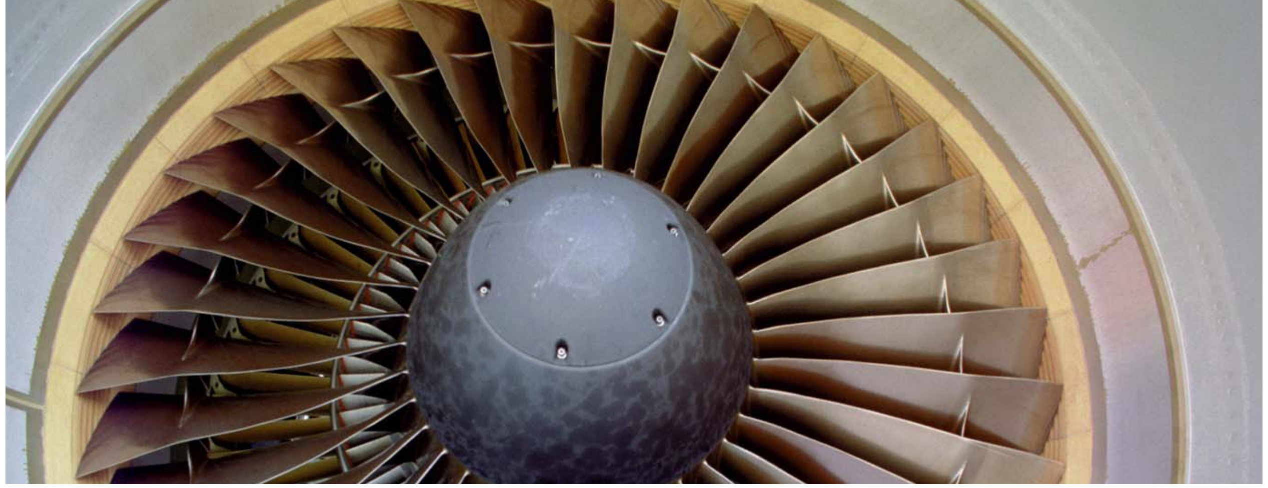


Gas turbine engines have a heat resistant coating to enable operation at higher temperatures

These thermal barrier coatings (TBCs) consist of an outer layer of zirconia, normally stabilised by the addition of yttrium, deposited using electron beam - physical vapour deposition (EB-PVD), over a bond coat. The continued integrity of the TBC is crucial to the service lifetime of the turbine blades and hence the safety of the aircraft.

The failure mechanism of the TBCs is the growth and subsequent cracking of a thermally-grown oxide (TGO) at the bond coat/TBC interface. This process is known as spallation. The thickness of the TGO is a simple function of temperature and exposure time. Current lifetime prediction models for the coated component are fairly basic and relate simply to the TGO reaching a critical thickness.

NPL is developing a range of techniques to detect and quantify changes in the TGO during thermal exposures and relating these to the failure event of the coating. One particular technique that shows promise is piezo-spectrometry. The technique relies upon the excitation of chromium ions within the (alumina) TGO by illumination with laser light. The internal stress in the TGO is measured through changes in the wavelength of the emitted light.

The residual stress within the TGO has been mapped at 1 mm square intervals on a series of specimens that had seen thermal exposures to simulate service conditions. The results show that the residual stress not only develops with exposure time (TGO thickness) but also with other parameters such as the heating and cooling rate during the thermal cycle. These measurements are being used to support and validate a modelling activity that will provide a more robust lifetime prediction methodology for components with TBCs.

