Improved toughness in a bainitic 38MnV7 steel

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Outline

1. Introduction
2. Experimental method
3. Results and Discussion
4. Conclusions

1. Introduction

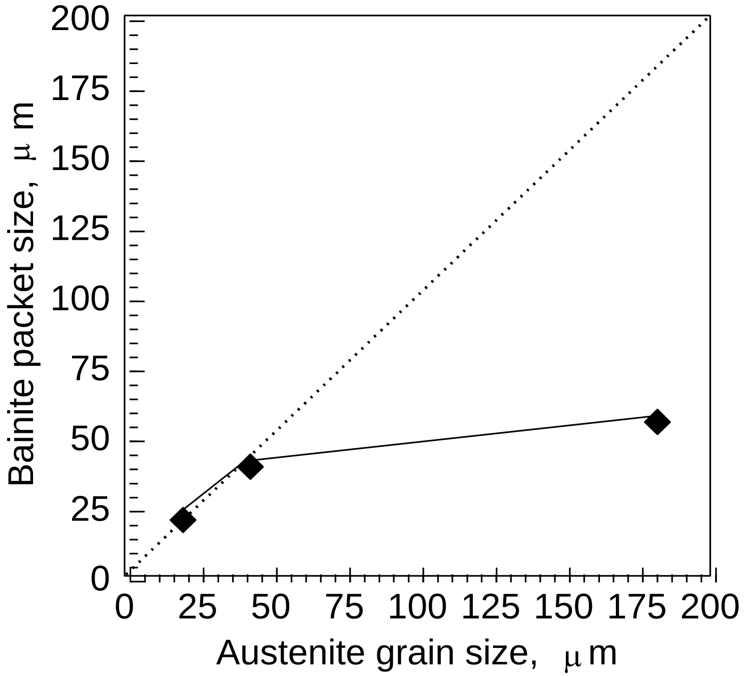
Steel 38MnV7 is presently used to manufacture automotive components. Under controlled thermal treatment a bainitic microstructure can provide UTS as high as 1000 MPa

However, its toughness, evaluated by Charpy test, strongly depends on the type of bainite, whether upper (obtained by continuous cooling) or lower bainite (isothermal treatment)

The mechanisms promoting high toughness in bainite are well known: small bainitic packet, low dislocation density and limited amount of carbides

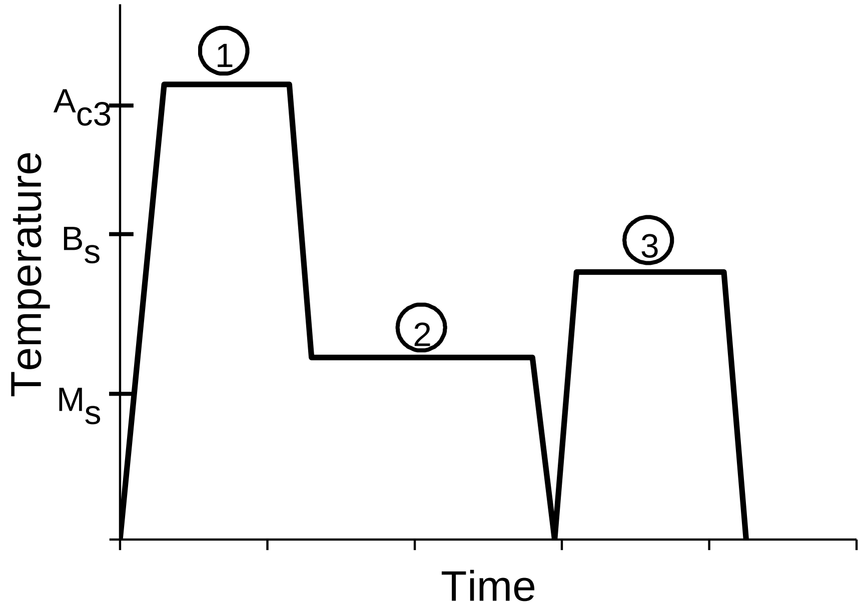
1. Introduction

The bainitic packet decreases at decreasing austenization temperatures. There is a direct relation between the austenitic grain size and the banitic packet at small austenitic grain sizes. In other words, when the austenitic grain size is relatively large, every grain will transform into several banitic packets, but when the austenitic grain size is small, into few packets



1. Introduction

An isothermal heat treatment was designed for the current steel to promote a very fine austenitic grain size. The austenization temperature was kept as low as possible, close to the transformation temperature Ac3. Then, a fast quenching to a temperature above Ms to obtain lower bainite. After full banitic transformation, air cooling at room temperature followed by a tempering treatment to reduce internal stresses due to the above transformation



1. Introduction

The study was carried out on the following steels

Steel	C	Si	Mn	V	Ti	N
MN4	0.38	0.25	1.53	0.11	-	0.0217
MN5	0.38	0.26	2.08	0.12	-	0.0245
MN6	0.38	0.25	2.23	0.12	-	0.0118
MN7	0.36	0.25	1.80	0.105	0.029	0.0111

C, Si and V at constant amount.
Mn varying from 1.5 to 2.23%
Steel MN7 with some Ti

1. Introduction

By dilatometry

Steel	B_s (ºC)	M_s (ºC)
MN4	560	296
MN5	535	275
MN6	527	299
MN7	550	301

Austenization temperature: 820ºC for 30 min

Bainitic isothermal temperature 360ºC for 90 min

Tempering temperature: 600ºC for 60 min

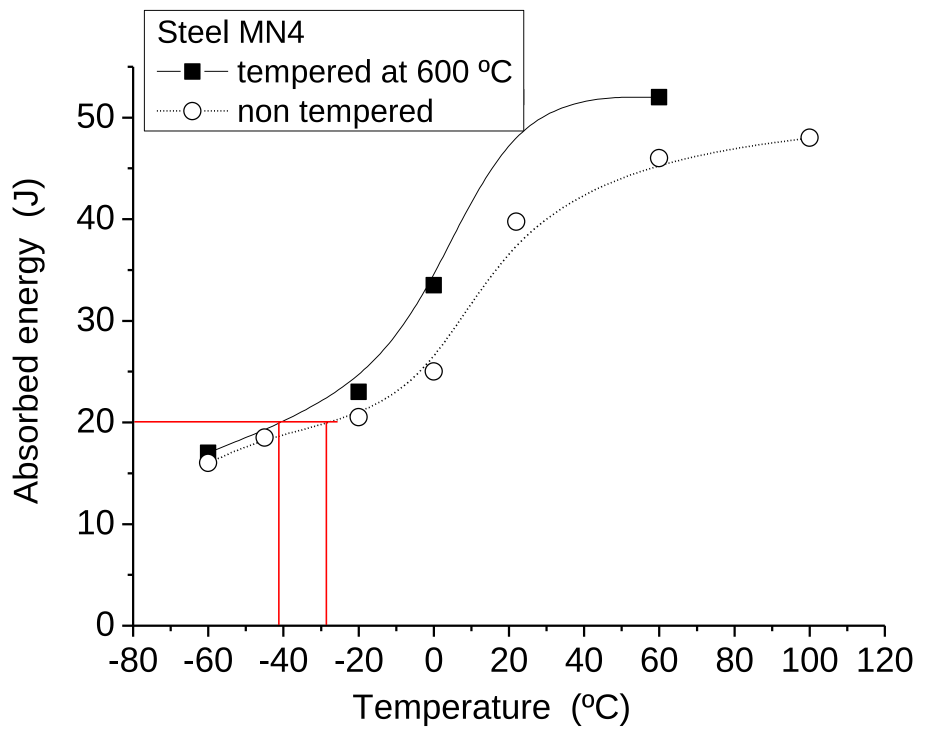
Steel	MN4	MN5	MN6	MN7
D_γ (μm)	11	12	13	16

