Characterisation of a Quenched, Quenched & Tempered AISI M2 HSS subjected to Deep Cryogenic Treatment

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1 Introduction

- Deep cryogenic treatment (DCT) involves treating materials at low temperatures 93K (-180°C) with aim of causing microstructural and beneficial changes e.g. improved hardness and wear resistance in martensitic steels [1 - 3].
- Despite the promising results, much debate surrounds the topic **due to lack of consistency of results encountered in the literature as well as limited published work presented on mechanisms responsible for changes observed for AISI M2 HSS**.
- Therefore, the effect of DCT have been studied on AISI M2 high speed steel **following different heat treatment processing sequences**, and characterised by a blend of techniques (XRD, SEM, Microhardness). Also **by varying the processing routes, the mechanical properties can be tailored to fit the relevant applications**.

2 Experimental process pathway

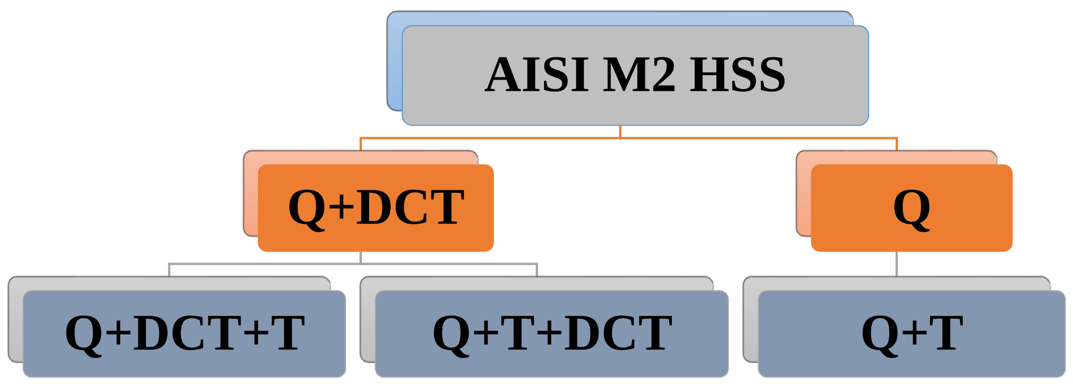

Figure 1: Process pathway

Nomenclature: Q – Quenched; T – Tempering; TiN – Titanium nitride; DCT – Deep cryogenic treatment

