LINCET Project - Minutes of 1st Progress Meeting

Downing College, Cambridge: 7th April 2016

Attending

Bill Clyne twc10@cam.ac.uk	TWC	Cambridge U. (UCAM)
Olivier Guillon o.guillon@fz-juelich.de	OG	Jülich (FZJ)
Robert Vassen r.vassen@fz-juelich.de	RV	Jülich (FZJ)
Dietmar Koch Dietmar.Koch@dlr.de	DK	DLR Stuttgart (DLR-S)
Paul Mantle pam73@cam.ac.uk	PAM	Cambridge U. (UCAM)

For Information

Roger Reed roger.reed@eng.ox.ac.uk	RCR	Oxford U. (UOX)
Robert Singer robert.singer@ww.uni-erlangen.de	RJS	Erlangen U. (FAU)
Hans-Peter Bossmann Hans-peter.bossmann@ansaldoenergia.com	HPB	Ansaldo Energia (AE)
Lee Marston Lee.Marston@dynamic-materials.com	LM	Fiberstone (FS)
James Dean jd362@cam.ac.uk	JD	Cambridge U. (UCAM)

1.1 Background

It was clarified that the project will start on 1st May 2016, with a duration of 3 years. It will be supported by an International Network grant recently awarded by the Leverhulme Trust (www.leverhulme.ac.uk), having the title "*A New Generation of Metal Fibre Reinforced Ceramics for Very High Temperatures*". The project will be given the acronym LINCET ("*Leverhulme International Network on Composites for Extreme Temperatures*"), subject to approval by the Trust. The main partners are Cambridge, Jülich and Stuttgart, although other institutions could become involved. Paul Mantle will be the Network Facilitator. The Steering Committee will be composed of TWC, PAM, OG, RV & DK. The budget for the project (excluding the cost of the Facilitator post) is as follows:

- Consumables (miscellaneous research expenses): £16k
- Subsistence (during exchange visits etc): £5k
- Accommodation (during exchange visits etc): £8k
- Travel (during exchange visits etc): £5k
- Website (including DoITPoMS summer schools): £29k
- Workshops (Symposia, including delegate expenses): £25k

1.2 Advisory Board

Part of the agreed arrangements is that project activities will be reviewed annually by a small Advisory Board. A possible membership of this Board was included in the proposal, but it should now be confirmed. The duties of the Board will be light - essentially, just attendance at the annual meeting, and perhaps the preparation of a very brief report. The annual meetings will be held around Easter (2017, 2018 & 2019), coinciding with project Symposia. Expenses will be covered (as will those for all Symposia attendees), but there will be no remuneration. It is proposed that the following people should be formally invited to join the Board:

- Prof. RC Reed, Oxford University (roger.reed@eng.ox.ac.uk)
- Prof. RJ Singer, Erlangen University / NMF (robert.singer@ww.uni-erlangen.de)
- Dr. H-P Bossmann, Ansaldo Energia (Hans-peter.bossmann@ansaldoenergia.com)

All of them attended the HELSMAC Symposium. These minutes will be circulated to them, so that they'll be able to see what will be involved in agreeing to join the Board.

1.3 Website

A project website will be set up shortly, with PAM acting as Webmaster. It will be hosted within the Materials Science Department site, at http://www.ccg.msm.cam.ac.uk/initiatives/lincet. The coverage will include information about meetings, publications, research collaborations etc.

1.4 Initial Collaborative Research

Initial work will focus on attempts to densify Fiberstone (www.fiberstone.co.uk/) by Hot Isostatic Pressing (HIP). Fiberstone is a ceramic (predominantly alumina) matrix composite, containing about 10-15vol% of short metallic fibres - usually stainless steel, such as 304 or 310. The material is produced by infiltration ("casting") of a ceramic slurry into a mould containing an assembly of fibres (either drawn or melt-extracted). Consolidation is mainly via chemical (hydration) reactions within the slurry. Although heat treatments can be applied, there is little or no sintering involved in normal production. The final product typically contains about 10-15% porosity, which is acceptable for many purposes, but is undesirable for highly demanding applications. LM is the Research Director at FS, and has been involved in extensive development work concerning the details of processing and microstructural development.

The HIPing will be carried out at FZJ, and also the prior encapsulation (in stainless steel cans). This will be done in July 2016, as part of a summer placement project, to be carried out by a 2nd year Cambridge undergraduate (Thomas Chalklen). Samples will be cylindrical, about 30 mm in diameter. RV will shortly confirm details about the number and dimensions of samples, and also the HIP conditions (probably at about 1200˚C). It is also planned that the stainless steel cylinders will be supplied from FZJ to FS, and the samples will be directly "cast" into these by LM at FS. These samples will then be returned to RV at FZJ for evacuation and sealing prior to HIPing. It is planned that the actual HIPing will be carried out during Thomas Chalklen's stay at FZJ, which will probably be towards the end of July. It is planned that samples (with and without HIPing) will be tested and examined microstructurally (including by X-ray Tomography) at FZJ and DLR-S, as well as at UCAM. An outline of the summer placement project is attached to these minutes as an Appendix.

