Experimental investigation of the effects of cryogenic treatment on the corrosion and tribocorrosion resistance of structural steels

James Kelly, *Rob Thornton, Jenny Shepherd, David Weston

University of Leicester, *University of Warwick

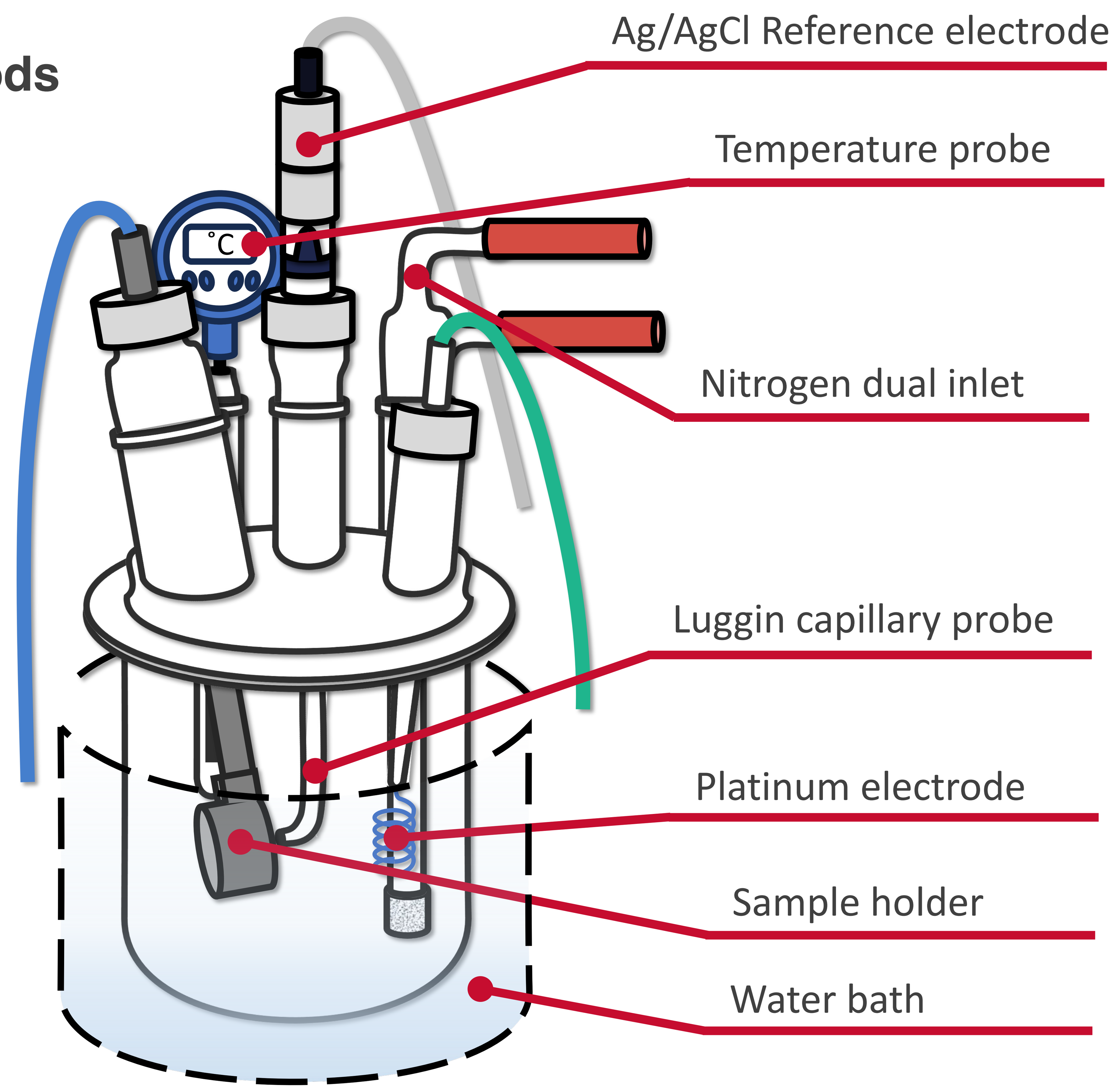
Introduction

Tribocorrosion is the combined effect of corrosion and wear, which causes severe damage and failure in many industries. Surface modification is the main method to prevent or resist tribocorrosion, but it has many drawbacks, such as complexity, cost, and maintenance. Therefore, as a more straightforward and cost-effective alternative for lower tribocorroding industries, cryogenic treatment (CT) could provide an easy solution for enhanced tribocorrosion resistance.

CT is a well-established technique for improving wear resistance, and recent studies have also suggested that microstructural alterations through deep cryogenic treatment (DCT) can improve corrosion resistance by inhibiting corrosion mechanisms, impeding chemical propagation, and altering their corrosion potential, believed to be attained by the overall stabilisation of the crystal structure.

This project can serve to investigate whether an improvement in corrosion resistance can be attained from DCT and, if possible, whether the combination of both improvements can lead to a consecutive gain in tribocorrosion resistance.

Methods



Deep cryogenic treatment will be performed after quenching and before tempering for what is currently the most recommended sequence for the greatest microstructural improvement.

The corrosion performance of the cryogenically and conventionally treated samples will be measured through electrochemical methods, such as linear and potentiodynamic polarisation resistance. In addition, surface corrosion is to be examined through SEM imaging. Microstructural alterations will be examined through SEM, EBSD and XRD characterisation.

The apparatus for the electrochemical testing has been designed to mitigate error and achieve repeatability. This consists of an air-tight reaction vessel to maintain a low oxygen level after nitrogen purging, with four additional necks for the respective three electrodes and one for monitoring temperature. The sample holder has been designed to expose a 1cm^2 surface area of the sample, incorporating O-rings for a water-tight chamber. 3D printing makes the design flexible, improvable, and replaceable. A Luggin probe is fitted to the reference electrode to reduce the error from the ohmic drop. A circulating water bath helps to maintain a consistent temperature throughout the experiment.

Microstructural possibilities

The benefit of DCT on steel wear resistance has been explored since the 1970s[1]. Predominantly, DCT has been found to reduce or even eliminate retained austenite[2] as well as enhance the precipitation and distribution of finer secondary carbides[3][4][5][6][7]. However, only some of these effects are anticipated for structural steels, having a lower carbon content than the typically studied tool steels. Nevertheless, research suggests that mechanical improvements can still be achieved through improved carbide distribution, homogeneous microstructure, and grain refinement[8][9][10].

Regarding corrosion resistance, limited studies exist, so there is a wide view of arguments to explain the possible improvement. Some speculate that the various alterations collectively stabilise the lattice, placing carbides and alloying elements in their most stable state [11][12][13]. Predominantly, authors attribute improvement to carbide modification. For one, carbide distribution and refinement prevent clusters, reducing the likelihood of initiation sites[14][15]. Alternatively, corrosion behaviour may be influenced by the specific type and proportion of carbide compounds formed[16][17][18].

Current direction

- Electrochemical test cryogenically treated and conventional heat-treated samples.
- Characterise microstructure, mechanical properties, and electrochemical results.
- Determine whether CT benefits SA508-4N and/or if modifying their typical heat treatment steps and parameters could lead to further improvement.
- Understand, design, and conduct tribocorrosion testing.
- Determine the effect of the wear couple on both treated samples.

References

Scan our QR code to see our list of references.

UNIVERSITY OF LEICESTER · Future 100 · Cryogenix Deep sub-zero processing