Paper:
Whittaker, M. (2014). Advances in structural metallic systems for gas turbines. *Materials Science and Technology, 30* (15), 1846-1847.

http://dx.doi.org/10.1179/0267083614Z.000000000820

Advances in structural metallic systems for gas turbines

M. T. Whittaker*

The EPSRC Rolls-Royce Strategic Partnership for Structural Metallic Systems for Advanced Gas Turbine Applications was initiated in 2009 with sponsorship secured to provide a ten year research and training programme underwritten by a memorandum of understanding between Rolls-Royce and EPSRC. This partnership is unique across the United Kingdom in the sense that it combines industry led research at the postdoctoral level with a parallel scheme of postgraduate research training. Research themes are defined through collaboration between leading UK materials academics and industrial colleagues based within Rolls-Royce and its key supply chain companies. The research conducted under the strategic partnership provides an exemplar of academic–industrial knowledge transfer. This special issue of Materials Science and Technology showcases some of the research performed during the initial four years of the strategic partnership. To act as a focal point for dissemination within the scheme, a conference is held at least every two years with one of the three core members of the partnership, Birmingham, Cambridge and Swansea universities, acting as host. The initial meeting was held in Cambridge in September 2011. This was followed by a meeting in Swansea in June 2013, from which the current selection of papers is taken. The conference deliberately encourages student presentations, with both EngD and PhD students presenting their work in either oral sessions structured around the six technical work packages of the strategic partnership, or through extensive poster sessions. The opportunity to present to an audience composed of fellow students, academics, industrial collaborators and funding body representatives provides the students with a friendly yet challenging environment where encouragement and alternative ideas, along with challenging questioning based around both academic quality and industrial relevance of the work, can help shape further research. In many cases the conference also provides a useful stepping stone to students looking to present their work to open audiences on the international stage. The contributions in this issue provide a range of papers from industry, where future engineering and materials requirements are examined, and all three core universities. In each case cross-institution and industrial collaboration is demonstrated. Indeed, the contributions to the partnership from the 'satellite' universities, including Sheffield, Imperial and Cranfield, provide impressive input in areas such as alloy development, material modelling, high temperature corrosion and characterisation, which further illustrates the inclusivity of the partnership. The special issue attempts to show the diversity of the research occurring within the academic establishments, with issues such as alloy development, improved experimental techniques, materials modelling and component lifing providing a snapshot of the ongoing research. Professor David Rugg sets the scene for the strategic partnership research with a paper focusing on the complexity of adopting new or using existing advanced alloy systems in demanding environments where safety is paramount.[1] The paper also provides a fascinating insight into the role of academia within the industrial based research environment. Professor Rugg is well placed to provide such an overview given his role as a Rolls-Royce Company Fellow supplemented by extended periods based in academia on a Royal Society Industrial Fellowship at both Oxford and Manchester universities. The paper emphasises the requirement for both experimental studies and modelling to advance the understanding of existing metallic systems and develop new materials for future applications. In 'The influence of elevated Co and Ti levels on a polycrystalline powder processed Ni-base superalloy', Jones et al.[2] investigate how these elements play a critical role in the behaviour of the nickel based superalloy RR1000, an alloy that features heavily in the research being undertaken by the partners. In its role as both a high performance turbine and compressor disc material, RR1000 continues to provide a wide range of research interest, as demonstrated in this submission, along with alternative programmes investigating the behaviour of the alloy under thermo-mechanical fatigue loading or exposure to hot corrosive sulphidising environments. A great advantage of the strategic partnership is the flexibility of its postgraduate programmes to diversify or change direction through contact with the industrial partners. A programme which began with a focus on lifing of RR1000 under thermo-mechanical fatigue loading evolved into an investigation into the nature of temperature measurement to control this form of testing. This change of direction followed a six week placement by the student at the Rolls-Royce Materials Testing Operations Centre (MTOC) in Germany. The subsequent results are presented in 'Non-invasive temperature measurement and control techniques under thermo-mechanical fatigue loading' by Jones et al.[3] Whilst many of the contributions focus on high strength metallic alloys for structural components, work to study the properties of abradable materials is also yielding positive results. The work by Davenport et al.[4] provides a useful insight into the current state of high temperature variants of these materials which are governed by a very different set of performance drivers to conventional materials. Returning to the theme of the high temperature capability of RR1000, the paper by Cruchley et al.[5] addresses the critical issue of oxidation under high temperature loading, in particular relating to the development of subsurface damage in oxidising environments. The combination of precise experimental studies coupled with appropriate modelling techniques is again prevalent, as is the strong relationship between academic and industrial partners. Similarly, the work performed by Pahlavanyali et al.[6] to investigate the effects of salt deposits on the oxidation behaviour of the single crystal alloy CMSX-4 reveals the benefits of the high magnification microscopy techniques which are available to the partners across the scheme. Notably, a coauthor from the defence aerospace sector has contributed to this paper, illustrating the benefits of the strategic partnership to a strategic 'end customer'. The paper by Connolly et al.[7] describes the application of appropriate models to high quality experimental data, in this case developing a methodology to consider constant load creep data without enforcing the requirement of a constant stress. The proposed model has already proven extremely valuable to Rolls-Royce in consideration of high strain events, due to the extensive back-catalogue of creep data which is only available as performed under a constant load. Similarly, with the drive towards the application of gamma titanium aluminides for low pressure turbine applications, the work of Yang et al.[8] proves invaluable in further understanding the material behaviour, and in particular the effect of lamellar orientation on the fatigue crack propagation threshold in a well established titanium aluminide alloy. The final two papers also indicate the unique manner in which the partnership allows academia to work hand in hand with industry on topics deemed to be 'service facing' and yet still suitable for open publications. The paper by Nygaard et al.[9] investigates the microstructure of bearing steels following 30 000 service hours and applies state of the art transmission electron microscopy techniques to reveal fundamental understanding of material behaviour. The work by Hewitt et al.[10] can be considered unique, in that the collaboration here was with TIMET UK, part of the Rolls-Royce supply chain, and relates to the development of novel titanium alloys for fan disc and aerofoil components. In conclusion, it is hoped that this collection of papers provides a useful insight into the high quality research being undertaken under the EPSRC Rolls-Royce Strategic Partnership and how the outputs offer impact to a critical sector of UK industry.