1.5 DoITPoMS Summer School

The DoITPoMS summer schools are focussed on creation and updating of web-based Materials Science teaching and research resources (www.doitpoms.ac.uk/), with Cambridge undergraduates employed in the Department for a period of 8 weeks (4th July – 26th August this year). The plan is to create three new Teaching and Learning Packages (TLPs), all in areas of some relevance to the LINCET project. Listed below are the students, TLP titles and academic supervisors:

- Luke Diana - "*Tribology and Wear*" (Kevin Knowles)
- Radu Bizga - "*The Finite Element Method*" (James Dean)
- Arthur Keunzi - "*Powder Processing*" (Bill Clyne)

The exact coverage of these TLPs will evolve during the summer, but there will clearly be some relevance to the work envisaged within LINCET. For example, the Powder Processing TLP will include treatment of HIPing. (There is in fact an existing TLP on the *Mechanics of Fibre-Reinforced Composites* - see http://www.doitpoms.ac.uk/tlplib/fibre_composites/index.php, although this relates predominantly to polymer composites.) Of course, these TLPs are essentially educational resources, but they are occasionally useful for research purposes.

1.6 Date of Next Meeting

The frequency of LINCET Steering Committee meetings has not yet been decided, but it will probably be no more than twice a year, with one taking place around Easter, coinciding with a

Symposium (and an Advisory Board meeting). If there are to be two meetings per year, then a logical time for the other would be September. For this year, there could be a meeting slightly before that, although it would probably be best to hold it after the HIP treatments at FZJ. It's likely, however, that holiday periods will have an influence on this. A date should in any event be confirmed soon. In the meantime, a provisional booking has been made for the facilities at Downing College, for the first LINCET Symposium, for 30th/31st March 2017. (This is a Thursday/Friday, and a similar format to HELSMAC could be followed, although the attendance will be more or less limited to those actively involved in the Network, and will probably be around half that of HELSMAC - ie ~20-25.)

Appendix: Summer Placement Project Outline

Densification of Fiberstone for Use at Very High Temperatures

Collaborative Partners: Fiberstone, FZ Jülich, DLR Stuttgart

This project will be carried out in collaboration with Fiberstone Products Ltd (<http://www.fiberstone.co.uk/>), a UK-based SME that manufactures and markets a novel Metal Fibre Reinforced Ceramic (MFC) composite material ("Fiberstone"). It is mainly used for high temperature static load-bearing applications, such as furnace components and downstream processes (ladle lip rings, nose rings, spouts and tuyères in blast furnaces). The material has a high toughness, combined with excellent high temperature stability, relatively low density and economically attractive cost. It is "cast" by infiltrating a ceramic slurry (mainly alumina) into an assembly of (stainless steel) fibres within a mould, with subsequent matrix consolidation occurring via chemical reactions. Complex shapes, over a wide size range (<1 kg to >1 tonne), can be created very cost-effectively. The partnership between Fiberstone and the Gordon Lab (in the Materials Science Department) has already led to improvements in the performance of the material, via control over its microstructure - particularly the architecture and composition of the (stainless steel) fibre reinforcement [1, 2]. For use in the most demanding applications, Fiberstone suffers from the drawback that the matrix has a relatively high porosity, which is not easy to eliminate by modifications to the slurry production and infiltration procedures. This porosity impairs the mechanical properties and promotes fibre oxidation. Conventional Fiberstone samples will be densified by Hot Isostatic Pressing (at Jülich, in Germany). The pore architecture before and after HIPing will be characterized by X-Ray tomography and the effect on mechanical (fracture) properties will also be investigated, before and after severe heat treatments.

[1] SR Pemberton, EK Oberg, J Dean, D Tsarouchas, AE Markaki, L Marston & TW Clyne, *The Fracture Energy of Metal Fibre Reinforced Ceramic Composites (MFCs)*, Comp. Sci. & Techn, **71** (2009) p.266-275. doi:10.1016/j.compscitech.2010.10.011

[2] SK Lam & TW Clyne, *Toughness of Metal Fibre / Ceramic Matrix Composites (MFCs) after Severe Heat Treatments*, Mat. Sci. & Techn. **30** (2013) p.1135-41. doi:10.1179/1743284713Y.0000000413