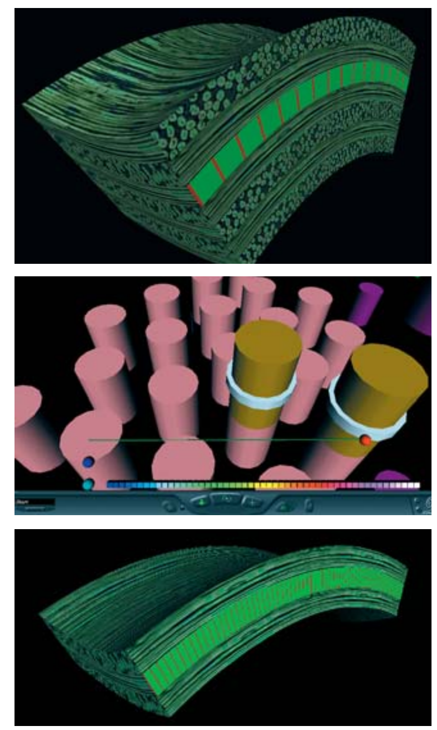
In parallel measurements have also been made on real components that have been withdrawn from service. It has been shown that the technique can be applied to this real-life situation non-destructively. NPL is currently negotiating with an equipment manufacturer to produce an instrument that can be used during maintenance periods to monitor the stress within the TGO without removing the blades from the engine. The availability of this instrument and supporting knowledge will allow airlines to reduce inspection times during maintenance periods and increase confidence in the reliability of their coated blades.

Virtual testing: materials development in cyberspace

You are turning your *Formula One* car into the final corner when suddenly the car lurches to one side and you crash. Luckily no one is hurt, and you track down the fault to a new composite material you are using in a suspension part. Although this type of new material offers performance benefits, there has not been time to optimise the material composition properly because of the time it takes for mechanical testing, the stretching, squeezing and twisting, that is needed to understand material behaviour. But this scenario could soon be a thing of the past due to work at NPL Materials Centre that will dramatically reduce the time and cost of new materials development using virtual testing.

Virtual testing is the replacement of time consuming and expensive mechanical testing with computer systems involving accurate mathematical models that are physically based and extensively tested. NPL has a Virtual Testing System for composite materials, such as carbon fibre reinforced plastics, where an epoxy plastic has been strengthened and stiffened by the incorporation of long carbon fibres. These materials are ideal for high performance applications such as F1 cars, aircraft, and sports equipment, where lightweight strong materials are essential, but the key to efficient design is understanding how these materials behave. Composite materials offer an additional benefit of retaining strength and structural integrity even when damaged, and the NPL Virtual Testing System offers a great benefit because it attempts to model the effects of damage accumulation.

To allow an engineer easy access to the mathematical models and to replicate the real process of materials development in cyberspace, we have developed a demonstrator working over the Internet that can be found at: www.materials.npl.co.uk/demonstrator This uses state-of-the art virtual reality techniques to allow users to interact with a composite material specimen, and to understand its behaviour using some very advanced composite models that potentially can replace weeks of routine mechanical testing with a few minutes of virtual testing. In time additional material models will be incorporated into the system and conventional mechanical testing will largely be a thing of the past, however we cannot guarantee you will win that *Formula One* race!



Examples of virtual reality imaging used in virtual testing

Reminder

Closing date for Metrology Awards application - 30 August
www.npl.co.uk/mwcm/
Contact: Anne Kearney
Tel: 020 8943 6557
E-mail: anne.kearney@npl.co.uk

Tool materials

Hard materials serve a myriad of purposes in the aerospace, automobile, electrical, electronics, metalworking, mining, oil, paper, construction, food processing, agricultural and horticultural industries.

Hardmetals are a group of tough, wear-resistant materials that are harder than the hardest steel. They are formed from carbides of tungsten, tantalum, titanium, molybdenum, niobium and vanadium, bonded with a metal of lower melting point, e.g. cobalt, nickel and their alloys. Tungsten carbide is the most widely used hard phase. The technology used in production is a powder metallurgy (PM) process. It depends on sintering, or heating microscopically fine powder to the melting point of the binder metal, which becomes liquid and aids the formation of a fully dense body. Rigorous process control is needed. By varying the carbide particle size, the amount of binder metal and the sintering conditions, properties like wear resistance, impact strength, resistance to cratering and hot hardness can be optimised.

