

# overview

The aerospace industry requires an in depth knowledge of the properties and behaviour of materials in extreme conditions. Jet engine components must endure intense stresses and temperatures of up to 1000 °C. Minute cracks introduced through sustained mechanical stress or foreign object damage not only reduce the lifetime of components but can cause catastrophic failures.

The ability to assess structural weakness of components and materials on a microscopic scale is crucial to ensuring safety whilst boosting performance. Synchrotron radiation enables high resolution, increased penetration stress analysis on a timescale far shorter than laboratory-based techniques. Combined with the capability to test at the high temperatures and pressures experienced in realistic operational conditions, the synchrotron provides a valuable tool for aerospace research and development.

## Key Challenges

- **Testing materials in operational conditions**  
Aircraft components need to withstand intense heat as well as high stresses and strains.
- **Non-destructive testing**  
It is essential to ensure that during testing any observed effects were not introduced during sample preparation.
- **Reducing foreign object damage**  
Creating accurate models to predict the impact of foreign object damage, estimated to cost the aerospace industry up to \$4 billion a year.

## The Synchrotron Solution

The high brilliance and high photon energy of synchrotron X-rays make it possible to penetrate more deeply into structures and with higher resolution. In addition X-ray techniques are non-destructive, which ensures that any observed effects have not been introduced during sample preparation. Diamond will also allow testing of materials in the high temperatures and pressure that components experience in operational conditions.

## Techniques

X-ray diffraction and imaging techniques which allow data to be gathered beneath the material surface at high resolution

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# case studies

## Taking the Heat

Jet engine components need to survive repeated heating and cooling in cycles of up to 1000 °C. At present metallic components are coated with ceramics to enable them to survive these conditions, but engineers are pushing to get the temperatures up even higher to increase engine thrust.

The response of ceramics to repeated heating and cooling has been studied using laboratory X-rays, but this only provides a view of what is going on at the surface of the material. To look at what is happening beneath the surface and at the metal/ceramic interface scientists in Australia have turned to the synchrotron.



By examining how atomic structure of ceramics varies with dopant levels

scientists were able to ascertain that some of the claims made by coating manufacturers were not entirely accurate.

John Thornton of the Australian Defence Science and Technology Organisation (DSTO) says,

“We found that zirconia with some of the supposedly superior dopants was less stable. So we have recommended against using them.”

This could lead to considerable savings in maintenance of jet engine components and more reliable coatings for future aircraft.

Source: Australian National Beamline at the Photon Factory, Japan and the Advance Photon Source, Chicago USA.

[www.synchrotron.vic.gov.au](http://www.synchrotron.vic.gov.au)

## Mapping stresses

Gas turbine compressor blades can experience foreign object damage on their leading edge in service. Such damage can act as a source for cracks to initiate and lead to unexpected failure.

Professor Phil Withers and his colleagues at the University of Manchester are looking at new ways of protecting the leading edge with Rolls-Royce plc. Cracks only open in tension, so by placing the surface in residual compression, very large tensile surface forces must be applied before a crack can grow. New methods such as deep rolling have been developed which can introduce compressive residual stresses into the whole thickness of the leading edge.

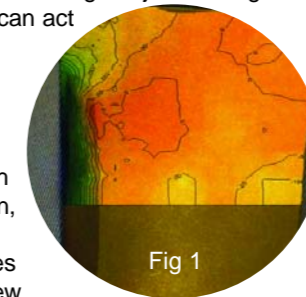


Fig 1

Colin Small, Project Manager External Research (materials) for Rolls-Royce plc explains, “Very highly penetrating synchrotron X-ray beams are used to measure the spacings between atoms in the blade by diffraction to find out whether the region of interest is in tension (larger spacing) or compression (smaller spacing). In this way the stress can be mapped to unrivalled spatial resolution throughout the blade (sub-millimeter). In addition, because the stresses can be mapped non destructively, it is also possible see the extent to which these protective stresses relax over the service life of the blade, leading to safer lifetime predictions”.

Fig 1: Stress contours in the compressor blade

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