Sparkling touchdown

Dr Benjamin Jones, Research Co-ordinator from the Experimental Techniques Centre at Brunel University, UK, describes the environmental benefits that can be gained by using diamond-like carbon coatings on aircraft.

Diamond-like carbon (DLC) combines the properties of graphite and diamond to provide an inert, hard wearing, low-friction, thin-film barrier coating that can be deposited uniformly over a large area. Medical and electronic applications, including surgical implants and hard-disk heads, benefit from this versatile material, which has recently been used on razor blades and for high-performance manufacturing applications. Researchers at Brunel University and Hawker Pacific Aerospace, Hayes, both in the UK, are collaborating on an EPSRC sponsored Environ-mental Technology Engineering Doctorate (EngD) scheme to investigate DLC as an anti-corrosion coating for aircraft components.

Chromium consequences

Hard chromium plating is extensively used on aircraft landing gear and hydraulic components to improve functionality and reduce wear. The plating process is used in manufacturing and for general restoration of worn or corroded parts.

Being a known carcinogen and toxicant, chromium exposure poses an occupational health hazard. The plating process disperses a fine mist of chromic acid into the air where hexavalent chromium (hex-Cr or Cr[VI]) is inhaled. Exposure can also occur via dermal contact. Chromium plating processes typically use lead anodes, which decompose over time. The lead chromates formed from this decomposition are classed as hazardous waste, which further complicates treatment and disposal.

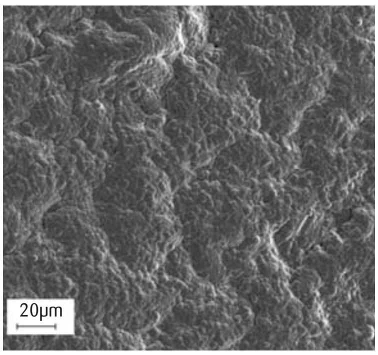
Furthermore, the plating process is time-consuming. It requires several pre- and post-plating treatments. In many cases, the coating is removed at every overhaul interval, and components are reworked to remove defects before a new coating is applied to achieve assembly design dimensions.

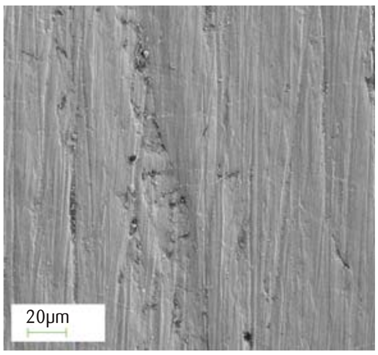
The image (see image p22, below) shows a typical landing gear trunnion pin where the chrome is worn and delaminated and needs to be replaced. Cyanide-based metal strippers are commonly used, resulting in cyanide-contaminated solutions that require special treatment and costly disposal procedures.

Chrome plating is also a prime source of hydrogen embrittlement of steels, which can produce a loss of ductility or time-delayed fractures, even without externally applied stress.