The result is a family of materials that is ideal for making components to withstand the tyranny of jet engines: tough enough to drill through the most solid rock; suitable for tools designed to keep punching millions of bolts, rivets, screws and other engineering products.

In the hardmetal industry there is a move towards finer grained microstructures to improve strength and reliability. Ceramic materials also have increasingly finer grain sizes. In addition, extensive research is leading to nanoscale microstructures for both mechanical and functional purposes. Even in conventional ceramics, submicrometre scale features, such as porosity and its distribution are critical factors in materials performance. The same is the case for powder metallurgy material.

Grain shape of ceramics and hardmetals is controllable, but means of quantifiable characterisation are absent. Automatic image analysis routines for studying measures of grain shape are being developed.

A critical issue for quality control of powder-route materials is evenness of structure or homogeneity. Mixing processes are never perfect, especially in the presence of clustering or settlement. Through a combination of microstructural image analysis and scanning probe testing, the potential for creating simple measures of homogeneity is being investigated. Simple evaluations on unfired products may also aid identification of problem batches before making large volume production runs.

In all powder route materials, residual porosity is a limitation to mechanical performance and corrosion resistance, or a parameter to be controlled at a defined level. In ultrafine grained ceramics and hardmetals, very fine pores may remain as the weak part of the microstructure, but are difficult to characterise. Techniques for evaluating porosity are being developed, using a variety of microstructural, image analysis and mechanical techniques.

Mining and tunnelling rely on hard materials for the borers

Clubs

UK Forum on Friction and Wear Testing covers the standardisation of test methods, and the VAMAS initiative on wear test methods. Meetings are held twice a year.
Contact: Mark Gee
Tel: 020 8943 6374
E-mail: mark.gee@npl.co.uk

Soldering Science and Technology Club
A club covering the electronics interconnection activities at NPL. One-day seminar meetings are held twice a year. Members also receive progress reports of NPL work.
Contact: Deborah Lea
Tel: 020 8943 6065
E-mail: deborah.lea@npl.co.uk

MTDATA Users Group.
A club for users of MTDATA, NPL's software/data package for the prediction of phase equilibria based upon critically assessed themodynamic data. Meetings are held annually and users are able to hear about new features, development plans and practical applications of MTDATA.
Contact:John Gisby
Tel: 020 8943 7098
E-mail: john.gisby@npl.co.uk

Measurement Methods for Processing of Plastics Working Group, to improve measurement methods for the plastics processing industry. Topics include viscosity, melt elasticity, data for software on plastics processing, thermophysical properties and dimensional stability.
Contact: Chris Brown
Tel: 020 8943 6769
E-mail: chris.brown@npl.co.uk

FORTHCOMING EVENTS

6 September 2001 NPL ANA uncertainties course
Contact: Sara Fletcher
Tel: 020 8943 6827
E-mail: sara.fletcher@npl.co.uk

9-14 September 2001 University of St Andrews, Scotland 6th Symposium on frequency standards and metrology
Contact: Robert Angus
Tel: 020 8943 7110
E-mail: robert.angus@npl.co.uk

12 September 2001 NPL Lead-free electronics workshop
Contact: Deborah Lea
Tel: 020 8943 6065
E-mail: deborah.lea@npl.co.uk

13-14 September 2001 NPL MTDATA data assessment course
Contact: John Gisby
Tel: 020 8943 7098
E-mail: john.gisby@npl.co.uk

14 September 2001 (location to be confirmed) Micro optics and lens arrays Joint NPL/Institute of Physics
Contact: Richard Stevens
Tel: 020 8943 6484
E-mail: richard.stevens@npl.co.uk

19-21 September 2001 Riso, Denmark 5th Composites: testing and standardisation
Contact: Graham Sims
Tel: 020 8943 6564
E-mail: graham.sims@npl.co.uk

