Evaluation of Quenching and Partitioning C20MnSi Steel microstructure

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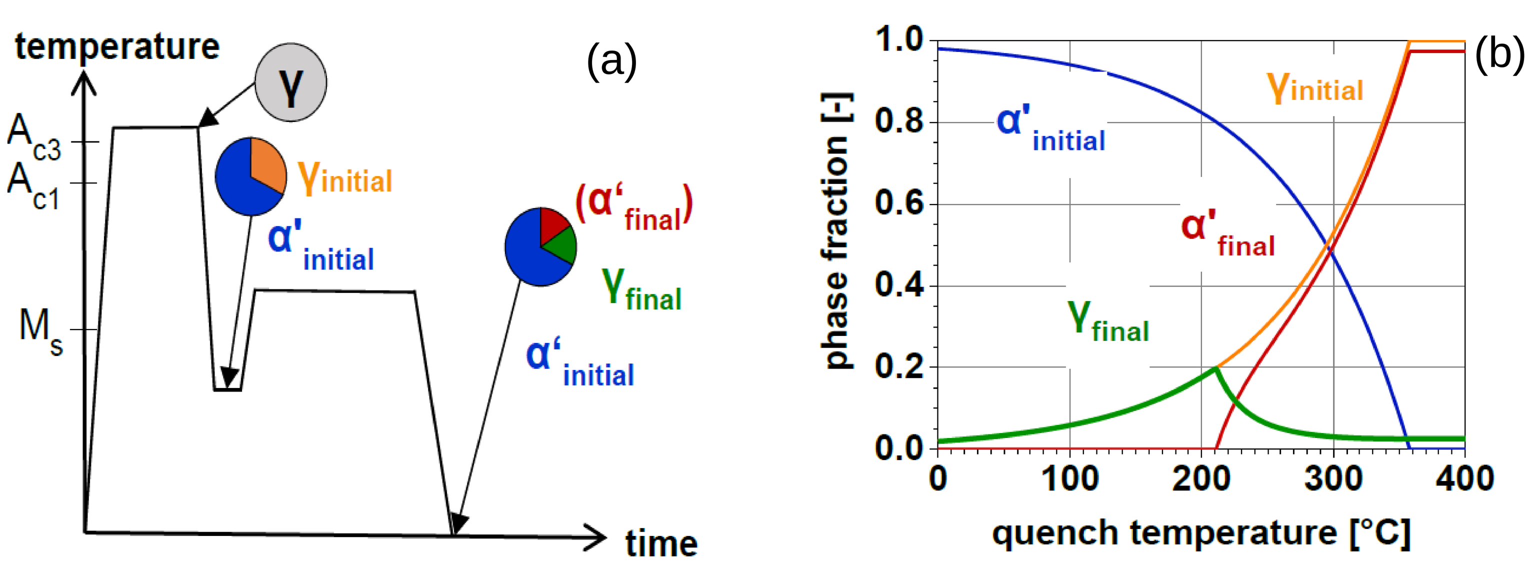
Abstract

Quenching and partitioning is a novel heat treatment that has been proposed to give a good mixture of tensile strength and the total elongation by producing martensitic steel containing a certain amount of retained austenite (RA). The 2-step Q&P process enhances the stabilization of austenite by carbon enrichment through the segregation of the carbon from martensite to RA. The microstructure was investigated using LOM, SEM, EBSD, and XRD. The X-ray diffraction has been carried out in order to assess the retained austenite (RA%) volume fraction. It showed convergent RA fractions for different heat treatments with different quenching and partitioning temperatures. However, for different holding time in quenching and partitioning steps, recognizable differences in RA% can be observed. The mechanical properties obtained by Q&P reported for 20CMnSi steel at different Q&P temperatures showed comparable results. While, at different Q&P holding time, observable change in the mechanical properties is reported.

