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Aircraft Technology
Engineering & Maintenance

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ENGINEERING & MAINTENANCE

Getting on the case

Andrew Williams investigates the nacelle maintenance sector and asks how designs have changed in the new generation of aircraft entering service and what impact this might have on MRO providers.

To the casual observer, aircraft nacelles might appear to be little more than a shell that covers vital engine components. However, the reality is that commercial aircraft nacelles are increasingly complex aero structures that not only house the engine, but also provide a wide range of other essential functions — including noise reduction, de-icing and deceleration. Although they are "on condition" items, meaning that they are not subject to compulsory maintenance events, nacelles are exposed to adverse and challenging environmental conditions, high temperatures and vibration, and are vulnerable to impact damage, meaning that regular inspections and maintenance activities are essential.

So, what are some of the key techniques and processes for maintaining nacelles and their sub-assemblies? What changes in nacelle design might be brought in with the next generation of aircraft? And how might changes to nacelle design impact on maintenance activities carried out by MRO providers?

Collaboration and partnership

The nacelle design and manufacturing sector features a wide range of companies from across the world. Key OEMs include French outfit Aircelle, a member of the Safran group, and US company UTC Aerospace Systems (UTAS), which between them account for the lion's share of the market — and are both capable of designing and building complete nacelle systems for clients such as Boeing and Airbus. A number of other companies, including Spirit AeroSystems, Bombardier Aerospace, GE Middle River Aircraft Systems (GE-MRAS) and UK firm GKN Aerospace make up the rest of the global sector.

In terms of nacelle maintenance and repair, key players include Lufthansa Technik (LHT), Nordam, ST Aerospace, Werner Aero Services and Aerostructures Middle East Services, a joint venture between Aircelle and Air France Industries KLM Engineering & Maintenance (AFI KLM E&M).

There is also a high degree of cross over and cooperation, both within and between the nacelle design, manufacture and maintenance sectors — with a number of partnerships and collaborative arrangements existing between OEMs and independent MRO providers. For example, since 2008, Aircelle and GE-MRAS have worked together on a joint venture called Nexcelle. In the maintenance sphere, LHT has also entered into agreements with ST Aerospace, on the maintenance of CFM56-7B and GE90-94/-115 thrust reversers and cowlings, and GE-MRAS for work on the GEnx nacelles.

Elsewhere, Larry Montreuil, vice-president of asset management and business development at Werner Aero Services confirms that his company "collaborates closely" with independent MROs and OEMs to provide nacelle support to airlines and says that airlines are "understandably reluctant to tie up valuable cash in these expensive insurance items".

"Component pooling solutions typically exclude nacelle components, because of their high repair costs and difficulty in predicting when repairs will be needed. As an asset management company, we integrate the availability of spare components with the provision of high quality nacelle maintenance services. In doing so, we provide the airline with spares and repairs coverage for this high cost, high impact area," he says.

Aircelle produces the nacelle for the Sukhoi Super Jet. Parent company Snecma has an MRO division and training school in Montereau near Paris.

As part of its focus on ensuring that there is "sufficient skilled MRO support" for its products, Dana Stephenson, director of commercial customer support — aerostructures at UTAS reveals that the OEM has entered into a number of licensing agreements with ST Aerospace, LHT and AFI KLM E&M to help ensure "world-class support of the newest platforms, such as the 787". In his view, nacelle maintenance "has been and will continue to be" an activity that is carried out by OEMs, airlines and third-party MROs alike.

He acknowledges, however, that: "The complexity of the bonding technology and the immense size of these components compared with their predecessors will challenge the market to upgrade skills, facilities and capabilities."

Key design features

Typical nacelle systems perform many functions, perhaps the most obvious of which is to enclose the aircraft engine in an aerodynamic shell that acts as a fire containment zone and is designed to withstand lightning strikes and impact from birds and hail, for example. However, they also perform a wide range of other tasks that are vital to the smooth operation of commercial aircraft, including the reduction of engine noise to acceptable limits in the cabin.

Nacelles also duct air to the engine fan to provide the required pressure gradient, while preventing ice build-up on the nacelle's leading-edge. In the process, this transfer of air helps to create forward thrust — through the converging volume of the aft fan duct of the nacelle — and reverse thrust, via a thrust-reverser mechanism. Critically, nacelles perform all of these functions while also providing for easy engine access for inspection, maintenance and repair activities.

Mike Aten, engineering fellow, research and development at UTAS, agrees that most of today's commercial jet aircraft nacelle systems are "multi-functional", and reveals that this is because they are generally designed to satisfy three primary sets of requirements. These are customer requirements, relating to issues such as performance, quality, reliability and schedule; regulatory requirements, relating mostly to safety; and internal requirements, which Aten says normally relate to "schedule, quality, producibility and cost".