MN7 steel, although bearing Ti, promoted larger grains, because low N, TiN particles, and therefore lower V(CN)

1. Introduction

Transition temperature (ITT)

Steel	Tempering at 600ºC; ITT at 20 J (ºC)	No-tempering ITT at 20 J (ºC)
MN4	-41	-29
MN5	-4	-
MN6	-5	-
MN7	-23	-



1. Introduction

Mechanical properties

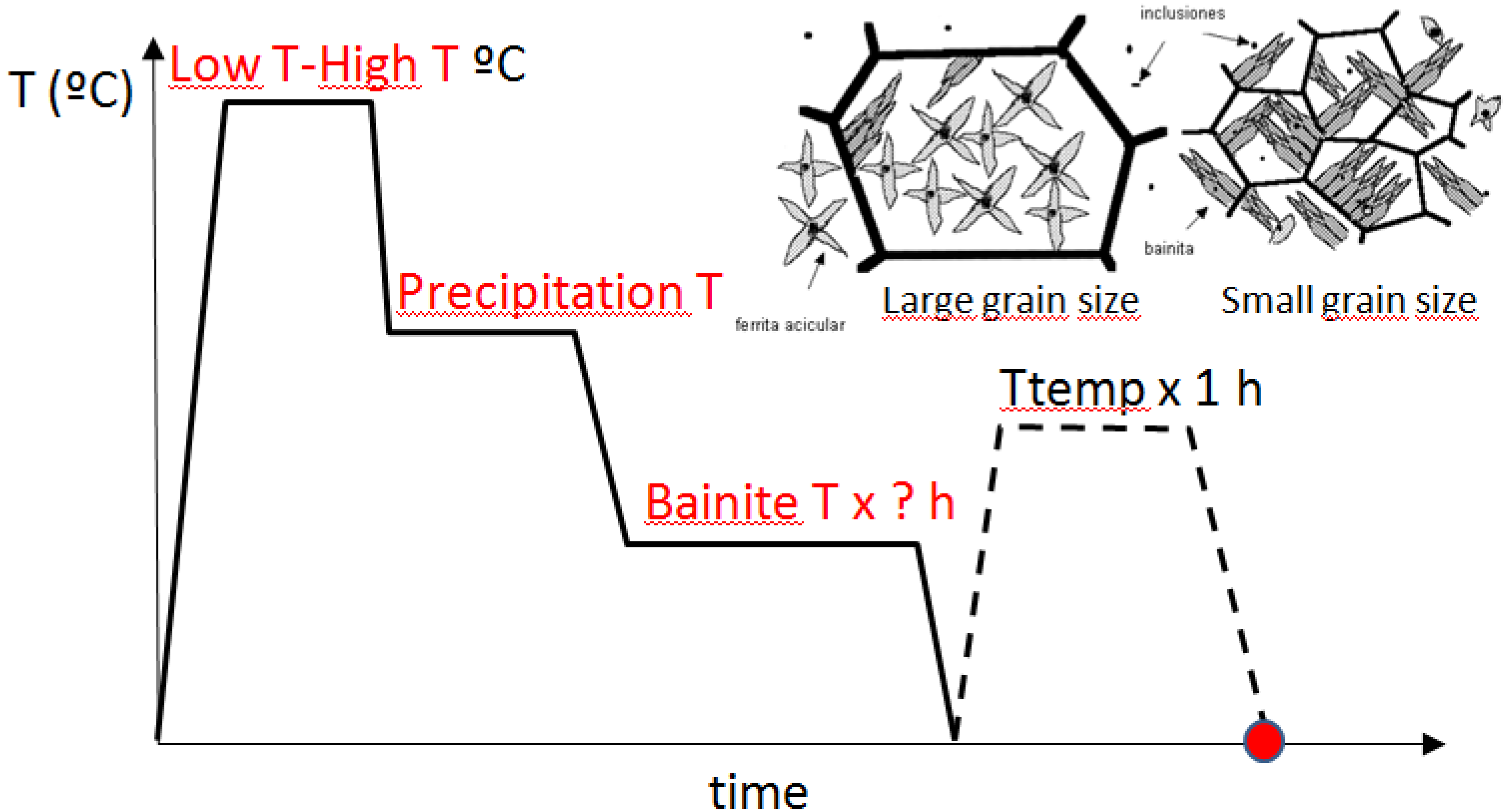
Steel	YS (MPa)	UTS (MPa)	A(%)	RA(%)
MN4	760 777*	905 954*	15 15*	49,2 52,5*
MN5	816	958	17,1	50,5
MN6	847	997	14,5	53,4
MN7	848	960	13,1	49,8

* non-tempered

It was concluded that the lower Mn content of steel MN4, and the lower segregation were responsible of its better toughness. It was then decided to take MN4 steel as reference steel, to improve its properties by adopting a new strategy

1. Introduction

New estrategy:



In order to accurately design the process, TTT and PTT curves must be obtained

2. Experimental method

New steels:

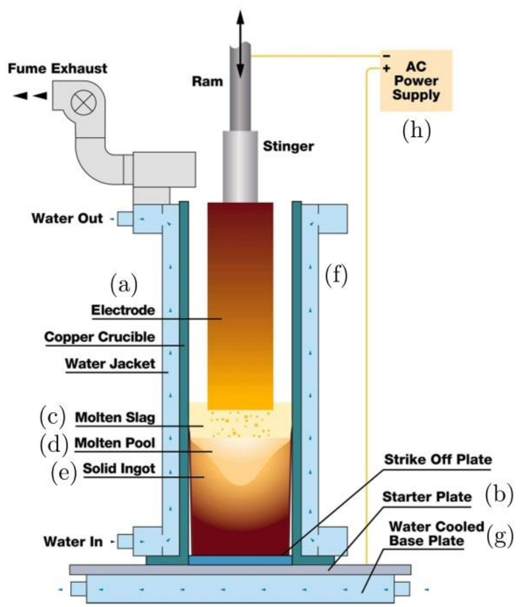
	%C	%Si	%Mn	%Al	%V	%Ti	%N
MN8	**0.36**	**0.27**	**1.7**	**0.013**	**0.097**	**<0.010**	**0.0152**
MN9	**0.37**	**0.26**	**1.66**	**0.012**	**0.14**	**<0.010**	**0.0131**
MN10	**0.35**	**0.23**	**1.45**	**0.01**	**0.086**	**0.018**	**0.0158**
M11	**0.46**	**0.3**	**1.61**	**<0.003**	**0.096**	**<0.010**	**0.0171**
MN12	**0.43**	**0.27**	**1.84**	**0.003**	**0.082**	**<0.010**	**0.0155**
MN13	**0.43**	**0.25**	**1.33**	**0.002**	**0.066**	**0.025**	**0.0127**

