The cosmetic presentation of aircraft is vital to an operator's public image . Paint schemes make fleets instantly identifiable to passengers. The treatments, techniques and costs of painting legacy, aluminium airframes and emerging composite fuselages are explored.

The process & costs of strip & paint

Airline livery and paint schemes are the primary means of identifying an operator. Presentation and appearance are important, and distinctive paint schemes are an effective marketing tool.

Airframe material will influence paint systems. While airframes have historically been manufactured with aluminium alloy, an increasing number are now built using composite materials. Composite materials have been used on certain areas of the aircraft in recent years, such as the horizontal stabiliser, yet its use as the main material for the fuselage is reasonably new. A popular choice of composite used in airframe production is carbon fibre reinforced plastic (CFRP). Composite materials are becoming increasingly widespread in fuselage production because they are lighter than aluminium alloys, and do not corrode under the same conditions. The treatment of composite materials has to be taken into consideration when painting new-generation aircraft.

Techniques and coatings

Regardless of aircraft size, material and type, one mainstream technique continues to be used in applying paint to fuselages. "Pretty much all paint techniques involve manual spraying by people, using a paint gun," explains Simon Cracknell, sales and marketing director at UK-based Airbourne Colours. "While robotic equipment is now being used in some stages of the manufacturing line, it is not yet suitable for painting an aircraft fuselage, due to the complexity and shape of a standard airframe."

"Spray guns are used by paint technicians, who are able to cover the whole aircraft via docking that is built around the aircraft once it is in the shop," adds Jim Rowbotham, managing director at Pexa Ltd. "While this is the most common technique used in paint shops, a more sophisticated technique used for areas of the fuselage that are difficult to access is a 'flying carpet'. This is a platform that the paint technician can operate and steer using a joystick. This makes accessing the airframe easier, but paint guns are still used to apply paint."

Original equipment manufacturers (OEMs) are competing to not only produce the most cutting-edge, efficient and reliable aircraft of a generation, but also to establish productive and agile manufacturing processes. One such example is implementation of robotics to speed up certain production lines, although as Rowbotham explains, robotics have not yet made it into the fuselage painting process. "The robotic processes used today are far better at painting and coating smaller objects, such as aircraft components, where larger numbers of the same component are in the production line," he says.

More aircraft are being built with composite fuselages that have to be treated and painted using different materials. Since airframes undergo certain environmental stresses, such as extreme weather conditions, lightning strikes and tropical or freezing temperatures, it is imperative that materials react appropriately to sudden changes in temperature and pressure.

When manufactured, composite material is usually primed before paint systems are then applied. Depending on the type of composite or the particular component, additional paint systems may be applied, such as high build primers and pore fillers. These close any pinholes in the surface and smooth out any apparent texture, giving a flat surface indistinguishable from metal.

Like plastic, and in contrast to the traditional metal airframe, composite materials are inherently non-conductive. Consideration needs to be given to treatments that could or must be applied during manufacturing and painting.

"The overheating of composite materials is an issue," says Rowbotham. Composite materials do not dissipate heat as effectively as legacy aluminium airframes. Pexa offers heat-reflecting paint for composite airframes, which allow depletion of solar heat.

"There are several areas on composite structures of the aircraft that have anti-static coatings to dissipate the static electricity generated," says Cracknell. "As aircraft become increasingly composite, this becomes a more critical issue."

Given their limited conductive capabilities, composite aircraft must be able to withstand environmental events, such as lightning strikes, which exert large amounts of energy and electrical charge throughout the airframe. Further consideration needs to be given to the fuselage structure. "Copper mesh is often layered up into the structure of the composite material during manufacture," says Rowbotham. "If copper mesh is not incorporated, then conductive coatings are applied to allow the composite material to effectively combat these environmental pressures." Conductive coatings are less common, with most OEMs opting instead to incorporate copper mesh.

Conductive coatings for composite materials have the added benefit of being applied after manufacture, and can also be used to further improve the performance of the composite fuselage if certain areas are not conducting effectively. Rowbotham also explains that conductive coatings and sealants can be applied where dissimilar materials or

Airbourne Colours has paint shops at Bournemouth International and East Midlands Airport. Both can perform strip and repainting services for aircraft up to 737-900 or A321 dimensions. Customers include European carriers.

components join on the fuselage to improve contact.