3 Results

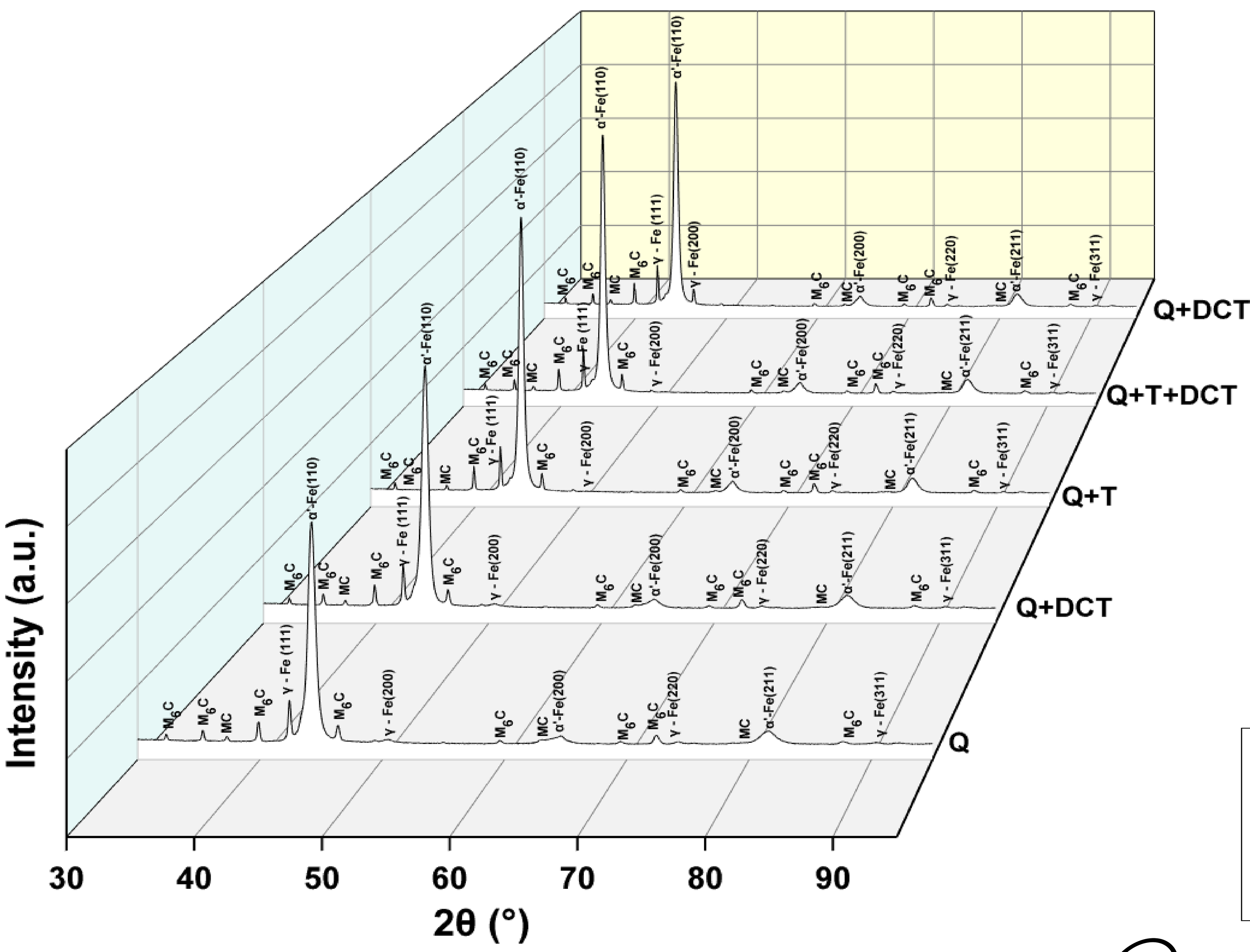

Figure 2: XRD patterns of the different heat treatment cycle

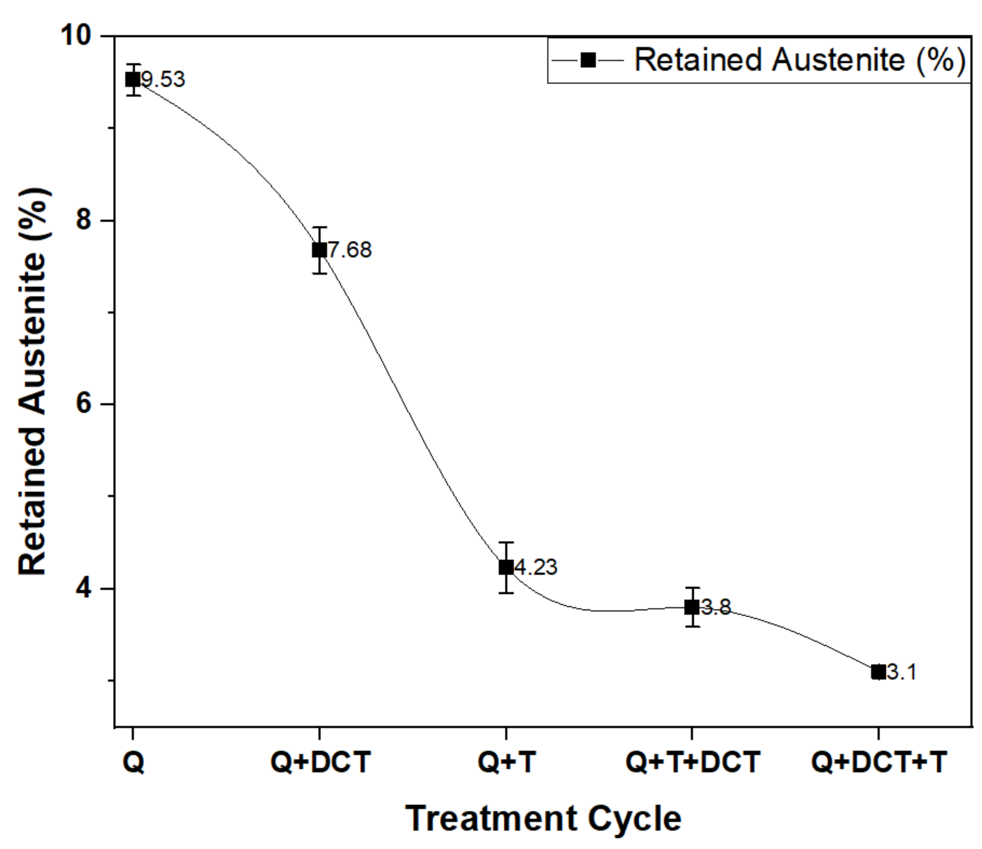

Figure 3: Retained austenite content in the different treatment cycle

Table 1: Lattice parameter, d-spacing, c/a ratio and carbon content of the different treatment routes

Treatment cycle	Lattice parameter (a) - α'a (nm)	Lattice parameter (a) - α'c (nm)	Lattice parameter (a) – γ (nm)	d – spacing (nm)	c/a ratio (α')	Calculated C content in γ (wt%)
Q	0.2860	0.2880	0.3600	0.2023	1.00700	0.156
Q+DCT	0.2885	0.2909	0.3664	0.2043	1.00832	0.187
Q+T	0.2884	0.2885	0.3606	0.2029	1.00035	0.018
Q+T+DCT	0.2940	0.2955	0.3666	0.2048	1.00510	0.113
Q+DCT+T	0.2980	0.2998	0.3760	0.2098	1.00604	0.134

