IMPaCT
EPSRC Centre for Doctoral Training in Innovative Metal Processing (IMPaCT)

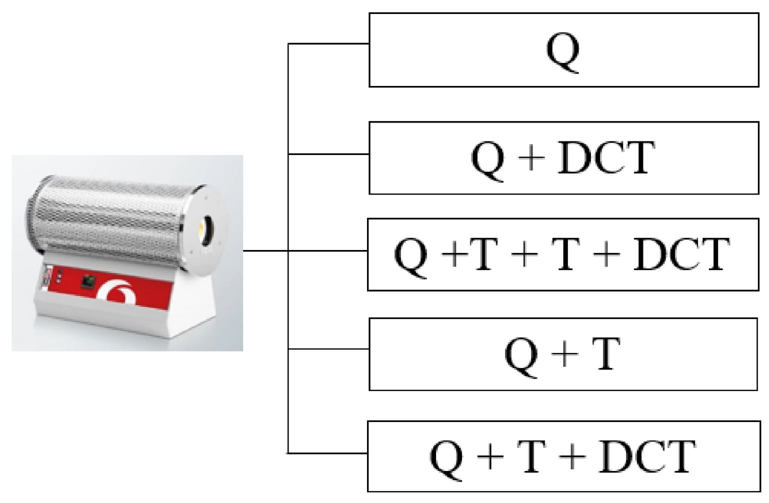
Investigating the effects of deep cryogenic treatment on ferrous alloys

Christian Chiadikobi, Kyle Nicholls, Rob Thornton, Dave Weston

School of Engineering, University of Leicester, Leicester, LE1 7RH, UK

① Background

- Owing to the growing demand in production industries to employ materials that will last longer and more efficient as well as reduced cost, focus has now been shifted to employ materials and strategic treatment geared towards addressing the above demands. Thus, Cryogenic treatment (CT) is being proposed geared towards enhancing engineering materials.
- CT is a novel approach that relates to the behaviour of materials typically below 193K, thus causing microstructural change; which in turn enhances the behaviour of the material e.g. hardness, toughness. For some applications CT materials are also coated as the have been found to work well and improves wear resistance.
- Nevertheless, in the literature the topic is still under much discussion due to inconsistency of results and appropriate experimental evidence. For coating – substrate systems, the driving force responsible for the microstructural change undergone have not been fully investigated to assess their significance.
- Microstructural and mechanical examination were performed to understand the effect of DCT on AISI M2 HSS and EN 31 bearing steel, with EN 31 investigated with respect to varying austenitising temperatures and hence retained austenite content.



Nomenclature:
Q – Quenched
T – Tempered
DCT – Deep Cryotreatment

Fig. 1.1 – Heat Treatment routes

② Microstructural Examination

Material composition (wt.%) for AISI M2 HSS: C 0.89, Cr 4.2, Mo 4.86, W 6.05, V 1.89, Mn 0.33, P 0.03, S 0.01, Si 0.31, Fe balance.

- SEM observations – Contains martensite, carbides

Fig. 2.1 – Scanning electron micrographs of the Microstructure of AISI M2 HSS in (a) as-quenched Q, and in (b) quenched & tempered followed by DCT, Q+T+DCT. Both consist of carbides in a martensite matrix

- Material composition (wt.%) for En 31: C 0.95-1.10, Cr 1.20-1.60, Mn 0.40-0.70, Si 0.10-0.35, S 0.050 max, P 0.040 max, Fe balance.

