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The Influence of Steel Composition and Wire Drawing on the Strain Ageing Response of High Strength Wire

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Introduction

Commercially drawn high strength pearlitic steel wires can achieve very high strengths (up to 4GPa) whilst maintaining reasonable toughness. As a result, steel wire is extensively used in applications such as bridge wires, mooring cables, lifting ropes, tyre reinforcement and springs.

Aims and Objectives

This project aims to investigate how composition affects the strain ageing reaction. A deeper understanding of the process could lead to two potential solutions: Either the reaction could be retarded or arrested to provide a longer service life, or the reaction could be accelerated to produce a more stable microstructure which could then be used in service.

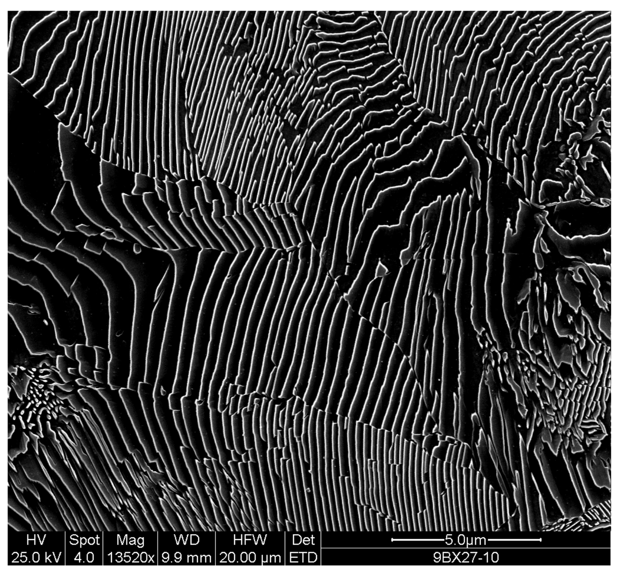

Fig. 1 – Undeformed Pearlite [1]

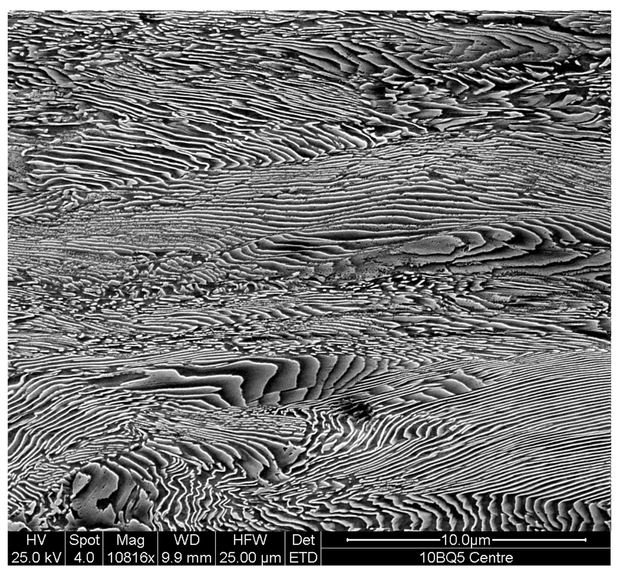

Fig. 2 – Cold Drawn Pearlite [1]

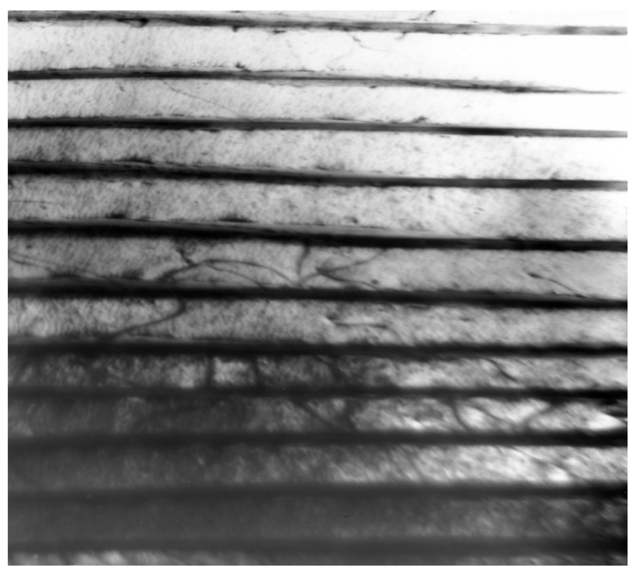

Fig. 3 – TEM Image of Drawn Pearlite [1]

Cementite Dissolution

The wire drawing process deforms the microstructure, elongating and realigning the laths, parallel to the drawing direction. At drawing strains of greater than approximately 1.5 true strain, cementite laths begin to dissolve, feeding carbon atoms into the ferrite.

