Effect of Ultrafast Heating on the Microstructure Evolution of a Medium Carbon Chromium Manganese Steel

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Ultrafast thermal cycles are being applied on low-alloyed steels with the aim to optimize their microstructure by increasing strength and ductility to surpass the properties of advanced high-strength steels (AHSS) currently used in various automotive applications. During the ultrafast heat treatment, both heating and soaking time in the austenitic range is in the order of a few seconds (total heating and quenching time < 30s). This time is insufficient for the evolution and progression of the diffusion phenomena responsible for the homogenization of the chemical composition in the microstructure. By controlling the critical process parameters with emphasis on rapid heating, mixed microstructures are obtained with the coexistence of martensite, carbides and (possible) bainitic ferrite. This complex final microstructure contributes to the achievement of superior mechanical properties on low-alloyed steels with a medium carbon content [1-4].

The aim of the present research is to study the effect of ultrafast heating rates on the microstructural evolution of a 42CrMn6 steel with a ferrite and spheroidized cementite initial microstructure. An **u**ltrafast **h**eat **t**reatment was applied using dilatometry (**UHT S**ample) and included rapid heating with 300°C/s, peak temperature (T_p) at the austenite region at 1080°C (higher than the A_3) for 2s (isothermal soaking) and direct quench to Room Temperature (RT) using Helium gas. For comparison reasons a **c**onventional **h**eat **t**reatment was applied to a similar steel sample (**CHT S**ample) with a heating rate of 10°C/s, T_p at 900°C (slightly higher than the A_3), isothermal soaking of 5min and then quench to RT. The obtained microstructures were evaluated using scanning & transmission electron microscopy (SEM, TEM) with EDS and Electron Backscattered Diffraction (EBSD).

CHTS got a fully martensitic microstructure (M) with fine laths with no cementite presence from the initial microstructure (**Fig. 1**). UHTS (**Fig. 2**) obtained a complex mixed microstructure consisting from martensite laths (M) with a finer lath size than of CHTS, undissolved spheroidized cementite (SC) and indications of bainitic ferrite (B). Additional TEM analysis is required in order to clearly characterize the found bainitic ferrite. Here some morphologies are presented (B) found in UHTS that seem similar to the representations of lower bainite of Takahashi and Bhadeshia [5] (**Fig. 3**). Spheroidized cementite (SC) was clearly revealed in the TEM analysis (**Fig. 4**). Also, nanoscaled carbides (PC) are observed in the microstructure (Fig.4) which have been precipitated on the grain boundaries. Increased density of dislocations (D) is observed either pinned by carbides (pinning effect) (**Fig. 3**) or not (**Fig. 4**). The dislocation density can be also seen on the GND distribution map (**Fig. 5**) from the EBSD analysis. The result of dislocations can be observed around the laths and the grain boundaries (green), while inside the lath, the dislocation density is lower (blue).

It is of the utmost importance to understand that due to very small heating time, diffusion of carbon and alloying elements cannot take place entirely, thus resulting in great heterogeneity in the chemical composition of the steel. Therefore, different composition and size of the austenite grains will result in different topical transformations; this concept can explain the possible presence of bainitic ferrite in the microstructure of an ultrafast heating cycle. Further research will be conducted in order to prove the existence of bainite in the microstructure and explain the transformation mechanism that takes place in para-equilibrium [6].