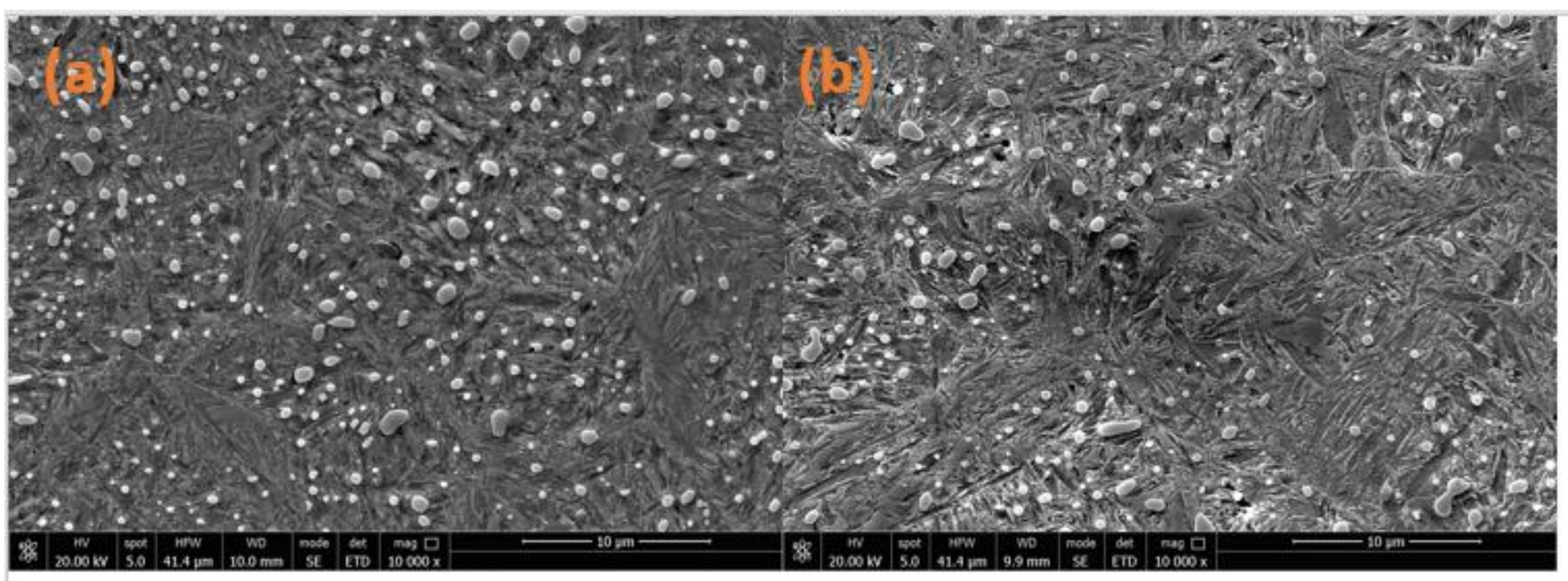


Fig. 2.2 – Scanning electron micrographs of the Microstructure of En 31 bearing steel in (a) as-quenched from 1123K, and in (b) quenched from 1123K and followed by DCT. Both consist of carbides in a martensite matrix.

⑤ Future Direction

- Characterise the amount of retained austenite, carbide phases.
- Characterise the effect on coating-substrate systems.
- Perform quantitative phase analysis on quenched samples and DCT samples
- Perform in-situ neutron diffraction on Engin-X at STFC ISIS to underpin the mechanisms active during DCT

⑥ Acknowledgements

- The author gratefully acknowledges financial support from the Centre for Doctoral Training in innovative Metal Processing (IMPaCT) funded by the UK Engineering and Physical Sciences Research Council (EPSRC).
- Thanks are due to Andy Priscott, former Owner of Cryogenic Treatment Services Ltd for cryogenically treating the DCT samples presented here.

③ Mechanical Examination - Hardness

- Bulk hardness for (a) AISI M2 HSS and (b) EN 31 bearing steel, with its effects on hardness established for three austenitising temperatures of 1123K, 1223K and 1323K – fig. 3.1

