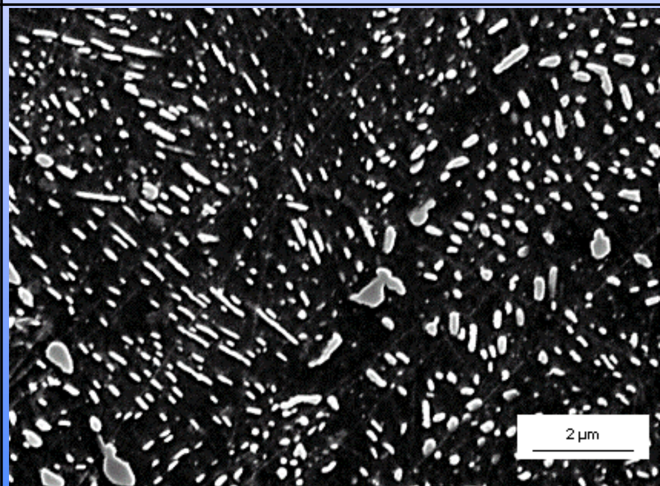
PER3	196±6	2.2±1.3	190±18	1.9±0.6	3	6
PER2	211±3	2.3±0.6	202±13	1.3±0.5	19	22
PER1	212±8	2.5±0.6	210±13	2.3±1.5	4	5
PER4	234±7	1.2±0.2	210±1	1±0.2	18	25

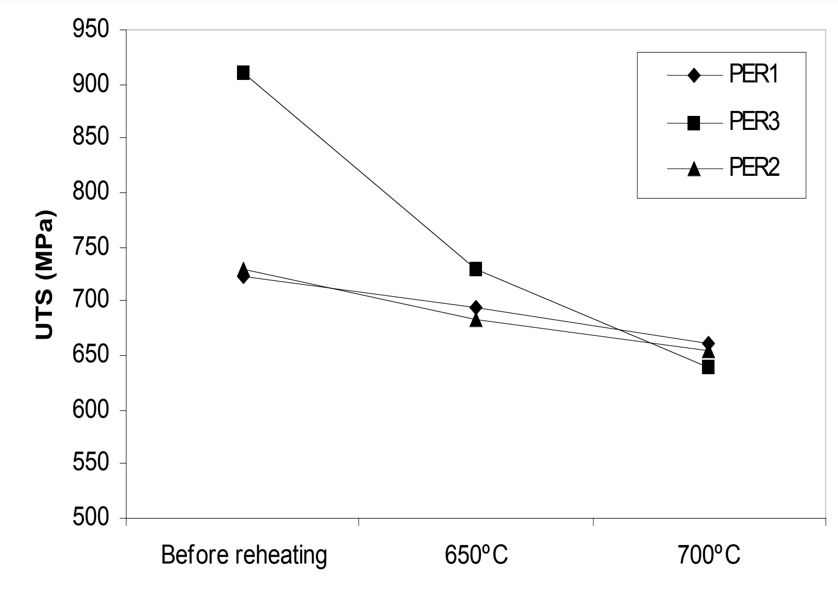
Globularisation Heat Treatment: **Results**

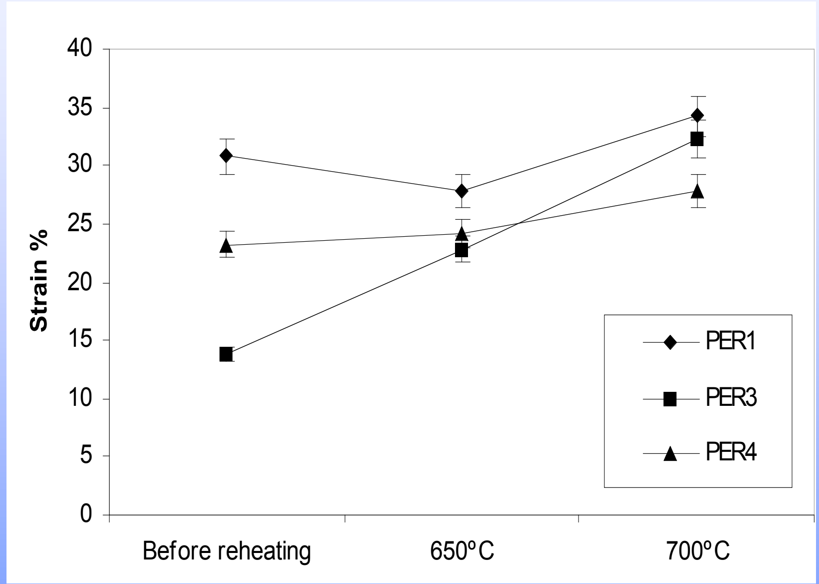
SEM micrographs from samples after 1.5h reheating at 700ºC

PER 1		PER 3	
PER 2		PER 4	

Globularisation Heat Treatment: **Results**

Mechanical properties





CONCLUTIONS

➊The influence of different pearlite microstructures obtained by thermal or thermomechanical treatments on globularisation by simulating an induction reheating device has been studied.

➋The lower interlamellar space promotes a quicker globularisation process and hence, a more significant change in mechanical properties.

➌The value of ductility tends to overcome those obtained after the same heat treatment with a bigger interlamellar space, maintaining higher strength levels.

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