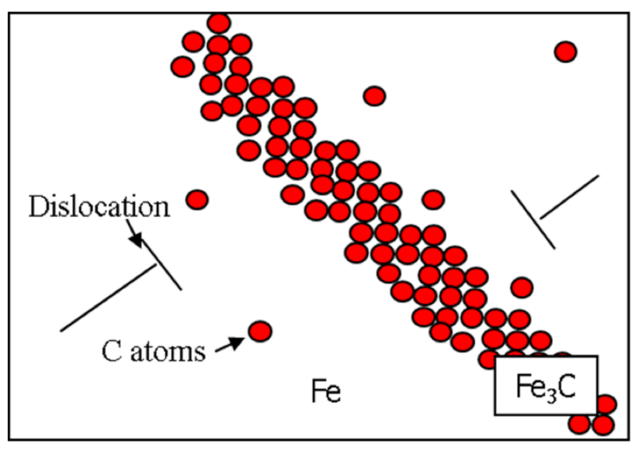

Fig. 4 – Drawing Strain <1.5 [1]

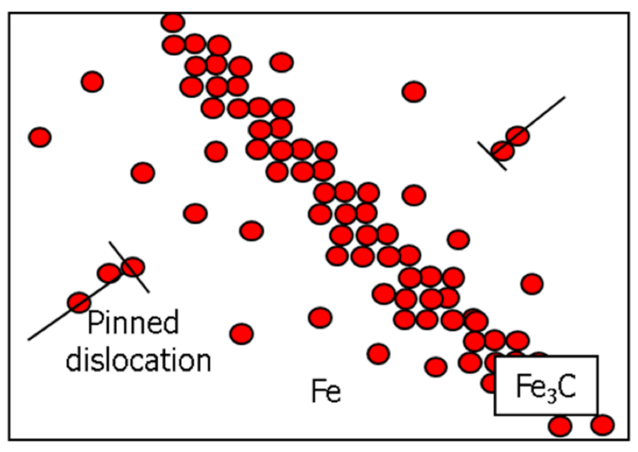

Fig. 5 – Drawing Strain ~1.5 [1]

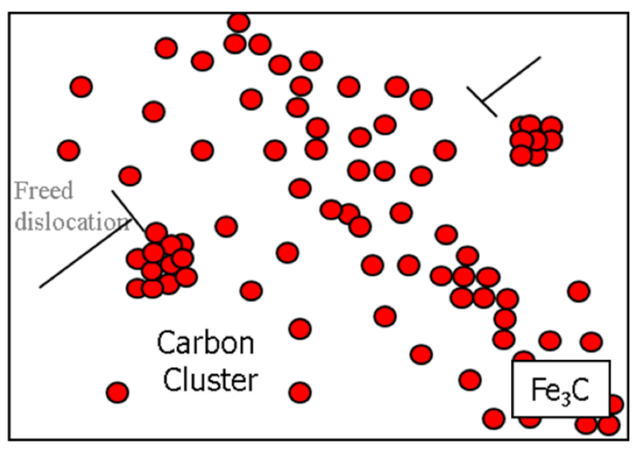

Fig. 6 – Drawing Strain >1.5 [1]

Carbon atoms diffuse to dislocations resulting in a pinning effect on the dislocations. This causes an increase in strength, and therefore a reduction in ductility. This is known as dynamic, during deformation and static, post deformation strain ageing. As carbon atoms cluster around the dislocations, the pinning effect is lost and the dislocations are freed, causing recovery and eventually over ageing, as carbon atoms grow as carbides.