Dr Mark Whittaker Guest Editor M.T. Whittaker*

References

1. D. Rugg: 'Materials for future gas turbine applications', Mater. Sci. Technol., 2014, 30, 1848–1852.

2. N. G. Jones, K. A. Christofidou, P. M. Mignanelli, J. P. Minshull, M. C. Hardy and H. J. Stone: 'Influence of elevated Co and Ti levels on polycrystalline powder processed Ni-base superalloy', Mater. Sci. Technol., 2014, 30, 1853–1861.

3. J. Jones, S. P. Brookes, M. T. Whittaker and R. J. Lancaster: 'Non-invasive temperature measurement and control techniques under thermomechanical fatigue loading', Mater. Sci. Technol., 2014, 30, 1862–1876.

4. J. R. Davenport, L. Mendez-Garcia, S. Purkayastha, M. E. Hancock, R. J. Stearn and W. J. Clegg: 'Material needs for turbine sealing at high temperature', Mater. Sci. Technol., 2014, 30, 1877–1883.

5. S. Cruchley, M. P. Taylor, H. E. Evans, M. C. Hardy and D. J. Child: 'Characterisation of subsurface oxidation damage in Ni based superalloy, RR1000', Mater. Sci. Technol., 2014, 30, 1884–1889.

6. S. Pahlavanyali, H. T. Pang, F. Li, S. Bagnall and C. Rae: 'On effect of salt deposits on oxidation behaviour of CMSX-4 above 1000uC', Mater. Sci. Technol., 2014, 30, 1890–1898.

7. M. Connolly, M. Whittaker and S. Williams: 'Development of true-stress creep model through analysis of constantload creep data with application to finite element methods', Mater. Sci. Technol., 2014, 30, 1899–1904.

8. J. Yang, H. Li, D. Hu, N. Martin and M. Dixon: 'Lamellar orientation effect on fatigue crack propagation threshold in coarse grained Ti46Al8Nb', Mater. Sci. Technol., 2014, 30, 1905–1910.

9. J. R. Nygaard, M. Rawson, P. Danson and H. K. D. H. Bhadeshia: 'Bearing steel microstructures after aircraft gas turbine engine service', Mater. Sci. Technol., 2014, 30, 1911–1918.

10. J. S. Hewitt, P. D. Davies, M. J. Thomas, P. Garratt and M. R. Bache: 'Titanium alloy developments for aeroengine fan systems', Mater. Sci. Technol., 2014, 30, 1919–1924.