Steel	C	Si	Mn	V	Ti	N
MN4	0.38	0.25	1.53	0.11	-	0.0217

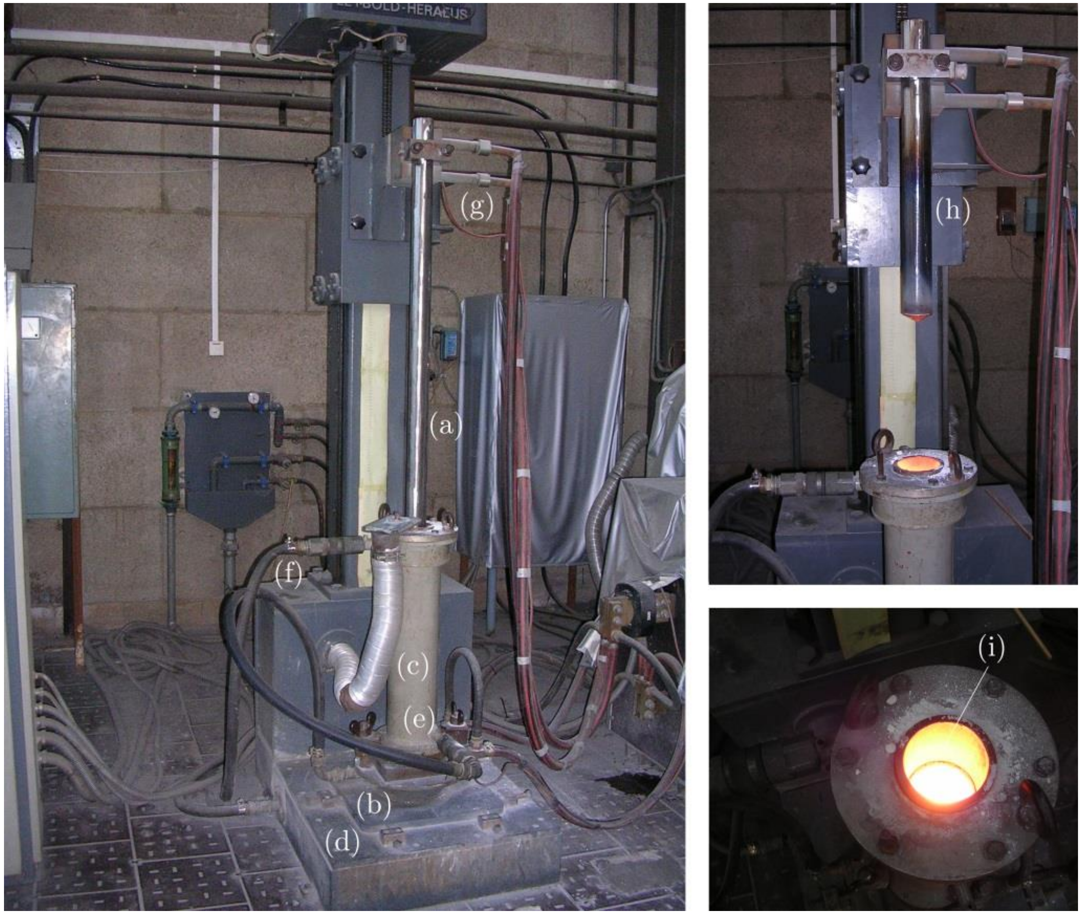
Increasing C, Mn upper and lower than MN4, and addition of Ti

2. Experimental method

Casts were made by Electro Slag Remelting at CENIM facilities



(a) electrodo consumible. (b) placa de inicio. (c) escoria fundida. (d) baño líquida. (e) lingote sólido. (f) molde refrigerado. (g) placa base refrigerada y (h) alimentación.



(a) Electrodo consumible. (b) placa de inicio. (c) molde refrigerado. (d) placa base refrigerada. (e) y (f) entrada y salida de circuito de refrigeración respectivamente. (g) alimentación. (h) aspecto del electrodo al finalizar la refusión y (i) baño líquido.

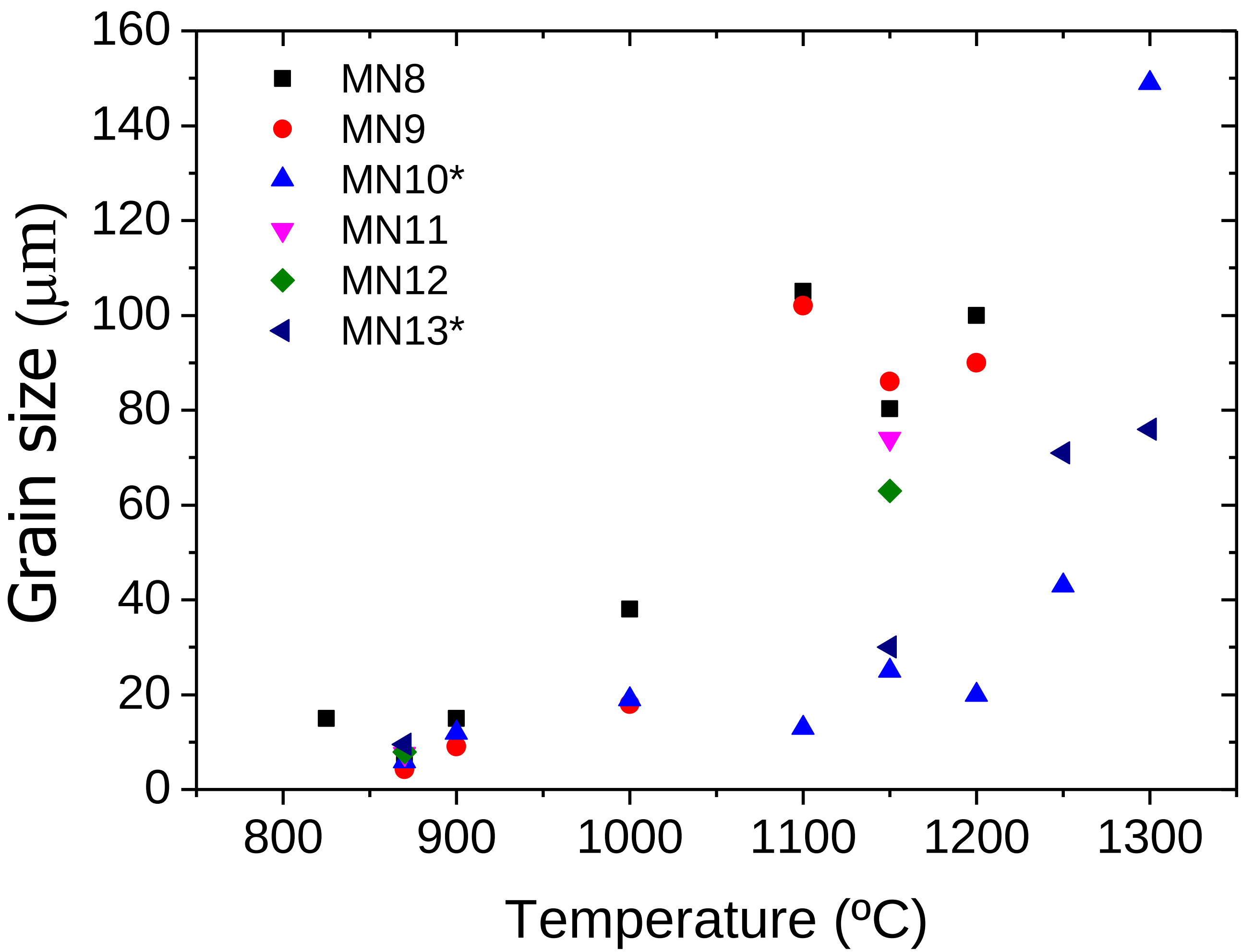
+ Forge + Annealing + Machining

2. Experimental method

TTT curves were determined by dilatometry
PTT curves were derived by stress relaxation technique