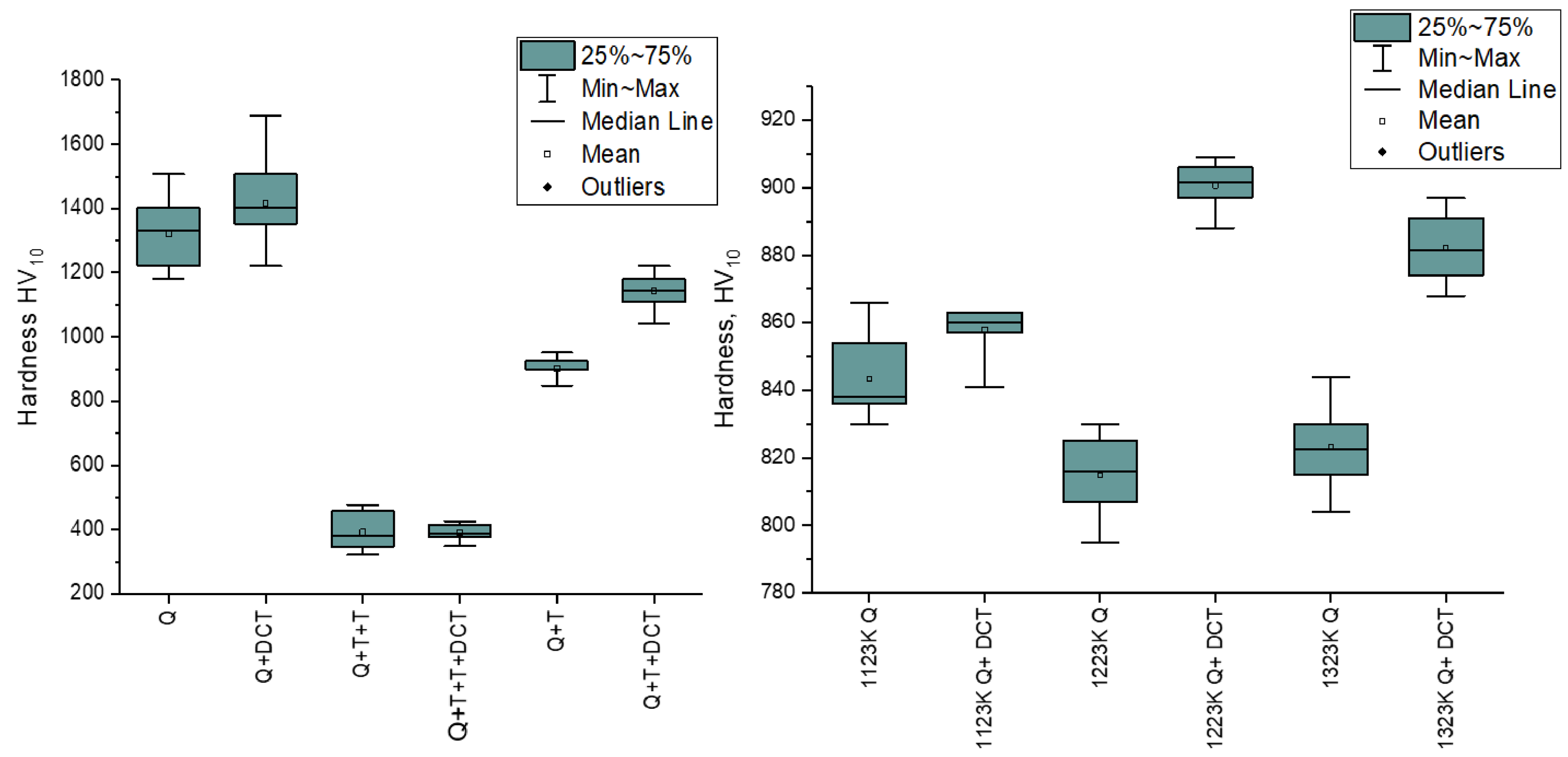


Fig 3.1 – Results from bulk hardness measurements

④ Conclusion

- Microstructures of as quenched, Q and quenched & tempering followed by DCT AISI M2 HSS revealed strong presence of carbide particles in a martensite matrix.
- Carbides classified as large (primary >3um) and small (secondary ~ 0.1 - 0.5um) carbides. The number of small carbides appeared to be lowered for the Q, than in DCT treated sample.
- Result in hardness indicate that DCT increases hardness of AISI M2 HSS. The increase in hardness shows that improvements experienced in Q+ T and Q+T+DCT are significant.
- Above results shows that DCT affects the metallurgy of AISI M2 HSS by precipitating out carbides, which improves the mechanical properties of the material.
- In En 31, DCT facilitates minor hardness improvements of 1.72% when the heat treatment cycle is performed with the recommended austenitising temperature (1123 K).
- With higher austenitising temperatures, 1223 K and 1323 K, hardness improvements for the En 31 are 10.5% and 7.19% respectively, with both higher than that attainable by the 1123 K austenitisation. The as-quenched structures are not as high owing to the retained austenite content, which is through to be diminished in the DCT samples.
- Micro-hardness and nano-hardness measurement are needed to verify this owing to harder martensite with higher austenitising temperatures, as well as quantitative phase analysis by X-ray diffraction.

⑦ Contact Information

- School Of Engineering, University of Leicester, University Road, Leicester, LE1 7RH
- Email:cic9@le.ac.uk; kgmn2@le.ac.uk

EPSRC Engineering and Physical Sciences Research Council | UNIVERSITY OF LEICESTER | UNIVERSITY OF BIRMINGHAM | The University of Nottingham UNITED KINGDOM · CHINA · MALAYSIA