More common than conductive paint coatings to discharge lightning, is the use of paint that enables the bleed-off of static electricity, known as anti-static coatings. Static interference, generated by airflow over the surface of a composite airframe, can disturb electrical systems or produce sparks upon landing if not properly dissipated. Most composite aircraft have anti-static coatings to achieve required static discharge on affected areas. There remain composite areas of an airframe that require lower conductivity to enable radars and radios to function, including, for instance, antenna and radomes.

In addition to the fuselage, most internal structures are painted. While this may be to aid identification of the component, the coating is often designed to protect it from corrosion. "Different primers may be used depending on the component," adds Rowbotham. "The nickel coating for the steel landing gear will require different treatments than the airframe, while flooring in toilets will require more resistant coatings to prevent corrosion from blue fluid leakage."

"As part of normal commercial aircraft repainting, areas of the airframe are typically split into fuselage, vertical stabiliser, engine cowlings and winglets (if fitted) and wings, horizontal stabilizers and flying controls, if required," explains Cracknell. "The landing gears and any internal panels are normally masked off, and not re-painted during this process."

"Similar tooling is used over the complete aircraft during the repaint process, except that chemical paint strippers can be used on metallic parts, but not on composite parts," adds Cracknell. "Aircraft OEM-approved sealant is also normally replaced on metallic parts, due to damage caused by the paint strippers. This is not normally the case for composite panels."

Paint removal

There are two main techniques to removing paint from an airframe for repainting. Simply adding another layer of paint to the previous scheme adds significant weight to the aircraft, which impedes performance. While removing paint takes time, it is highly desirable.

Airframes are either sanded to remove this paint, commonly known as abrading, or it is chemically removed, typically using Benzyl Alcohol based chemical paint remover. While aluminium airframes and wings can be abraded or stripped, composites are only sanded. "The composite fuselage is sanded down as far as it can be without showing the weave-like structure," says Rowbotham. "Sanding therefore stops when the basic primer that covers the OEM-applied treatments is exposed. The only exception to this is if the repainting is due to damage, for example from hail or bird strike, which may have exposed the internal structure. These areas must be repaired before paint can be reapplied."

In the military sphere plastic media are more frequently used to gently blast the paint from the surface of an airframe, but this practice has yet to be widely adopted by civil operators.

Considerations

Rowbotham explains that sanding and repainting, rather than using a chemical stripper, builds weight over time. The more times an aircraft is repainted, the longer the abrading process will take. As the process is less effective than a chemical strip, additional layers of paint make the job difficult. "The manuals may advise the paint shop to sand all the way down to the primer, but this is a lengthy process if abrading is used and is difficult to achieve within the time demands of an operator," adds Rowbotham. "If an operator needs the aircraft back in a quick turnaround time (TAT) then the paint will often be sanded down to a point that the shop is satisfied a good substrate has been achieved, and that a consistent level has been removed throughout the fuselage. This allows a shorter TAT to get the aircraft flying."

While chemically removing paint from the fuselage and tail sections can remove up to 150Kg (330lbs) on a single-aisle jet, Rowbotham advises that the sanding process might only remove a fraction of this. This means that some weight might be added with the new paint scheme.

"With aluminium airframes, chemical stripping is more expensive than abrading," adds Cracknell. "Most other areas on the aircraft, such as the wings, would normally be abraded."

When applying paint to composite airframes, the paint type must be taken into consideration. The differing properties of metal and composites mean that paint interacts differently between the materials. While metal is prone to corrosion, a key benefit of composite structures is their ability to withstand it. "Paints that contain metal chromate pigments are often used in painting aluminium airframes, because they inhibit corrosion," says Rowbotham. "They also partially dissolve in water, delivering the required protection to exposed metal. As composite materials do not corrode, the protection given by metal-chromate-based paint is redundant. Moreover, using this paint on composite material encourages water absorption, which is potentially damaging to composite materials." Chromate paint is also hazardous and subject to increasing regulation. Chromate-free paint is used when painting composites, other than in areas where metal elements are attached, such as vortex generators and pitot heaters.

Traditional sanding processes are inefficient for new-generation aircraft.

Airbourne Colours has recently completed a complex paint scheme for Brussels Airlines that promotes the Tomorrowland music festival. The paint shop visit took 15 days; about double the turnaround time of the average paint shop visit.