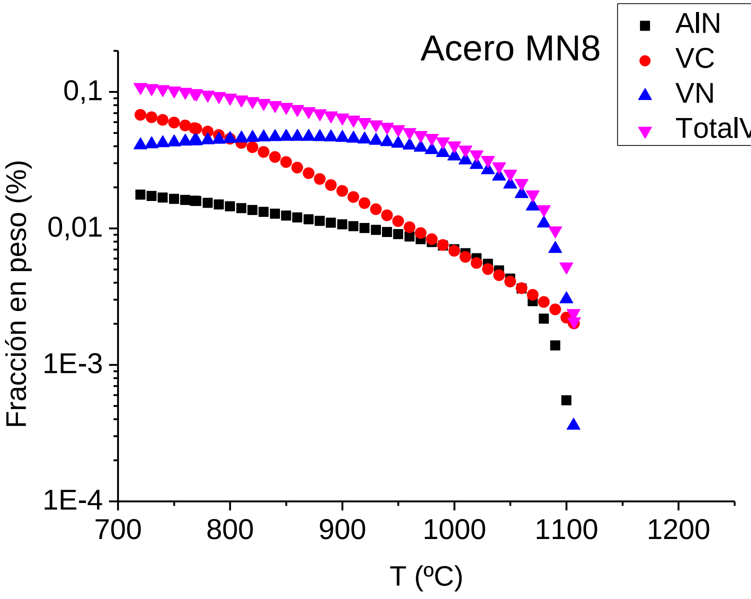
3. Results and Discussion

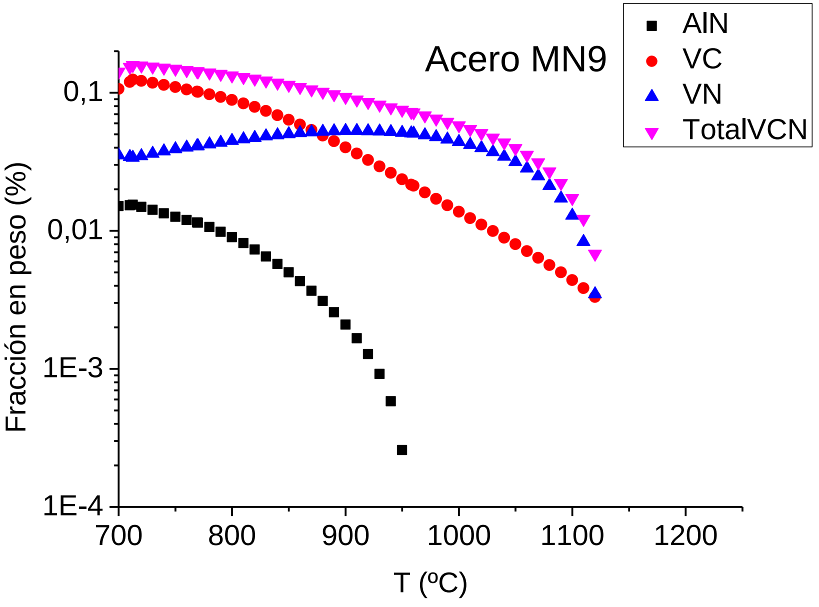
Study of the austenitization grain size (holding time 15 min, heating 1ºC/s)



3. Results and Discussion

Thermodynamic calculations: FactSage





	%C	%Si	%Mn	%Al	%V	%Ti	%N
MN8	**0.36**	**0.27**	**1.7**	**0.013**	**0.097**	**<0.010**	**0.0152**
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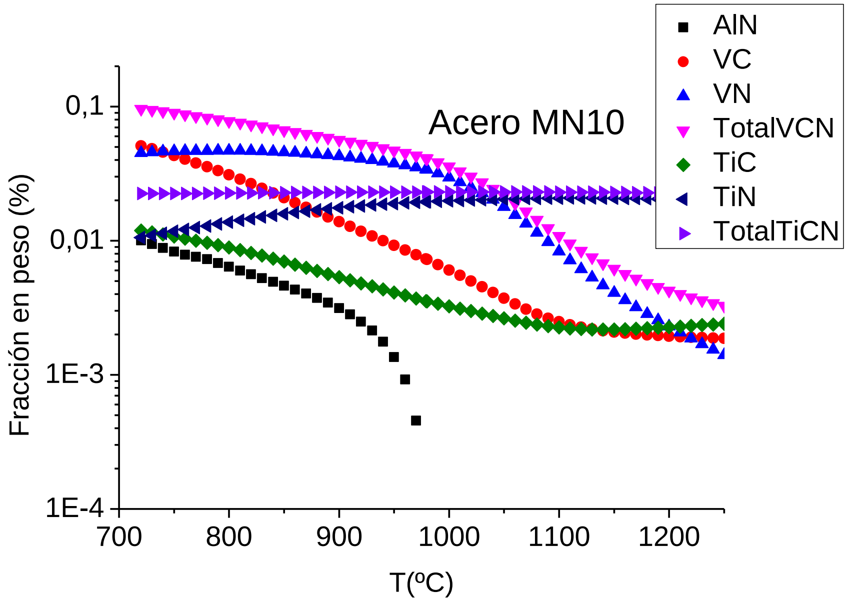

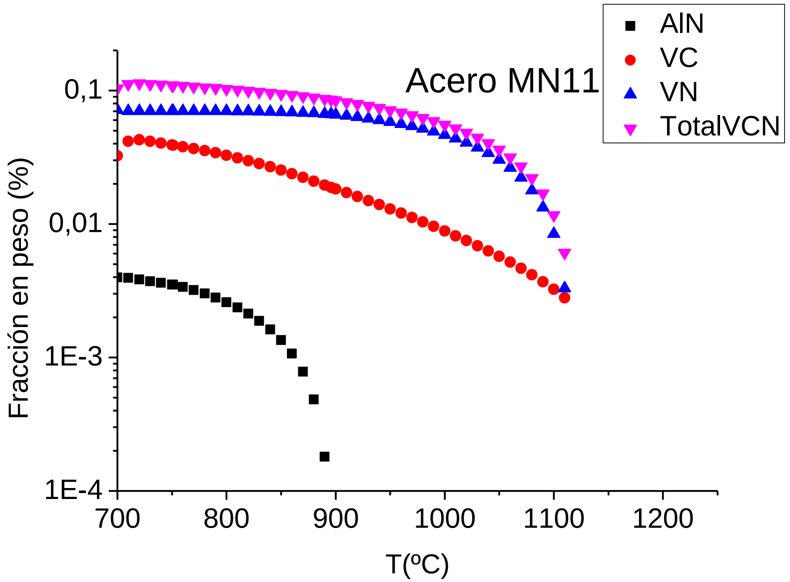

	%C	%Si	%Mn	%Al	%V	%Ti	%N
MN10	**0.35**	**0.23**	**1.45**	**0.01**	**0.086**	**0.018**	**0.0158**
M11	**0.46**	**0.3**	**1.61**	**<0.003**	**0.096**	**<0.010**	**0.0171**