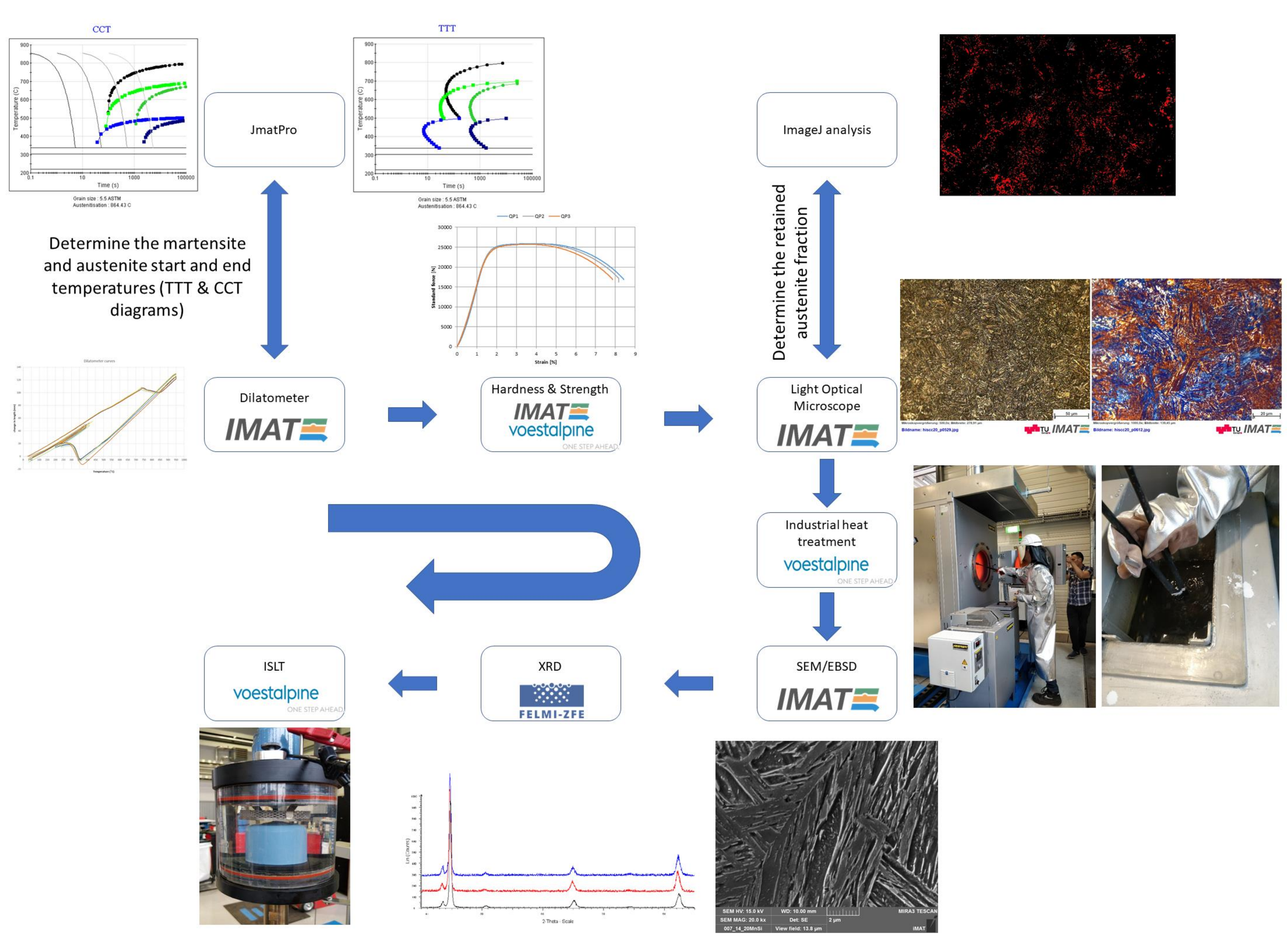
Introduction

Advanced High strength steels (AHSS) with significant amounts of retained austenite were designed in the last years due to the market requests, specially, the automotive industry for downsizing aspects and pollution reduction [1]. New metallurgical solutions were investigated to meet these targets providing steels with enhanced strength and ductility. Quenching and Partitioning (Q&P) seems to be a good procedure to produce such type of steels. The Q&P process was firstly proposed by Speer et al [2]. Q&P process produces a new type of TRIP steels, where the martensite is the main phase and retained austenite appears with a fraction, which results in a very good combination between strength and ductility. Q&P process consists of several steps; Heating above the Ac3, then rapid cooling between Martensite start (Ms) and Martensite finish (Mf) temperatures. Followed by partitioning process (TP/t_P) either by heating above or holding at the quenching temperature (TQ/t_Q) to promote the diffusion of carbon from supersaturated martensite to austenite. Finally, quenching to the room temperature.



(a) 2-step Q&P heat treatment process (b) Constrained Carbon Equilibrium diagram [2]