Given the size of the 787, for example, alternative chemical stripping processes are essential. Rowbotham explains that paint-stripping systems have been developed that strip the topcoat yet leave the original OEM primer in place. By using an intermediate coat between primer and topcoat layers that is resistant to paint stripper, the primer is preserved and contact between chemical and composite is avoided.

"While operators must distinguish between anti-static and chromate paints, the same primers and topcoats are used on both composite and metallic parts of an aircraft," says Cracknell. "What one normally finds with composite panels is that the paint degrades and starts to craze more on composites due to their internal structure's flexibility and the nature of the resins used within it."

"On metal airframes, this always involves an etch primer for corrosion protection, followed by an intermediate primer and topcoat. On composite panels a similar process is followed, but the etch primer is only used to protect the metal fasteners and screws on the composite," adds Cracknell.

"Inevitably the downside of painting is that it adds weight to the aircraft," continues Cracknell. "The weight gained depends on whether the aircraft is chemically stripped or abraded, on the amount of paint on the aircraft when it arrives at the shop, and also on when it was last stripped in its paint cycle."

If an operator uses decal stickers to add detail, this adds more weight on top of a paint scheme. At the top end of the scale, where extensive use of decals is required, this may be at the expense of passenger seating, and can lead to a row of seats being removed to accommodate the additional weight.

For a widebody, such as the 777, Rowbotham advises that its paint scheme will add about 400Kg (880lbs). Meanwhile, for a narrowbody, such as the 737NG, a paint scheme will account for about 200Kg (440lbs). While a chemical strip between paint schemes will take away about 150Kg (330lbs) on the 737NG, for instance, Rowbotham explains that chemical strips are not applied to the wing or horizontal stabilisers, so not all the original paint can be removed between paint shop visits. A regional jet, such as an Embraer E-Jet's paint scheme, will add about 100Kg (220lbs). Abrading the fuselage, rather than stripping, may only remove 20-30Kg (44-66lbs) of paint before the new paint is added.

"The painting of the complex internal structures within the airframe will add three to four times these weights," says Rowbotham. "Modern aircraft benefit from slightly lower paint weight. Composite material is lighter, and the designs of these aircraft use fewer rivets and fairings, as the structure comprises fewer pieces."

Frequency and cost

Operators decide how frequently aircraft are painted. Paint enhancements, such as touching up nacelles, radomes or entry doors, as and when damage is noted, will be performed on an ad-hoc basis, for example, when chips, flakes or damage are observed during flight checks.

Larger paint jobs, such as total repainting of a fuselage and wings, will be performed at longer intervals, most likely to coincide with heavy airframe maintenance events, such as base checks, to minimise time on the ground.

The cost of a paint job varies according to the scale of the repainting and the complexity of the paint scheme, which is dictated by the operator's livery. "The cost depends on the scheme of the aircraft and the paint system," says Cracknell. "For example, Airbourne Colours has recently completed a paint scheme that required 23 colours. This sort of livery is more expensive than standard commercial aircraft livery, which would normally have a base colour, such as white, and two or three supplemental colours.

Approximate costs are provided for regional, narrowbody and widebody aircraft, taking into account materials and labour. These assume a typical white base coat plus two colours for livery. According to Rowbotham, the average paint shop visit will take one week, although specialist applications will extend the downtime. A chemical strip and subsequent repaint for a widebody aircraft will cost £140,000 ($210,000). This same shop visit for a narrowbody airframe will cost £65,000 ($100,000), while for a regional jet it will cost closer to £35,000 ($53,000). The paint used will account for about 10% of these amounts, the remainder being labour.

"Depending on requirements, aircraft are normally painted every five to seven years," explains Cracknell. "This interval can change if the airline decides to alter its corporate colour scheme, due to re-branding for instance. While the fuselage is commonly stripped, most other areas are abraded. If an aircraft arrives that has only previously had abrading carried out, it is possible to achieve a small weight saving if chemical stripping is applied to remove the previous paint schemes."

"Generally, one abrade-and-repaint shop visit is enough over the lifetime of an aircraft," says Rowbotham. "If this process is repeated more than once, it can become very difficult to remove enough paint to allow a new scheme to be applied. The weight implications are also not advantageous to an operator, despite the cost of chemical strips."