3. Results and Discussion

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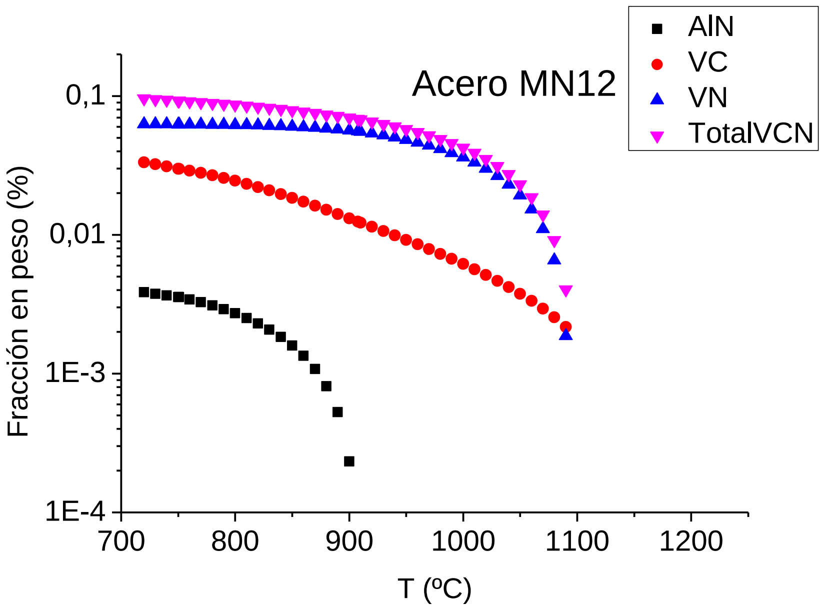
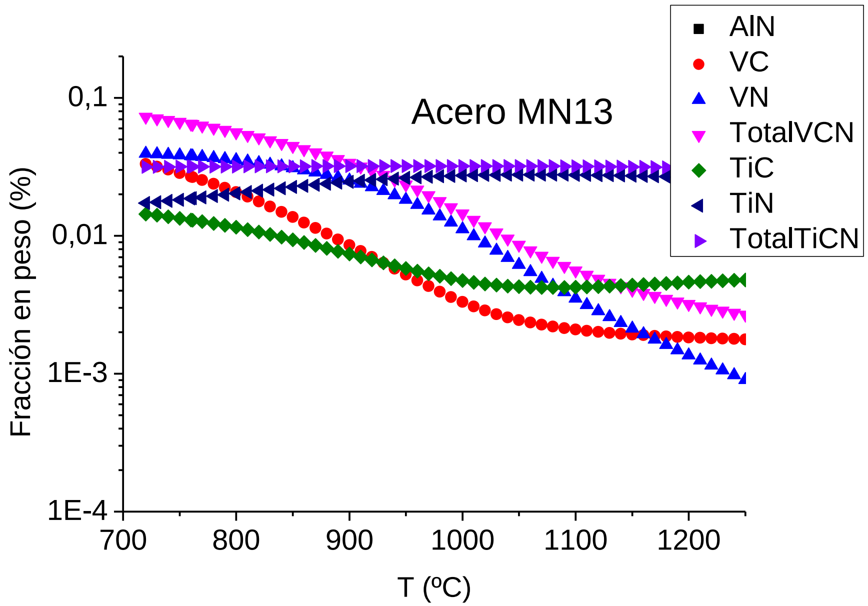


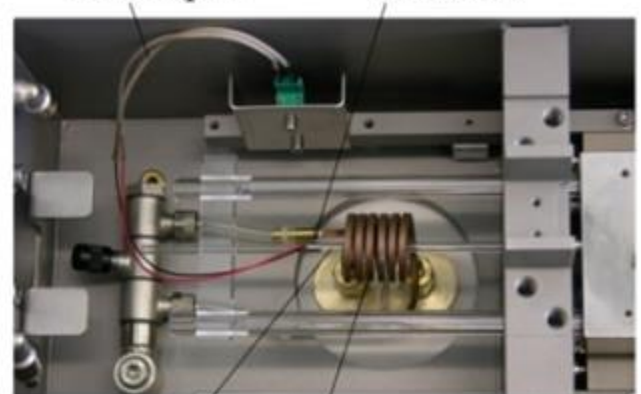


	%C	%Si	%Mn	%Al	%V	%Ti	%N
MN12	**0.43**	**0.27**	**1.84**	**0.003**	**0.082**	**<0.010**	**0.0155**
MN13	**0.43**	**0.25**	**1.33**	**0.002**	**0.066**	**0.025**	**0.0127**

3. Results and Discussion

Dilatometric study: TTT curves. Quenching dilatometer

(a)



(c)

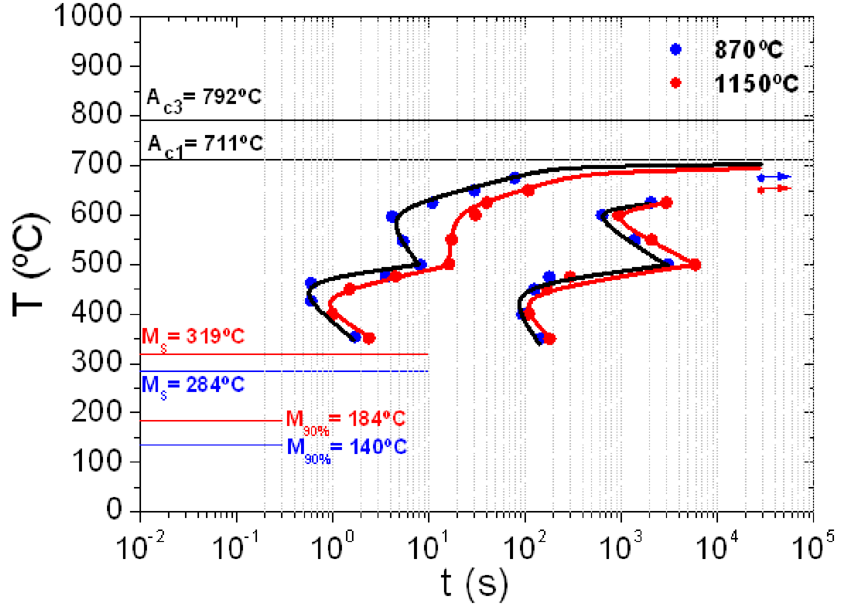
BAHR DIL 805A/D (CTM)