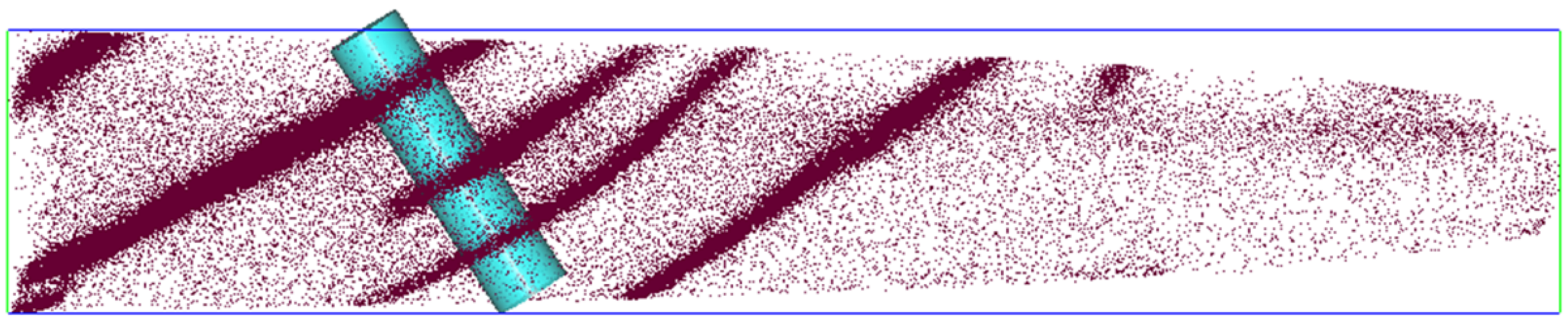

Fig. 7 – APT Image Showing Atomic Scale Map of Carbon Atoms [1]

Why Control Cementite Dissolution?

Cementite dissolution plays an essential role in strain ageing in high strength wire. It is responsible for the gradual deterioration in mechanical properties associated with both dynamic and static strain ageing. Controlling cementite dissolution could lead to a better product in several ways:

- Stabilising properties increases the life of wires and ropes
- Increase the drawing limits (producing finer wires).
- Improve ductility for a given level of strength.
- Extending the UTS of fine wires beyond the current limits.

EngD Project

Figures 8 and 9 show the affect strain ageing has on UTS and torsional ductility. This **increase in strength** and **reduction of ductility** (torsional properties) are a result of the decomposition of the cementite.

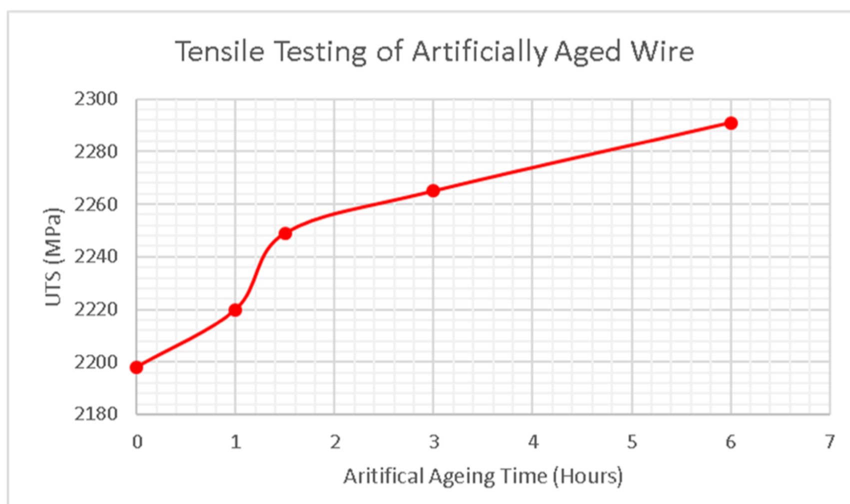

Fig.8 – A Graph Showing the change in UTS due to strain ageing in 1.44mm Wire (60 Minutes Artificial ageing at 100°C is equal to ~2 months RT ageing for carbon)