For him, it is this combined set of requirements that drives the design of the entire nacelle system — helping to make it an "integral part" of every modern commercial aircraft power plant system and enabling the engine to achieve an "optimised level of efficiency". Although each nacelle system is different, the fact that these requirements are the same for each manufacturer also means that the basic designs of nacelles do not tend to change at a fundamental level from aircraft to aircraft.

"Most of the differences in nacelle systems across the range of large passenger jets relate to their aerodynamic shape and reverse thrust stopping force, as well as the configuration of the thrust reverser mechanism and interfaces with the engine and pylon systems," says Aten.

Modern aircraft nacelle characteristics

- Larger in diameter to accommodate "high-bypass" engines.
- Increased use of electric systems as opposed to hydraulics.
- Lighter structures achieved through increased use of advanced composite materials, integrated structures and optimised designs.
- Increased acoustic attenuation.
- Minimised use of honeycomb materials on external panels for robustness.
- Increased engine temperatures are driving use of new more robust materials.
- New requirements are driving design changes, such as latch detection systems.

One common cause of nacelle repairs is the disbonding of honeycomb structures as a result of corrosion.

> **"The repair of these complex composite structures requires skills and processes that are not as prevalent in the industry as legacy sheet metal construction."**
>
> Dana Stephenson, director of commercial customer support — aerostructures at UTAS

"With few exceptions, every nacelle system is a custom-point design that is optimised to a specific set of engine and aircraft requirements and interfaces," he adds.

Harsh environment

On the current generation of aircraft, engine nacelles are complex composite bonded structures. Operating, as they are, in the harsh physical environment surrounding aircraft in flight, they are susceptible to a wide range of potential hazards, including lightning strikes and foreign object damage (FOD). According to Werner Aero Services' Montreuil, such demanding conditions mean that, in addition to FOD, nacelles experience wear and tear that is "directly proportional" to the flight hours and cycle times that the nacelles have been operated. He cites the example of one airline, which found a peak in removals of thrust reversers at approximately 18,000 to 20,000 hours, with a corresponding increase in the cost of shop visits at this level. "This prompts some operators to proactively manage their thrust reversers on a 'soft time' basis and accomplish preventative maintenance shop visits to address minor problems before they get worse," he says.

In Montreuil's view, engine nacelles, and particularly inlet and fan cowls, are also highly susceptible to damage from ground support equipment used to service the aircraft. This is largely because, in an effort to maximise their return on assets, airline schedule planners are trying to squeeze "the highest utilisation they can" from their operations. He says that the pressure to minimise turn times at the gate "increases the intensity of all of the ground handling services that have to be performed in a small area and a limited time".

"Consider all the services that create a buzz of activity around an aircraft at the gate — fuel trucks, lavatory service trucks, catering trucks, baggage carts and tractors, water trucks, cargo and belt loaders. Despite carefully choreographing of these vehicles around an aircraft, accidents happen," he says.

Corrosion is also a common cause of repairs, Montreuil confirms: "On inlet and fan cowls we see disbonding of honeycomb structures as a result of corrosion that breaks down metal and the adhesive bonds of the honeycomb structure. The resulting delamination requires attention in the shop to replace sections of structure to regain the nacelle's overall integrity and the design contours are restored to produce the intended aerodynamic properties."

A 3D CAD representation of one of UTC Aerospace Systems' nacelles.

Maintenance techniques

For Dr Christian Sauer, manager engineering and planning — airframe related component services at LHT, the variety of necessary repair tasks on a modern nacelle system is likely to depend on the condition and the reason for its removal and can range from local repairs to complete bonding repair processes in the case of delamination.

At LHT, the total repair and overhaul TAT (turnaround time) for such repairs depends on the findings of the initial inspection, as well as on the required repair and overhaul workscope, but Sauer says that nacelle repair TAT generally varies "between five and 45 days". Meanwhile, Andy Mackay, customer engagement manager at GTS MRO — where the most common repairs entail the replacement of protective coverings, boots and defective connectors on nacelle electrical harnesses — says that the average TAT is "five days for test and 18 days for repair".

In general terms, Sauer points out that the condition of the nacelle is mostly related to the operational profile of the aircraft and the relation between hours flown and cycle times, as well as the geographical location in which flight occurred — hot, humid, dusty or wet conditions. Another important factor is what Sauer calls the underlying "design philosophy" of the nacelle, in particular whether it features a translating sleeve or a pivoting door type thrust reverser.

The types of bonded structures used in nacelles are also subject to a number of issues related to ageing, UV light, moisture or water ingress, erosion and corrosion. In these cases,

As nacelles are a high-cost item Werner Aero Services offers spare parts with repair services.

the types of repair required include metal bonding — which Sauer says entails a "complex and extensive galvanic pre-treatment" of the bonding surfaces, followed by what he describes as a "strictly-controlled bonding process" — as well as composite or sandwich-structure repairs and complete re-skinnings. "The most common repairs are minor and major bonding repairs, large part re-skinnings and major parts replacements, which require OEM or LHT-designed assembly and aligning tools," he adds.