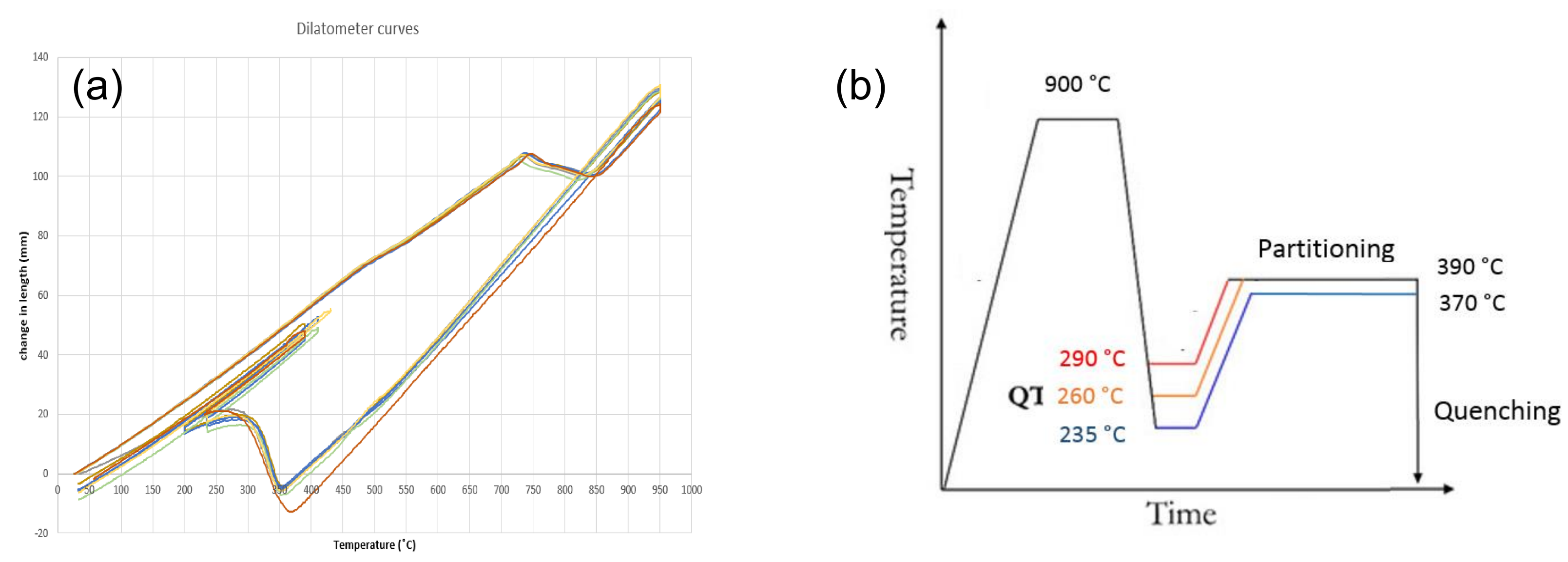
Methodological Approach



Experimental investigation & Results

Heat Treatment

The 2-step Quenching and Partitioning heat treatment was done by Bähr dilatometer 805 A/D and Ms and Mf temperatures can be detected from dilatometer curves with a value 360 ℃ and 230℃ respectively. Industrial heat treatment at voestalpine Wire Rod by Nabertherm furnaces for different quenching and partitioning temperatures and holding times.

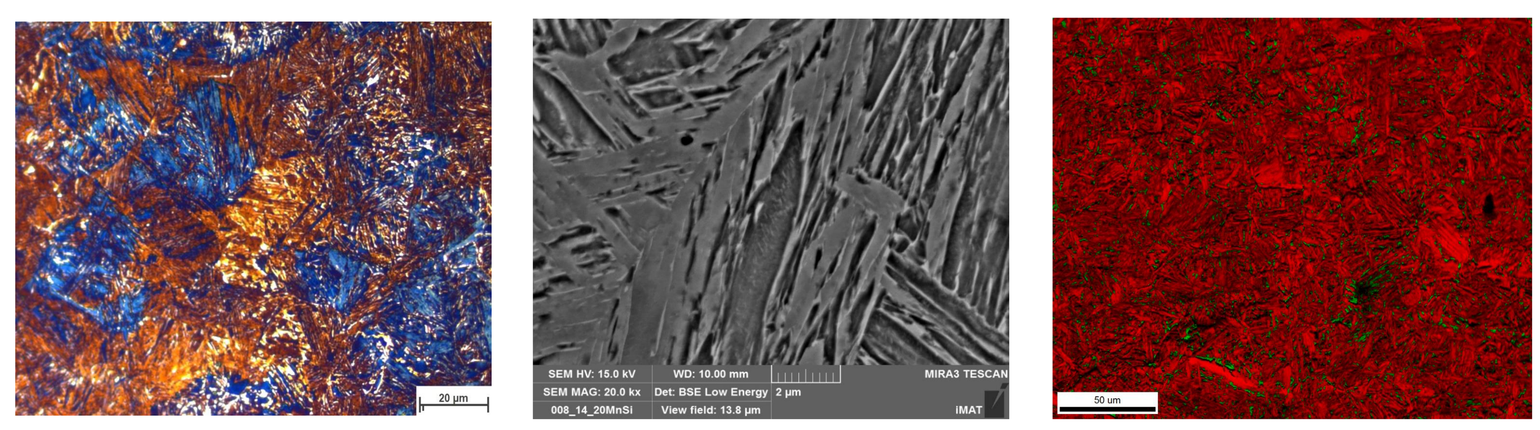


(a) Dilatometer curves (b) Q&P heat treatment process

Microstructure

Klemm I and Nital 3% etchants were used for the LOM, SEM & EBSD. XRD was also used to quantify the volume fraction of retained austenite.