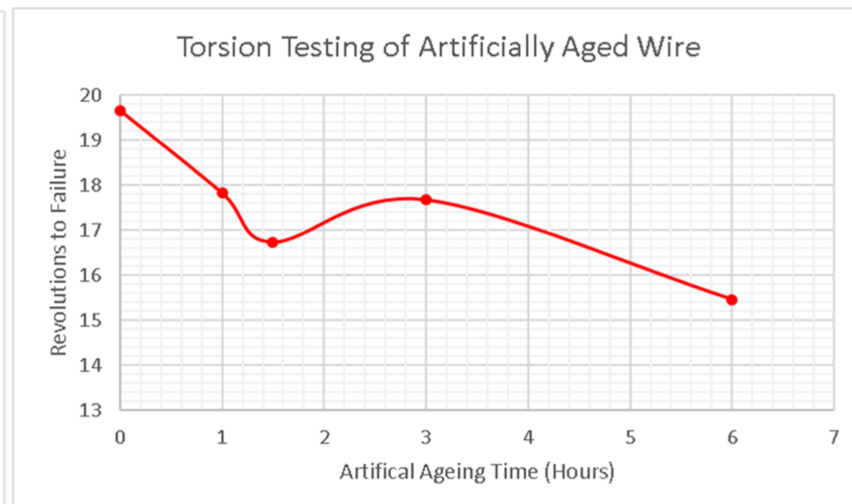

Fig.9 – A Graph Showing the Reduction in Torsional Ductility With Artificial Ageing in 1.44mm Wire (60 minutes artificial ageing at 100°C is equal to ~2 months RT ageing for carbon)

Experimental Steel Production

In order to demonstrate the affect of composition on strain ageing, novel experimental steels have been produced. The development of the experimental steels required an in depth literature review, knowledge and past experience from both British Steel & Bekaert, and **thermodynamic modelling**.

Atom Probe Tomography (APT)

If the Ageing reaction is influenced, mechanical property tests alone will not be enough to explain the process, as strain ageing occurs on an atomic level.

Atomic scale experimental procedures are necessary in order to observe and begin to understand cementite dissolution and strain ageing. TEM and APT has the potential to provide a fascinating insight into how composition and wire drawing affects the dissolution mechanism(s).

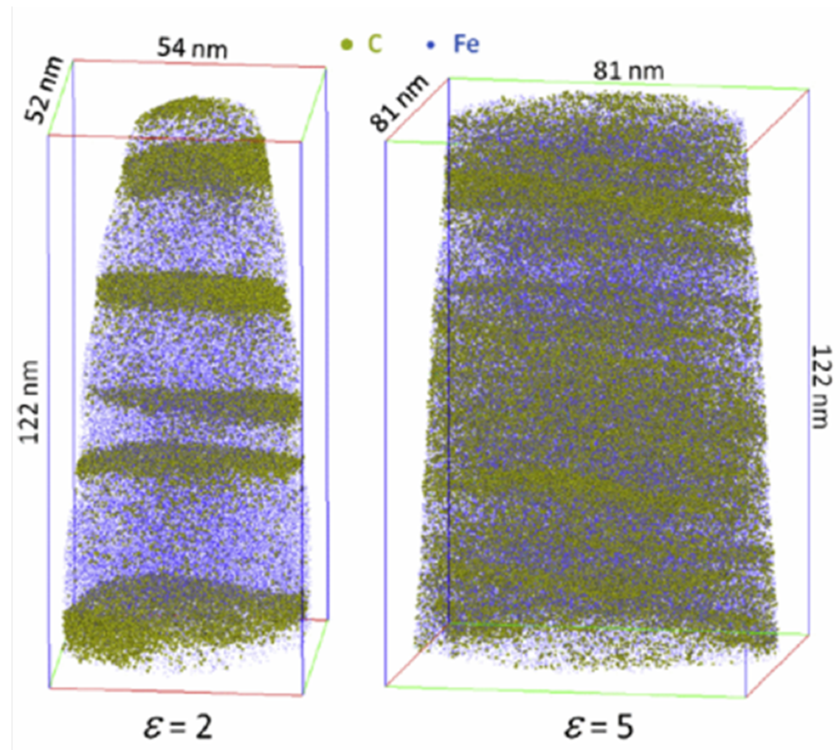

Fig. 10 – APT Image of Cementite Dissolution in Wire [2]

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References

[1] S. Hobson, Private Communication, British Steel R&D (January 2018).

[2] Y.J. Li, P. Choi, C. Borchers, S. Westerkamp, S. Goto, D. Raabe, R. Kirchheim, Atomic-scale mechanisms of deformation-induced cementite decomposition in pearlite, Acta Materialia, Volume 59, Issue 10, June 2011, Pages 3965-3977, ISSN 1359-6454.