Aerospace engineering coatings: today and next five years

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This article is based on the Keynote Address given by the author, Chairman of the Organic Finishing Group, the Institute of Metal Finishing, at the IMFAir09 Conference held at the Royal Air Force Museum Cosford, Shropshire, 10–11 June 2009. The article describes how the requirements of paint suppliers' aerospace clients will drive the design and development of surface coatings now and during the next 5 years. It also illustrates the demands placed on the coating industry's raw material suppliers and the effects of 'green' legislation.

A larger number of demands are currently being placed on the surface coatings industry in the areas of performance and the environment than ever before. This situation is expected to continue for the foreseeable future, at least the next 5 years.

Manufacturers such as Indestructible Paint Ltd produce literally hundreds of coatings for the aerospace market, and virtually all of these have been, or will have to be, updated or replaced. Examples of coating types currently produced for this market include:

- diffusion coatings
- dry film lubricants
- inorganic coatings
- intumescent/thermal barrier coatings
- organic coatings including; epoxies, polyurethanes, acrylics, silicones, silicate and polyimides
- primer filler coatings for composites
- sacrificial coatings.

Many of the materials described above are designed to exist in a variety of applications where they have to resist one or more of the following:

- chemical attack from, for example, skydrol hydraulic fluid and deicing fluids
- corrosive environments
- erosion caused by rain, sand or other particles
- fuel and lubricants
- high temperatures, often above 500°C
- thermal conduction.

Environmental and legislative issues governing the changing situation include:

- Cr^{vi} elimination (hexavalent chromium)
- REACH
- Cr^{iii} elimination (trivalent chromium)
- SVHCs
- GHS (replacement of CHIP)
- the solvents directive
- HAPS solvent emissions
- VOC reduction/elimination
- chemical labelling and packaging regulations.

The volume of development work needed to achieve these changes is obviously very significant. Fortunately, this situation was foreseen and in the author's own organisation, the necessary facilities have been put in place and expanded as necessary. The current facilities include:

- an innovative coatings development team to meet ever increasing technical demands
- commercial and technical teams to provide total back-up for distributors and clients
- complete in-house product manufacturing
- development and quality control laboratories
- full product stocking
- an export packing and despatch team.

So, how are the problems being dealt with? It is useful to think of surface protection in terms of systems. A coating system will almost always consist of two or more layers.

A wide range of metal types are used in aircraft construction. These include aluminium, magnesium, titanium and steel, plus a variety of alloys. In addition to metals, there is also extensive use of fibre reinforced composites. Metals used in aircraft manufacture are selected to achieve minimum weight consistent with the necessary strength for the component in question. Magnesium, aluminium and various alloys are commonly used.

To apply the correct coating system, the first layer is the pretreatment. This could be one of a range of processes from a thorough clean to a conversion coating, where the top surface of the substrate, steel, for example, is chemically converted to a phosphate. Chromate rinses have also been used (and still are in many cases) either on their own or in addition to phosphate, depending on metal types and other considerations.

However, the complete elimination of all chromium compounds from finishing processes is now on the agenda. Priority is being given to the elimination of hexavalent 'chrome' (Cr^{vi}). As a result, new chromium free thin film conversion coating alternatives are rapidly becoming a necessity for these materials.

Development work on these involving the use of sol gels, polysiloxiranes and anodic 'chrome' free processes is currently taking place at the author's organisation.

Subsequent layers or films' will usually be 'conventional' organic single coat protective coatings or primer plus finishing topcoat systems.

Over the last few years, the meaning of the word 'conventional', in this context, has changed somewhat. Not too long ago, 'conventional' would have implied organic solvent based coating systems often requiring high cure temperatures. Environmental legislation has stimulated the development of water based resins for organic coatings and these have now become, or are rapidly becoming, 'conventional'.

At present, we have or can source water based:

- stoving epoxies: with high or low temperature cure
- two-component epoxies: with cold and low temperature cure
- two-component urethanes

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- high temperature resistant silicones: cold cure and stoving.

Further development work will continue on these for many years to come but we still need more environmentally friendly organic resin types. Examples of these include water based/reducible, or otherwise safer, alternatives to existing phenolic and polyimide resins.

Development programmes are, of course, not restricted to the use of environmentally friendly resin systems. We also need a number of new pigments and additives for environmental reasons, especially:

- chromium free anticorrosive pigments with greater corrosion protection than those currently available. Ideally, these would equal or exceed the performance currently achieved with chromates
- toxic emission free intumescent pigments
- smoke emission free flame retardant pigments or additives.

Paint suppliers, such as Indestructible, have to rely, for these in particular, on their raw material suppliers.

In the future, we will still, almost certainly, need solvents for some coating systems and they will have to meet both current and predicted emission limits and be HAPS friendly. A major change in coating systems for high temperature applications is the move away from organic systems to inorganic. These are principally 'slurry coatings' typified by the Ipcote range, for example.

Mainly used within both the low pressure and high pressure compressors on turbine engines (Fig. 1), these coatings have to withstand temperatures up to 600ºC and provide extreme corrosion and chemical resistance. To meet impending legislation, and increasing requirements from the engine manufacturers, development work on these coatings is ongoing to:

- eliminate hexavalent 'chrome' (Cr^{vi}), followed by trivalent 'chrome' (Cr^{iii})
- increase stability of Cr free products for long term storage
- produce single component Cr free systems
- increase performance capabilities.

Similar legislative requirements will also affect the range of inorganic metallic ceramic anticorrosion coatings (Fig. 2) now being specified on undercarriage components.

In this particular instance, increased temperature resistance will be less of an issue than corrosion and chemical resistance.

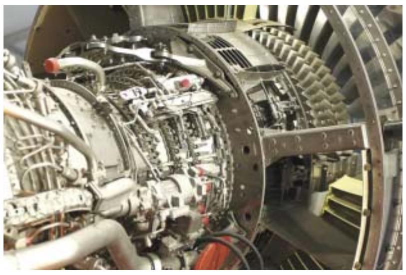
The increased heat resistance required of coatings such as the Ipcote range is an example of the performance enhancements that will be needed for the majority of products, in addition to the environmental demands discussed above.

Examples of increased performance requirements are listed below:

- temperature resistance: increasing to 800ºC or greater
- corrosion resistance: 2000+ h HSS to ASTM B-117
- cyclic corrosion: prohesion >10 cycles
- fluids and chemical resistance: tributyl phosphate: 350+ h at 70ºC
- erosion and abrasion resistance: rain and particle erosion
- steam resistance: 760ºC and 350 bar.

In addition to these increases in performance, paint manufacturers' clients naturally require easier application, reduced cure times and temperatures, safer products and fewer storage issues.

It is perhaps inevitable that the environmental and performance issues are in conflict, but it is the job of coatings process manufacturers to make them inclusive. It is all part of the service and leads to a more sustainable industry for the foreseeable future.



1 A gas turbine engine. The various coatings used on internal and external engine components need to provide protection against one or more of the following: an extremely corrosive environment, very high temperature, erosion and chemical attack

2 Ipal, an Indestructible inorganic metallic ceramic anticorrosion coating (MCAC) Ipcote derivative being applied to a jet engine stator

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