Blue regions represent the martensite, also brown regions shows martensite but highly alloyed regions. The white areas represent the retained austenite.

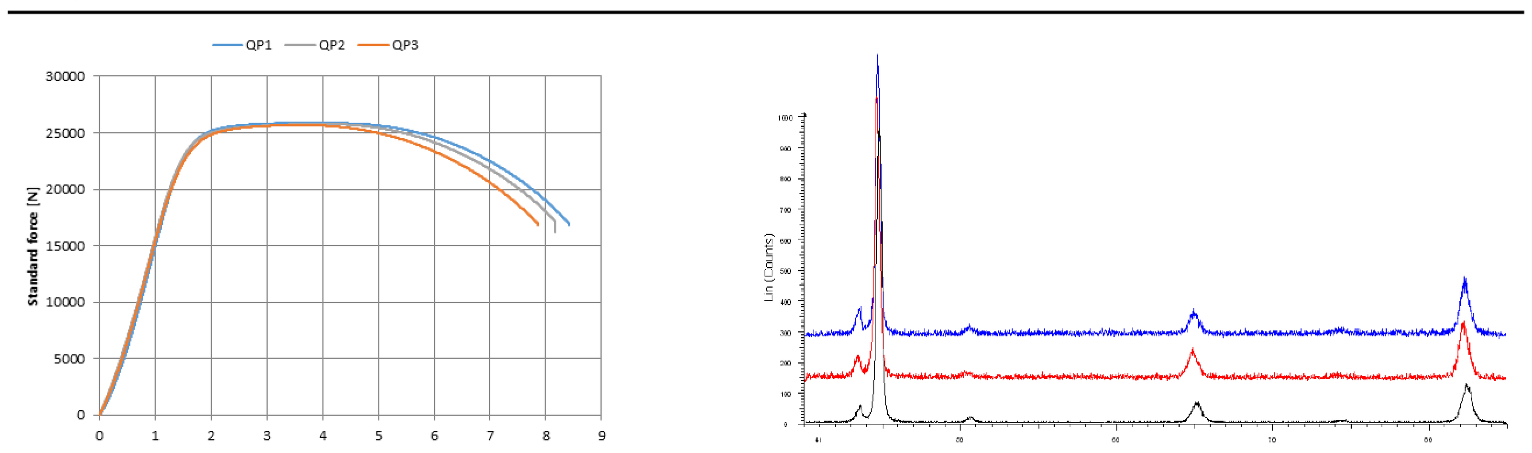


Klemm (I) etchant *Back scattered electron* *EBSD*

Mechanical testing

Vickers Hardness tests (HV10) and tensile tests were executed for the different heat treatments.

HT	TQ(°C)	TP(°C)	tQ (s)	tP(s)	HV10	TS (MPa)	XRD RA%
QP1	235	390	100	1800	405	1317	8.6
QP2	260	370	100	1800	400	1312	8.8
QP3	290	390	100	1800	395	1307	9.2
QP4	235	390	10	120	423	1376	7.4
QP5	260	370	10	120	406	1320	12.4
QP6	290	390	10	120	407	1323	11



Conclusion

The results give an evidence that the Q&P process influences significantly the microstructure and mechanical properties of 20CMnSi. At higher TQ, the strength showed to be lower, that can be explained by the formation of smaller amount of austenite at lower TQ which can be confirmed by the XRD, SEM and LOM investigations.

The Quenching and Partitioning temperatures and holding times should be carefully adjusted to enhance the RA stabilization which can be investigated by Incremental Step Load Test.

Literatur / Zitat

1 Forouzan, Farnoosh & Vuorinen, Esa & Guitar, Maria & Mücklich, Frank. (2018). Effect of Carbon Partitioning, Carbide Precipitation, and Grain Size on Brittle Fracture of Ultra-High-Strength, Low-Carbon Steel after Welding by a Quenching and Partitioning Process. Metals. 8. 747. 10.3390/met8100747.

2 Kaar, Simone & Schneider, Reinhold & Krizan, Daniel & Beal, Coline & Sommitsch, Christof. (2019). Influence of the Quenching and Partitioning Process on the Transformation Kinetics and Hardness in a Lean Medium Manganese TRIP Steel. Metals. 9. 353. 10.3390/met9030353.

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