3. Results and Discussion

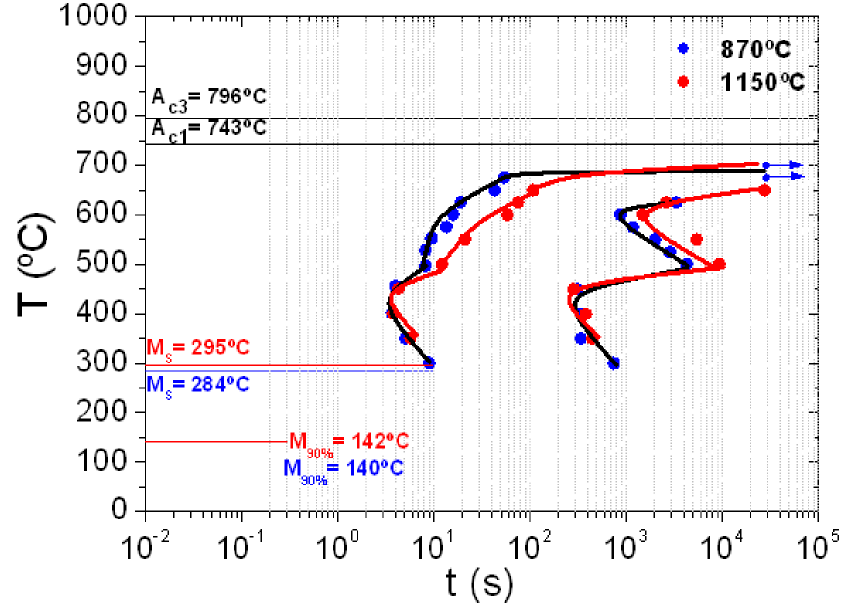
Dilatometric study: TTT curves at two conditions
Low Austenization Temp.: 870ºC (10 μm)
High Austenization Temp.: 1150ºC (60-80 μm)
and 1300 ºC (80-150 μm) (Ti steels)

Heating rate: 1ºC/s, holding time 15 min
Two type samples: Solid cylinders (at high T)
Hollow samples (low T) to achieve high cooling rates

3. Results and Discussion



MN8



MN9

No practical effect of initial grain size, neither of V in solution

	%C	%Si	%Mn	%Al	%V	%Ti	%N
MN8	**0.36**	**0.27**	**1.7**	**0.013**	**0.097**	<0.010	**0.0152**
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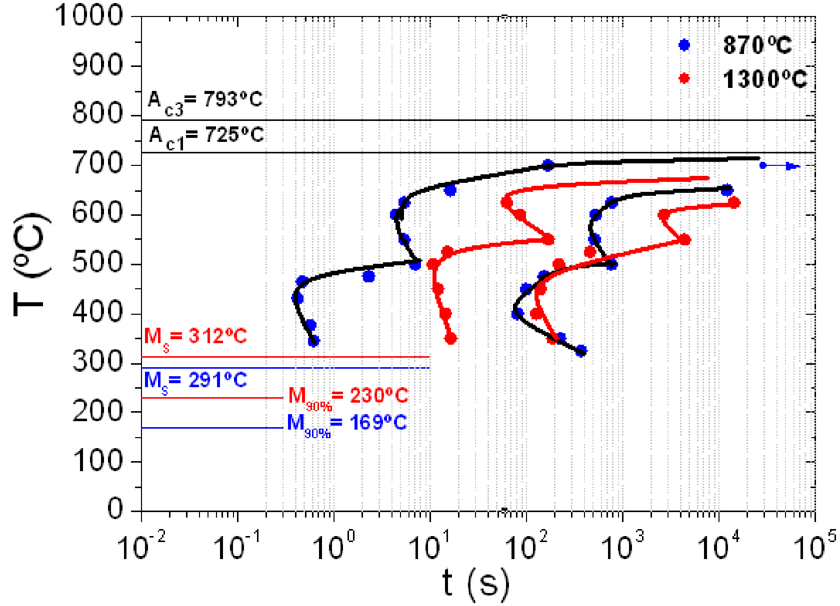
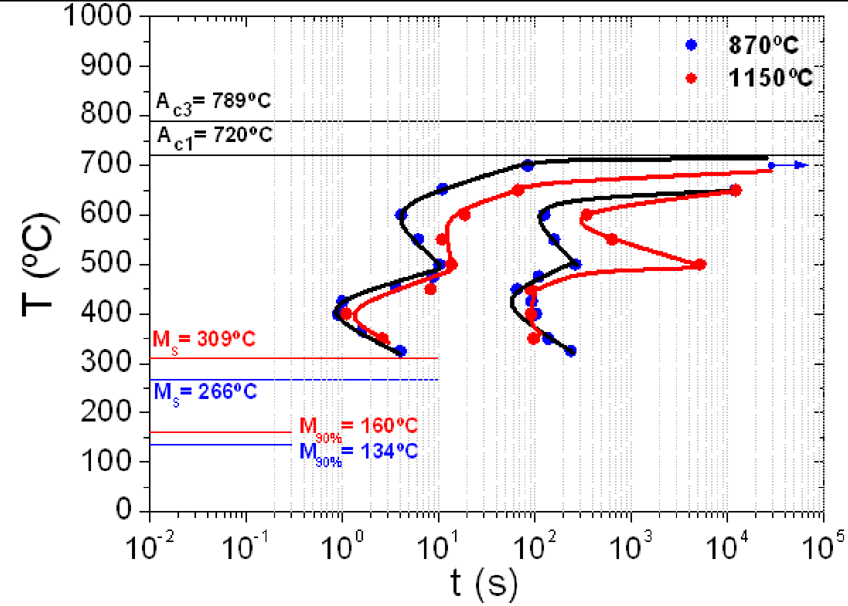
3. Results and Discussion