Selected references

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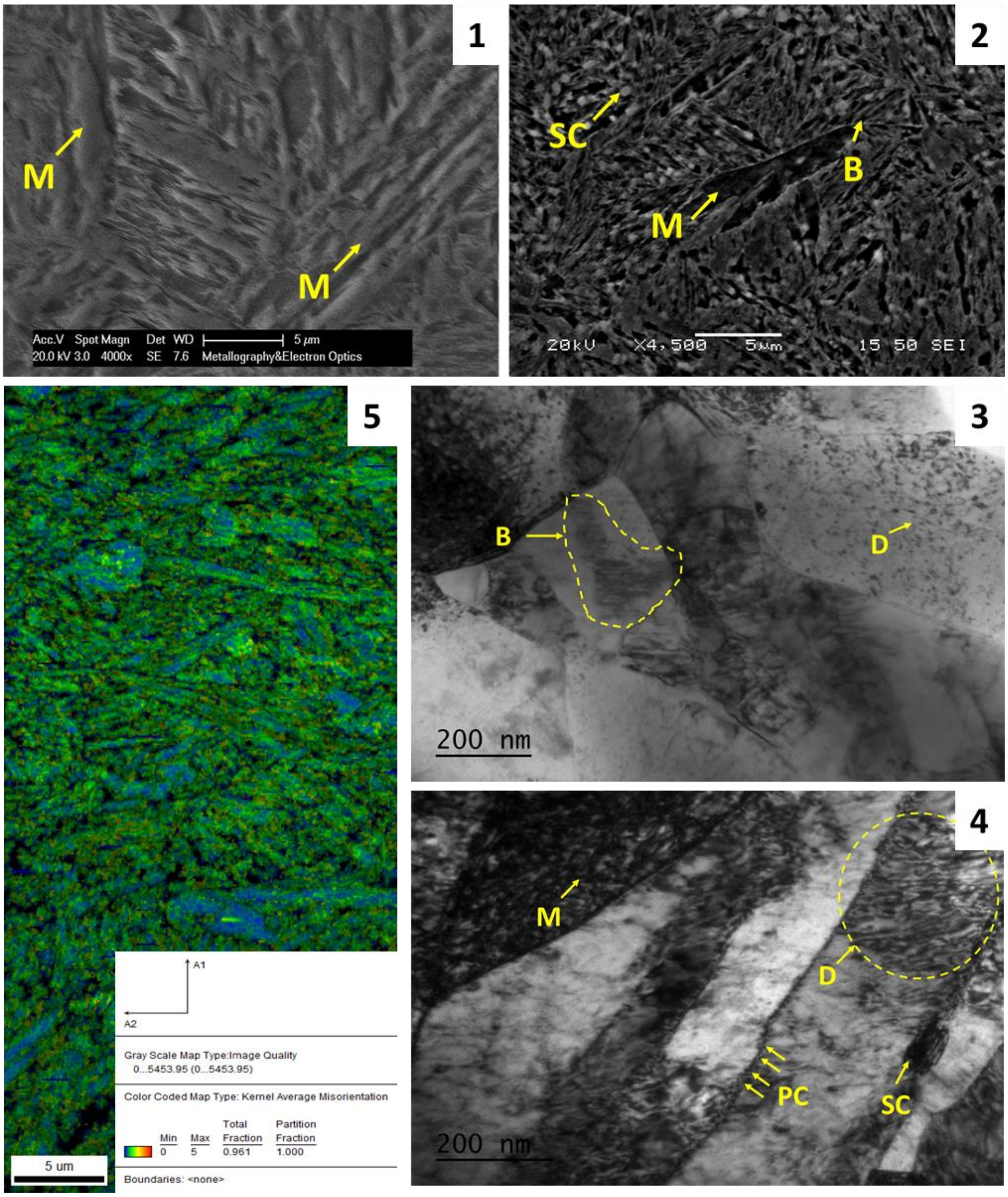

Figures: 1) SEM image of CHTS showing a fully martensitic microstructure, 2) SEM image of UHTS showing a martensitic microstructure with undissolved cementite and indications of bainitic ferrite. 3) TEM image of UHTS showing the pinning effect of dislocations by carbides and indication of bainitic ferrite. 4) TEM image of UHTS showing martensite and probably bainite laths with the existence of newly precipitated carbides and spheroidized cementite from the initial microstructure. 5) GND distribution map of UHTS taken from EBSD that shows the dislocation density (green) around the grains and laths (blue).