19 September 2001 NPL Surface mount electronics assembly workshop
Contact: Deborah Lea
Tel: 020 8943 6065
E-mail: deborah.lea@npl.co.uk

24 September 2001 (provisional date) NPL FREEMET antenna calibration training course
Contact: Sara Fletcher
Tel: 020 8943 6827
E-mail: sara.fletcher@npl.co.uk

25 September 2001 Cambridge Fibre optics polarisation tutorial/workshop
Contact: Joan Smith
Tel: 020 8943 6199
E-mail: joan.smith@npl.co.uk

25 September 2001 NPL Neutron Users' Club meeting
Contact: Peter Kolkowski
Tel: 020 8943 6855
E-mail: peter.kolkowski@npl.co.uk

25 September 2001 NPL BGA electronics assembly workshop
Contact: Deborah Lea
Tel: 020 8943 6065
E-mail: deborah.lea@npl.co.uk

26-28 September 2001 Montpellier, France EC Commission (JRC-Ispra) - International conference
Subject: Measuring air pollutants by diffusive sampling
Contact: Peter Woods
Tel: 020 8943 7095
E-mail: peter.woods@npl.co.uk

26-28 September 2001 Bordeaux, France Global network for detection of stratospheric change international symposium
Subject: Ground based remote measurements of stratospheric and greenhouse gases
Contact: Peter Woods
Tel: 020 8943 7095
E-mail: peter.woods@npl.co.uk

26-28 September 2001 Girton College Cambridge 6th Optical fibre measurement conference (OFMC '01)
Contact: Andrew Deadman
Tel: 020 8943 6077
E-mail: andrew.deadman@npl.co.uk

3 October 2001 Kempton Park Soldering Science and Technology Club (SSTC) meeting
Contact: Deborah Lea
Tel: 020 8943 6065
E-mail: deborah.lea@npl.co.uk

16-17 October 2001 NPL Obtaining time and frequency traceability via GPS
Contact: Karen Hood
Tel: 020 8943 6582
Email: karen.hood@npl.co.uk

18 October 2001 NPL Reliability of electronics workshop
Contact: Deborah Lea

FURTHER INFORMATION

For additional copies of this newsletter, or for more information on any aspect of NPL's work and the range of services available from the Laboratory, call the NPL Helpline:

Tel: 020 8943 6880 Fax: 020 8943 6458 E-mail: enquiry@npl.co.uk
Switchboard: 020 8977 3222
Website: www.npl.co.uk

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NEWS FROM THE
National Physical Laboratory

METROMNIA

LIVING IN A MATERIAL WORLD

There is a fundamental relationship between measurement and manufacturing that has been established since goods were first traded. Measurement is still economically important, underpinning trade and controlling costs by reducing wastage and ensuring specifications are met. Measurement is also an essential part of the innovation process allowing the performance of products and processes to be compared and evaluated.

NPL has always responded to the ever-changing needs of industrial and commercial life. Forward-looking companies are searching for ways to reduce their costs, to differentiate their products and to manage the product life cycle. Materials measurement helps them reach these objectives.

Materials for gas turbine engines

Modern aircraft engines present one of the most challenging environments to the materials engineer. The principle of the turbine is that air passes into the front of the turbine, is compressed, mixed with fuel and ignited. The resulting gas mixture is ejected from the rear of the engine after passing through the turbine stage, which drives the initial compressor. Operating temperatures are continually increasing in the pursuit of higher efficiency but reliability must always remain the critical parameter, as passenger safety is paramount to all airlines.

Current gas inlet temperatures in the turbine are actually higher than the melting point of the nickel-base alloys used for turbine blades in the first stage. The problem is addressed through sophisticated cooling in the blades, using air that bypasses the combustion chamber after the compressor and low thermal conductivity coatings on the surface of the blade.

NPL
National Physical Laboratory

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