MN10

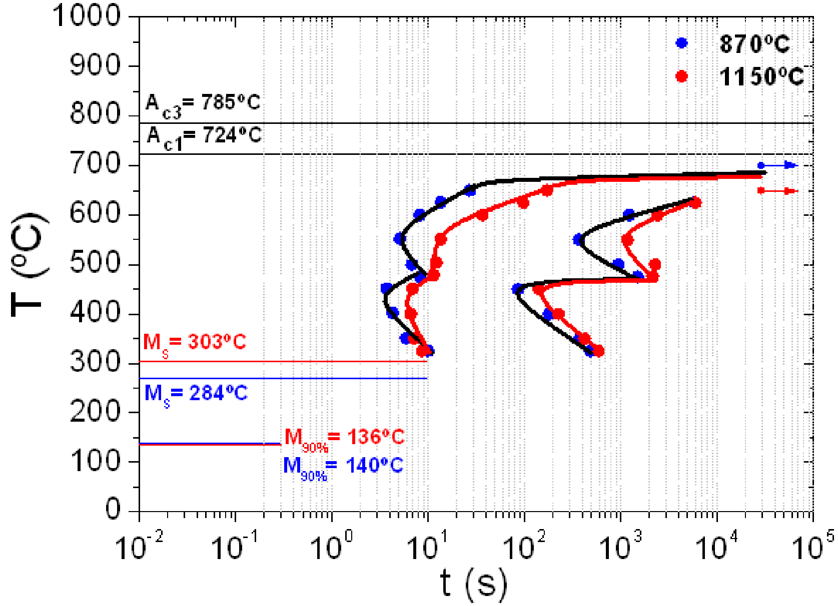


MN11

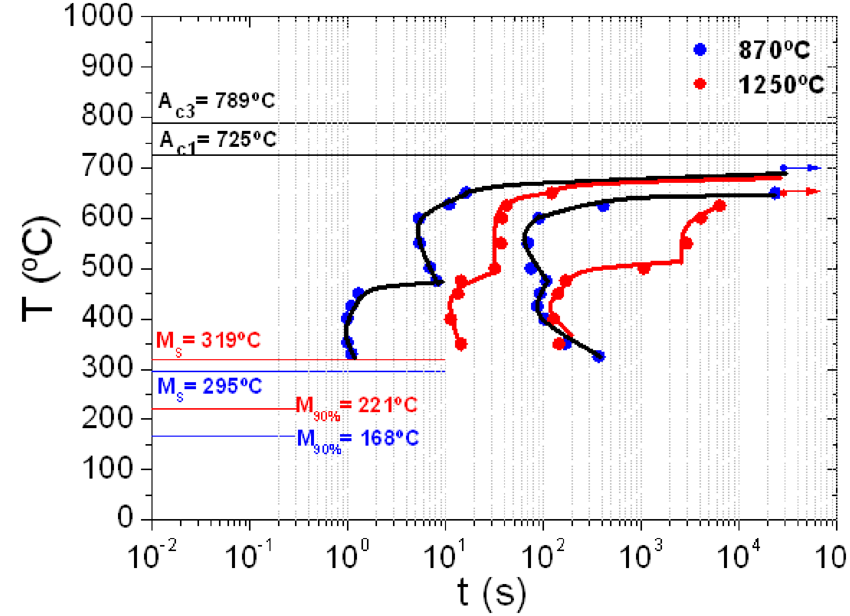
Ti in solution promotes a delay on the onset of transformation kinetics

	%C	%Si	%Mn	%Al	%V	%Ti	%N
MN10	**0.35**	**0.23**	**1.45**	**0.01**	**0.086**	**0.018**	**0.0158**
M11	**0.46**	**0.3**	**1.61**	**<0.003**	**0.096**	**<0.010**	**0.0171**

3. Results and Discussion



MN12



MN13

	%C	%Si	%Mn	%Al	%V	%Ti	%N
MN12	**0.43**	**0.27**	**1.84**	**0.003**	**0.082**	**<0.010**	**0.0155**
MN13	**0.43**	**0.25**	**1.33**	**0.002**	**0.066**	**0.025**	**0.0127**

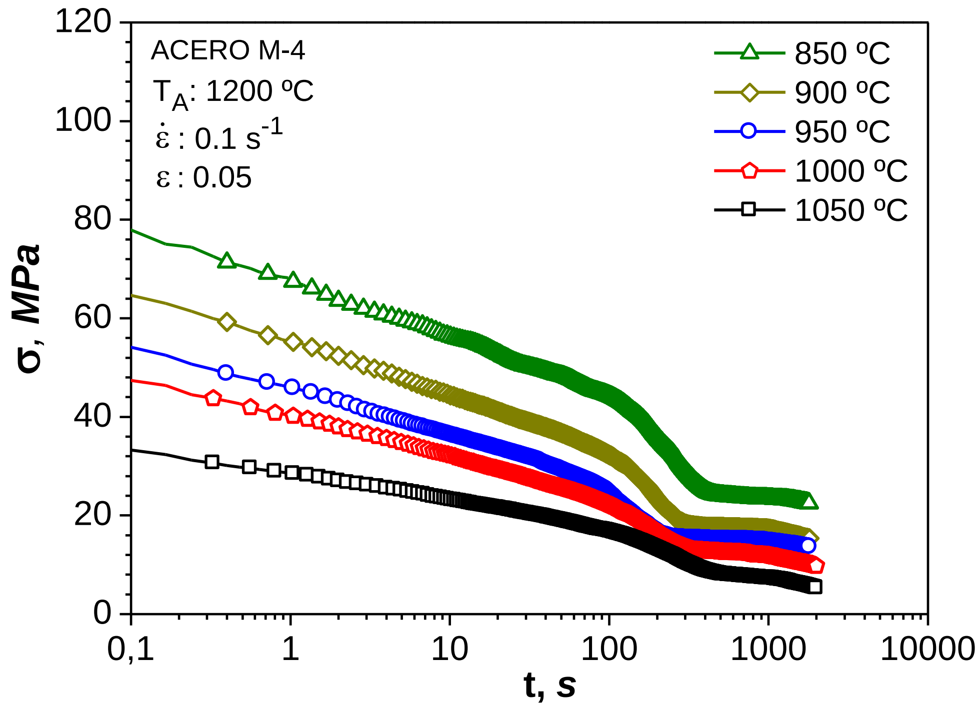
3. Results and Discussion

	Bainitic nose hardness (HV)	
	Low Aust T	High Aust T
MN8	465	359
MN9	458	353
MN10*	318	292
MN11	352	366
MN12	383	351
MN13*	397	357

As a general trend lower hardness values when soaking at high temperatures.
Differences cannot be only attributed to grain sizes (larger bainitic packets) but also to suppression of precipitation

3. Results and Discussion

On going work to derive PTT curves by the stress relaxation technique



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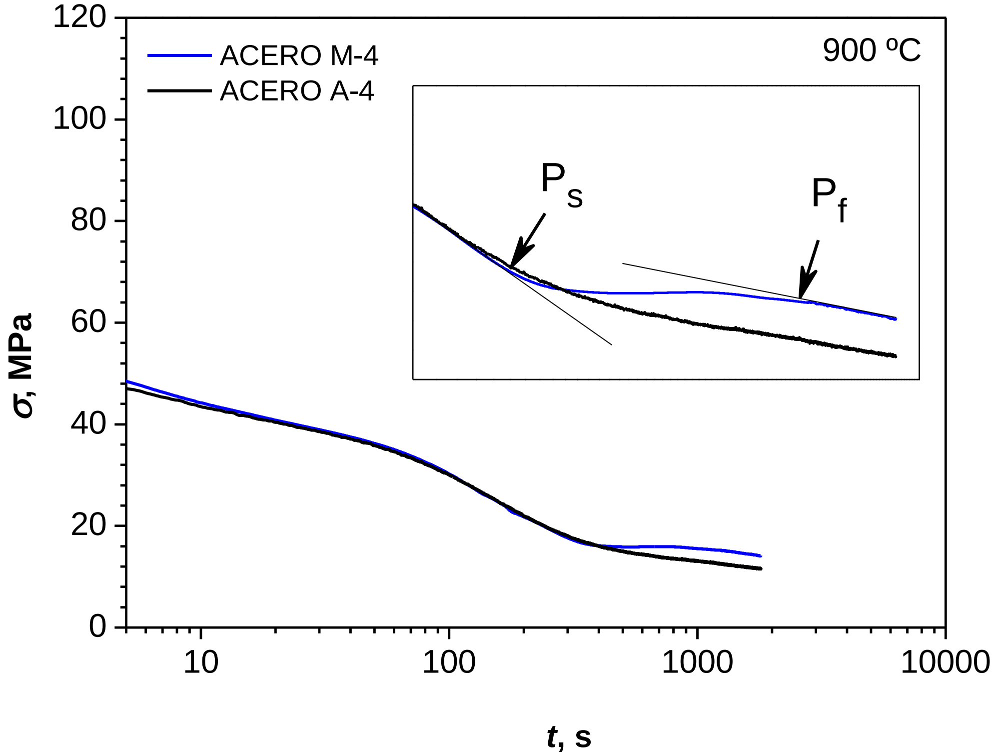

