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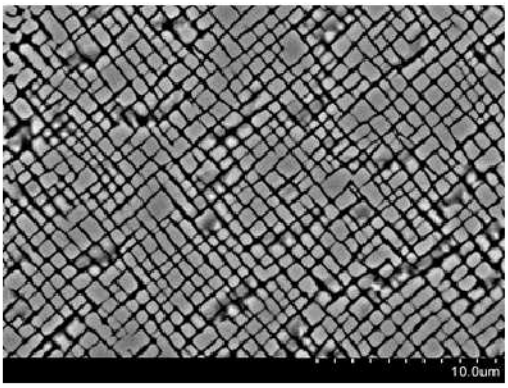
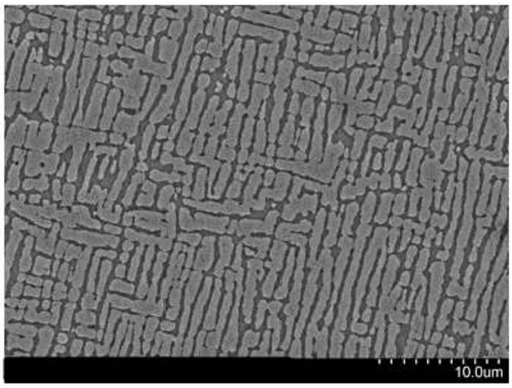
Professor Scott Lockyer is Technical Head of Materials & Corrosion in Uniper Technologies Limited's (UTL) Integrity and Quality Management Department. He provides technical leadership and oversight of materials R&D, failure investigation and component life assessment. Scott joined UTL in 2005 following technical management and principal engineer roles in two engineering consultancies. Prior to that Scott was a Research Fellow in the Department of Materials at Oxford University. He holds a BEng in Metallurgy & Materials Science and a PhD in Metallurgy from the University of Liverpool. Scott is a member of the IOM3 Energy Materials Group, Chair of the UK High Temperature Power Plant Forum (HTPPF) and a Visiting Professor in Advanced Materials at Loughborough University.

Uniper Technologies Limited (UTL) is part of Uniper SE, an international energy company with 22.5GW of generation capacity which is active in >40 countries with ~7,000 employees and a 100+ years engineering experience in power generation. UTL provides engineering and technical support to Uniper's generation assets through their complete life cycle. UTL is actively working to enable Uniper's decarbonisation goal of 80 percent of its installed power capacity being from carbon-free sources by 2035 and achieving $CO_2$ neutrality by 2040 through innovating and delivering engineering solutions with active workstreams in hydrogen, biofuels and renewables.

Power generation presents a number of significant materials challenges. In conventional generation, high temperature (560-610°C) high pressure (165-250bar) steam is used to power turbines to drive generators. The operating conditions require materials, predominantly steels, that can withstand this environment for in excess of 150,000 hours without any threat to the integrity of the power plant. The arduous nature of this can be seen below where a pipe carrying steam is glowing red during operation.

As the plant ages the material performance can be impacted for example by creep cavitation occurring at welds or high stress locations, precipitation of embrittling phases, overageing of strengthening precipitates, etc. Therefore microstructural assessments and mechanical testing are required to determine the magnitude of the impact on performance and allow more accurate determination of component life. These assessments coupled with detailed structural analysis can prevent failure but also allow life extension of components to ensure their full life is utilised. One such example is gas turbine components where through detailed destructive examination, damage analysis and risk review, Uniper have safely extended their life thereby maximising the value of the power plant. The destructive examination requires extensive knowledge of Ni- and Co-base superalloys, their respective coating systems and damage mechanisms. The micrographs below show the effect of exposure to elevated temperatures and stress on the strengthening gamma prime precipitates in a Ni-base superalloy.




Component failures can however still occur and it is vitally important that the cause is correctly identified to allow mitigation measures to be put in place to prevent repeat failures. In many cases the failure is a result of changes to operating conditions that were not considered in the original design, a good example is the increasing amount of renewable generation resulting in conventional power plant operating flexibly, i.e. switching on and off to provide power at times of peak demand. Components primarily designed for constant (baseload) operation with a design life based on hours of operation, are now life limited by the number of plant starts/stops. In terms of damage this results in a change from creep dominated to fatigue dominated mechanisms, which can manifest as thermal fatigue, corrosion fatigue, etc. The images below show a classical corrosion-fatigue crack and a leak resulting from this damage mechanism.

In some cases failures can occur because the actual service conditions are not fully understood, are more onerous than assumed and/or the selection of poor design features. Understanding which of these have contributed to a failure can allow selection of more appropriate materials, design modification, development and implementation of repair processes. One such failure occurred when routine inspections identified extensive cracking in the nacelle bedplates of a number of wind turbines. The bedplate is the framework that supports all the equipment in the turbine nacelle, i.e. the hub, main shaft, gearbox, generator and transformer, and is therefore critical to the integrity of the turbine. In this case an in situ repair process was developed alongside an inspection method to accurately measure the crack lengths, monitor their growth and, where possible, underwrite continued operation of the turbines whilst awaiting repair. The repair process presented challenges due to the bedplate being galvanised, the cracks requiring large gap welding and restricted access, all whilst working in the turbine nacelle many metres off the ground. To ensure good quality repairs, the weld repair process was qualified, as were all the welders who undertook the repairs. The repairs were successfully undertaken and to date there has been no re-occurrence of the cracking on any of the repaired turbines.

Looking forward, the goal of net zero generation presents a number of new challenges for materials. The use of hydrogen as a fuel for gas turbines raises the issues of material compatibility. Fuel supply systems that were designed for natural gas may not be appropriate for hydrogen due to the possibility of hydrogen embrittlement. Carbon capture, utilisation and storage processes (CCUS) use a range of chemicals to capture $CO_2$ whose compatibility with the process equipment can be challenging especially as their impact can depend upon where they are in the process, i.e. before $CO_2$ capture, during or after. Pilot plant studies have identified corrosion can be an issue and therefore the selection of the correct materials and/or coatings is key to avoid or limit this damage mechanism. One of the key roles of UTL is to act as Uniper's "Owners Engineer". This entails having a good understanding of processes, operation, design and materials, in order to provide support to both new and existing assets to ensure that are provided with the best solutions working with suppliers, and where necessary challenging them.

Like all technical fields, materials is constantly developing, therefore it is essential to not only maintain knowledge but also to actively develop it. This is especially true for energy materials, as new generation technologies continue to be implemented there is a real challenge to ensure that materials engineers are up to date and able to support them when they come operational. In this respect the IOM3 Energy Materials Group provides a good source of information and contacts across the spectrum of energy materials.