Leased aircraft may undergo more irregular or more frequent paint shop visits. Lease return conditions often require the lessee (operator) to return an

Aircraft are typically repainted every 5-7 years. This may vary, depending on whether a lease-return occurs, or whether rebranding of the airline necessitates new paint schemes.

aircraft or leased fleet back to the lessor in the same state in which it was received. According to Rowbotham, lease return conditions often demand that a chemical strip, rather than abrading, is used. If the aircraft is going back to a lessor's stock, it will be returned as a 'white tail,' just painted white. Registration markings will remain the same unless otherwise advised by the lessor, but all operator branding is removed. If another lessee is lined up to take delivery of the aircraft, it is likely to remain in the paint shop to be rebranded accordingly.

More painting techniques are emerging that are intended to make the paint shop visit for new aircraft types more efficient, and reduce weight. OEMs are beginning to adopt these new technologies. One such new technology is the Base Coat Clear Coat system, which involves a newly developed base colour paint, and clear lacquer top coat. While the clear coat is designed to be more durable than its pigmented top coats, the base coat is heavily pigmented, so it can potentially provide the required paint standard in only one coat of paint, instead of multiple layers. The base coat colours can be applied at a thickness of as little as 30 microns, which is potentially half the thickness of a conventional direct gloss top coat. It is also about 20% lighter than a typical pigmented top coat. This system also suggests a much faster turnaround for paint shops, to the extent that it could be fitted in during a light base check. The drying time for the paint is a couple of hours, rather than the 12 needed by traditional heavy pigment paints. The more colours there are in a paint scheme, then the greater the time saving offered by this approach.

Care and maintenance

Regular and appropriate maintenance of paint can reduce paint shop visits for the operator. Naturally, it also enhances the aircraft's cosmetic appearance, which is essential for an airline's public image. While many of the larger carriers have in-house cleaning capabilities, smaller ones may enlist the services of a detailing company. Vertigo Aviation Detailing provides a range of paint restoration and sealant services, and interior cleaning and maintenance technical washes.

An external wash for a regional jet will use about 25 man-hours (MH), while narrowbody and widebody aircraft take 40MH and 60MH respectively.

Vertigo advises that only certain cleaning products and polishes can be used on airframes, and these vary between aircraft types depending on references listed in the aircraft maintenance manual (AMM). "We use products that comply with the relevant AMM references, for example Boeing D6-17487 Rev. N and Airbus AMS 1650B, which are the standard aircraft cleaning documents of each OEM," explains Luke Dale, managing director at Vertigo Aviation Detailing. "Some products that have non-technical objection (NTO) can also be used."

In addition to aircraft cleaning, specialist sealants offer further paint protection. This weightless addition on top of aircraft paint creates a barrier to increase protection. It has also been proven to reduce fuel burn.

"There are a range of specialist sealants available such as ceramic, polymer, fluoro-polymer, silicone, and polysiloxane resin products out there all with different properties, but that all advertise the same type of additional protection," continues Dale. "We have to assess how they are applied, maintained and removed, because the labour intensity is a factor in deciding which product to apply. Some can be wiped on with a simple two-stage process, for example, while others require hours of preparation polishing, followed by a lengthy application. If we are treating a widebody, then the latter process is arguably neither efficient nor economic." He adds that some sealants cannot have caustic cleaning agents applied, while others cannot be polished because it may remove some of the coating.

As described, the inclusion of regular cleaning to an operator's approved maintenance programme (AMP) can help aid the longevity of the paint scheme. "As aircraft deal with harsh environments, such as hail storms, desert climates, and salty atmospheres, a regular external clean helps to remove contaminants," says Dale. "These can include skydrol, acid rain and exhaust soot in day-to-day operation. Contaminants that are allowed to build up on painted surfaces can cause increased skin friction and etching damage to the paint surface. In addition, the application of dry wash products can add a barrier of UV protection to the airframe, which will again help increase the longevity between repaint."

While technical cleaning processes, such as engine washing, are gradually becoming more popular to increase engine performance, Dale explains that deep external cleans are not conducted as regularly. "The frequency with which operators conduct external cleaning programmes depends on many factors," Dale says. "Primarily these include aircraft cycles, the condition of its paint, and the operator's geographic location." For example, there is a global cargo operator, whose maintenance planners schedule regular cleaning between two of its fixed base locations on rotation. Meanwhile, others have a monthly cleaning mandate, and at the other end of the spectrum some operators perform deep internal and external cleans after every flight, while others only do this when the aircraft is in heavy maintenance. *-CLD* AC