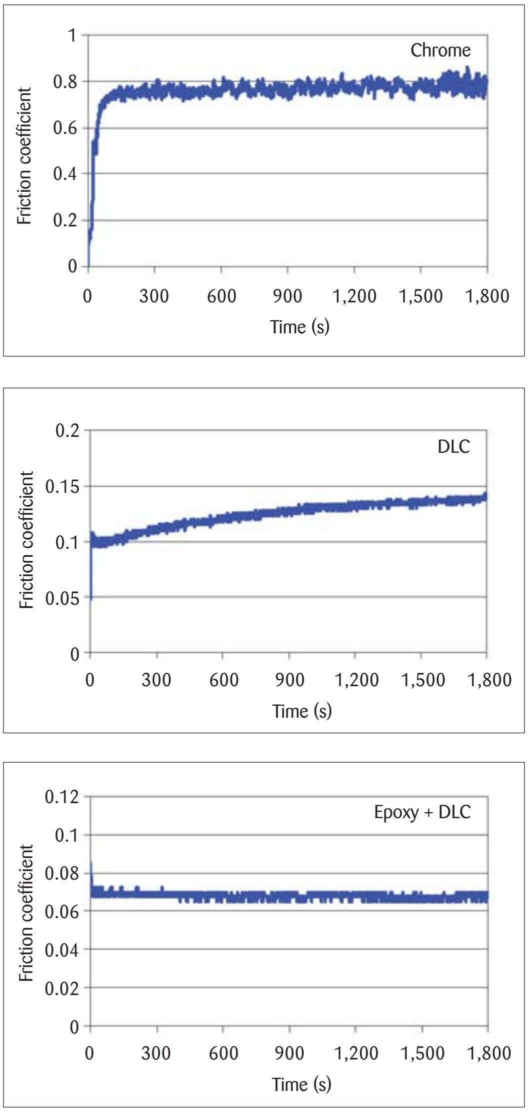
During plating, hydrogen released at the surface of the steel infiltrates the structure, generating and accelerating the cracking effect. Hydrogen related failures and accidents have been reported on high-strength steel landing gear components at low cycles of stresses. A time consuming post-plating heat treatment is typically performed to relieve

Below left: Scanning electron micrograph of an epoxy/diamond-like carbon (DLC) structure. The DLC conforms to the substrate layer on the macro-scale. Below right: Scanning electron micrograph of polished chrome plate – micro cracks inherent to chrome plating contribute to coating delamination and corrosion of the substrate





Right: Comparisons of friction tests for Cr, DLC, and DLC and epoxy coatings.



Below: Typical landing gear component exhibiting chrome plate failure and substrate damage

hydrogen embrittlement and restore the material's mechanical properties.

Like diamond

Non-toxic, high-performance coatings could benefit aircraft manufacturing and maintenance by reducing electroplating emissions. However, due to the combination of properties needed, it is difficult to find alternative coating technologies. As well as its hardness and resistance to corrosive environments, chromium plating also improves smoothness, wear and galling of different substrates.

Several manufacturers have trialled alternative technologies. Tungsten carbide cobalt-chrome coating, approved for some manufacturing processes, does not cause hydrogen embrittlement and produces a better wear resistance and finish than chrome. Resin-based composite processes have also been shown to combine corrosion prevention with a self-lubricating behaviour. Unfortunately, there are limitations to these techniques regarding coating thickness and suitability for all locations.

Diamond-like carbon coatings provide wear resistant surfaces. The plasma-enhanced chemical vapour deposition process enables film deposition over a large area, combined with easily adjusted deposition parameters to produce films with tailored microstructure and properties.

However, the vacuum technology required puts limits on the dimension and type of substrate coated, and the coating can only be deposited as a thin film of a few micrometres – in thicker layers the internal stresses induce defects and, potentially, delamination.

Film flexibility

These drawbacks can be mitigated to a degree by tuning coating deposition and hence film structure. Plasma-enhanced chemical vapour deposition is a flexible process allowing control over the composition of DLC, including the graphitic/diamond-like ratio, as well as the incorporation of hydrogen and other substances. This can affect residual stress as well as film properties, such as hardness and elasticity, the concentration of defects, the ability of the film to bond

to different materials, and the final surface structure and chemistry.

Inevitably, there is a trade off – increasing coating flexibility and reducing stresses produces a film of lower hardness. To achieve a thick coating with optimum wear properties, a different approach is required.

A system based on a layered structure of epoxy interlayer with DLC for the surface finish has the potential to restore worn or damaged aircraft components in a more efficient and environmentally friendly manner. Epoxy coating is applied on top of the substrate and machined to the required dimensions. A graded DLC thin film is then deposited to provide a final layered coating.

Thanks to contributors – S Podgoric, R Bulpett and J Franks.

Further information

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