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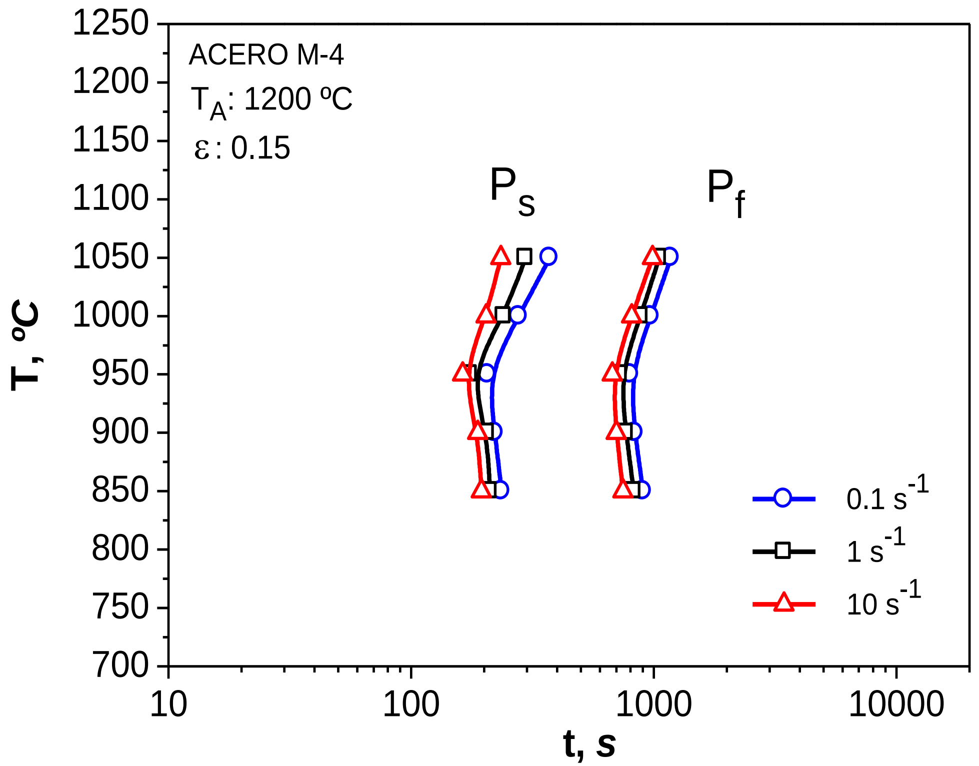
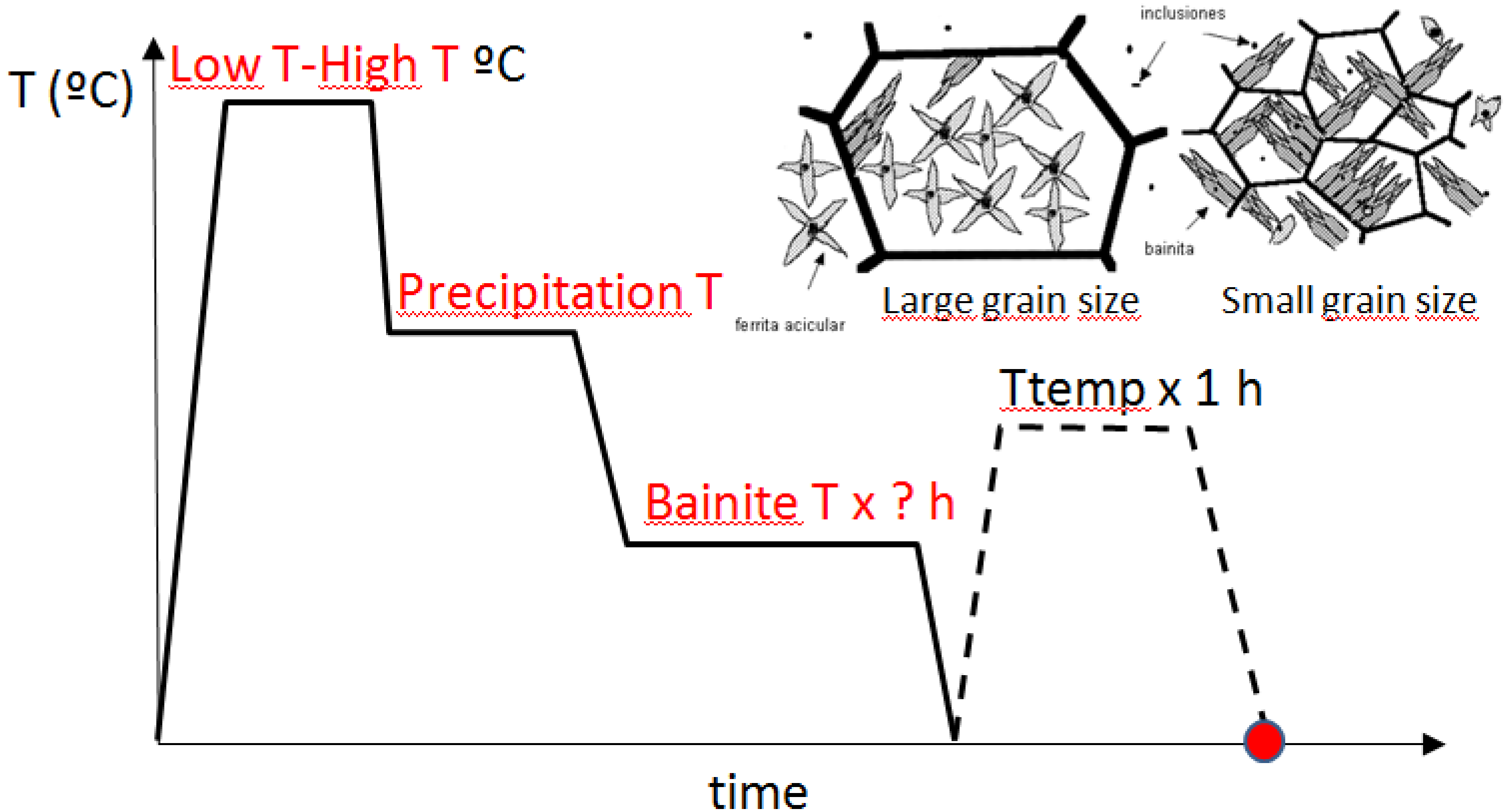


3. Results and Discussion

We are almost ready to quantify the alternative route



4.Conclusions

- The high soaking temperatures significantly delayed the onset of the bainitic transformation of the Ti steels
- The larger initial grain sizes (putting into solution microalloying elements) slightly increased the Ms temperature
- The hardness of bainite (at nose conditions) was larger when soaking at high temperature (large bainitic packets and abscence of precipitation)

ACKNOWLEDGEMENTS

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