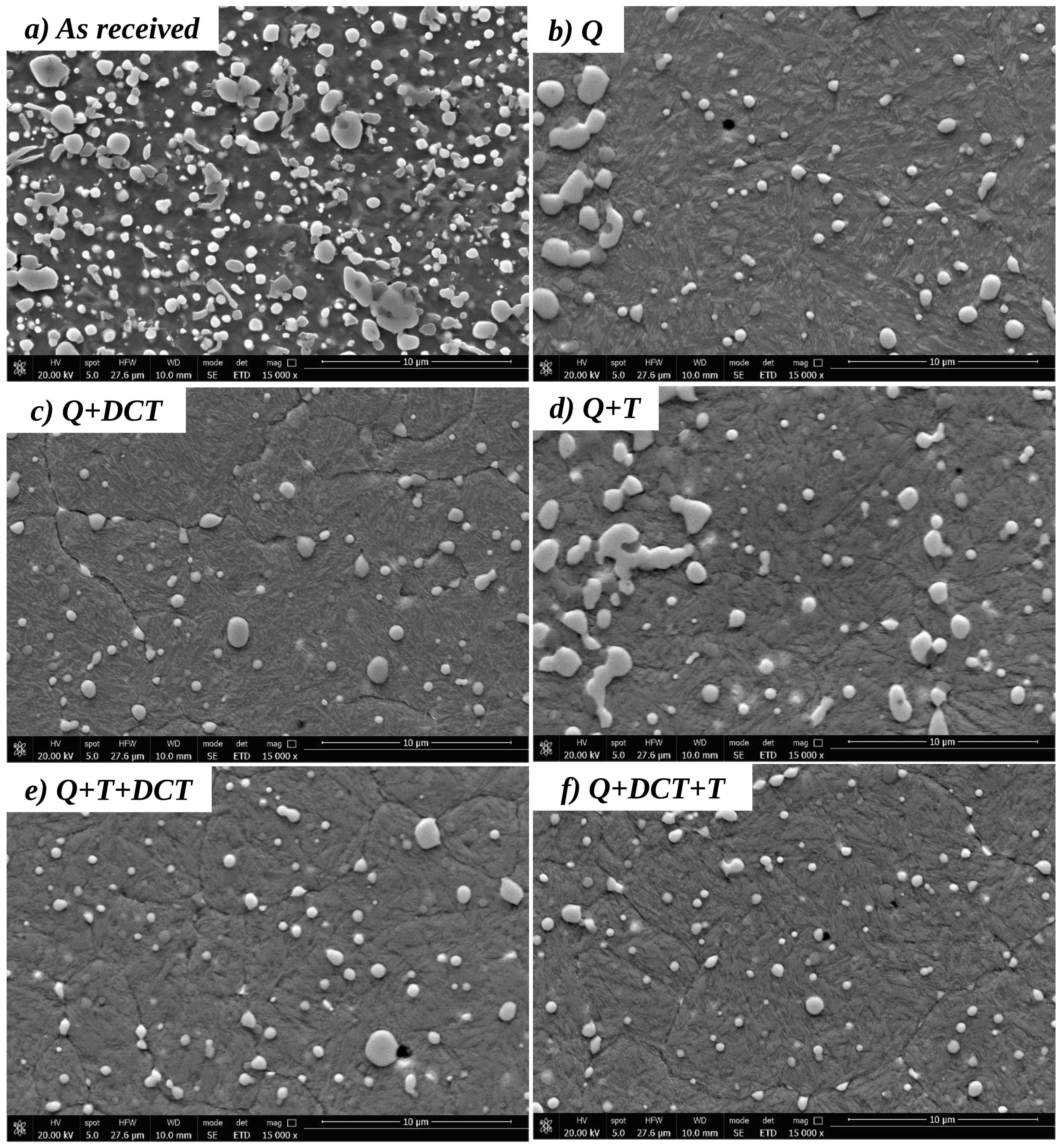

Figure 4: SEM micrographs of the different heat treatment routes (a) As received (b) Q (c) Q+DCT (d) Q+T (e) Q+T+DCT (f) Q+DCT+T

Table 2: Hardness measurement and T-statistics

Hardness measurement ($HV_{0.1}$)	T-statistics (Q & Q+DCT)	T-statistics (Q & Q+T)	T-statistics (Q+T & Q+T+DCT)	T-statistics (Q+T+DCT & Q+DCT+T)
Q: 1019.7 ± 10.20 HV **Q+DCT**: 1080.94 ± 8.66 HV **Q+T**: 960.17 ± 7.89 HV **Q+T+DCT**: 980.41 ± 5.42 HV **Q+DCT+T**: 999.88 ± 5.2 HV	(P-value): **0.012** **Significant**	(P-value): **6.94163E-0.6** **Significant**	(P-value): **0.029** **Significant**	(P-value): **0.009** **Significant**

4 Conclusion

- SEM examination revealed the presence of different carbide sizes, further classed (XRD) as the M_6C and MC carbide type in all samples.
- Further analysis suggests that the amount of these carbides appeared to be more for the DCT samples and homogenous distributed than in the non-DCT samples.
- The presence of these carbides are considered beneficial and contributes to the material strength and resistance to wear.
- For all DCT samples, the retained austenite was found to be low, with lowest reduction obtained for Q+DCT+T (3.1%) compared to the untreated counter part.
- Hardness measurement showed that increase in hardness could be obtained following DCT. A clear trend found suggests that employing DCT between Q & T increased hardness of approximately 4.1 %, with T-statistics (p value < 0.05) suggesting the values obtained are significant (0.009).
- From the examination, the increased carbide particles and reduction in retained austenite are attributed to the changes observed.

5 References

[1] Slatter, T., and Thornton, R., Cryogenic Treatment of Engineering Materials in Comprehensive Materials Finishing, M.S.J. Hashmi, Editor. 2017, Elsevier: Oxford. Pp. 421-454.

[2] Jovičević-Klug, P. et al., *Influence of heat treatment parameters on effectiveness of deep cryogenic treatment on properties of high-speed steels.* Materials Science and Engineering: A, 2022. 829.

[3] Jovičević-Klug, P. and Podgornik, B., *Comparative study of conventional and deep cryogenic treatment of AISI M3:2 (EN 1.3395) high-speed steels.* Journal of Materials Research and Technology, 2020. **9**(6) pp. 13118-13127.

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