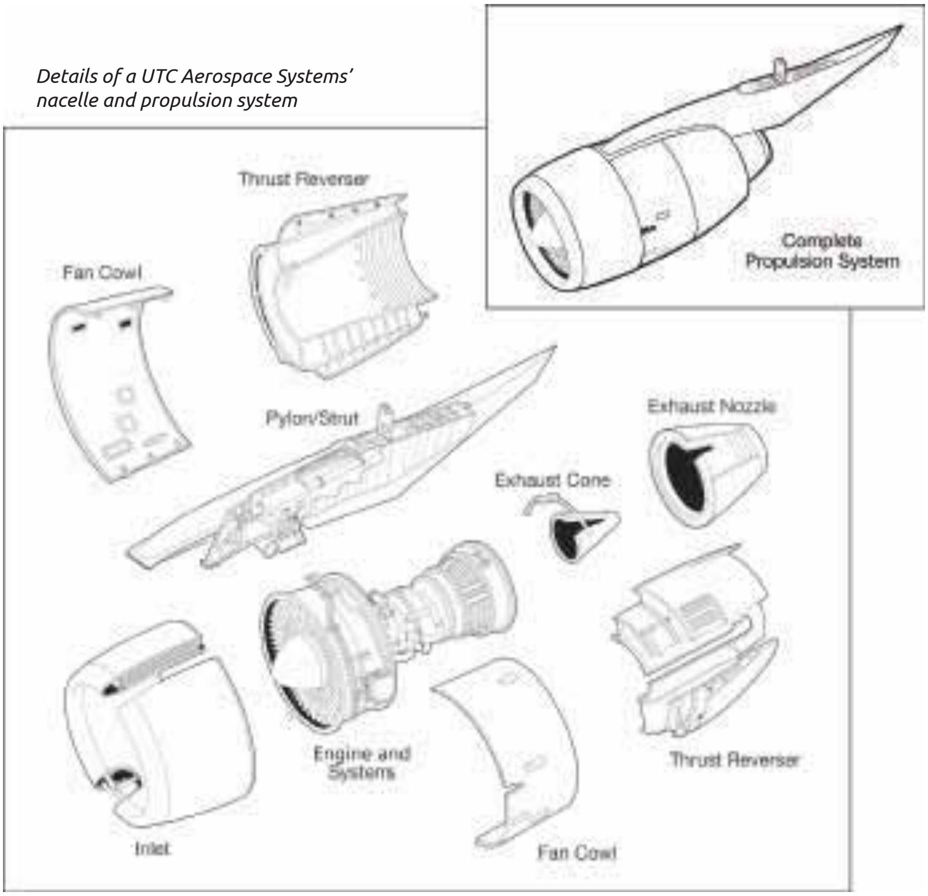
UTAS' Stephenson agrees that the sheer size of these large composite structures means that repair activities require "very large assembly and bond tools and associated autoclaves that were not necessary on legacy programmes". "Likewise, the repair of these complex composite structures requires skills and processes that are not as prevalent in the industry as legacy sheet metal construction," he says.

Modern nacelle designs

There are many differences between the nacelle systems of legacy aircraft and the latest generation of commercial jet aircraft, some of which are more visible than others. One of the obvious differences is in the use of materials: legacy aircraft nacelles are mostly made from aluminium structures, while the latest nacelle systems are largely composite structures and only include metallic materials when needed. According to Aten, this change has mostly occurred in an effort to reduce overall weight of the nacelle which reduces fuel burn helping to make modern aircraft "greener", especially when combined with noise reduction systems.

"Some of the less visibly obvious differences are in better step-and-gap control at nacelle component split lines for improved aerodynamic performance; greater use of composite skin-and-frame designs for external nacelle structures for greater robustness and ease of repairability; use of electric actuation systems for deploying the thrust reverser; and exhaust systems capable of retaining useful properties at higher engine exhaust temperatures," he adds.

Details of a UTC Aerospace Systems' nacelle and propulsion system



Technical knowledge

Looking ahead, it is likely that changes to aircraft technology — including more electric aircraft, integrated propulsion systems and O-ducts — as well as refinements to nacelle designs, will impact the extent and nature of maintenance activities on the ground. One key change that Sauer expects with next-generation nacelles is a greater focus on aerodynamic smoothness and laminar flow properties, as well an ongoing drive towards weight reduction. Moreover, he predicts that specific design changes to individual components, particularly inlet cowl lipskins and inner acoustic barrels, will lead to an "increasing level of technical knowledge and repair precision in terms of process control, tooling requirements and tolerances".

"In addition, extremely tight allowable damage limits require earlier repair actions, resulting in potential additional aircraft downtime and high costs for major parts replacements," he says.

Mackay also reveals that in recent years OEM's have become increasingly reluctant to let MROs carry out repairs on electrical harnesses, with some repairs even being removed from repair manuals. As a result, he warns that parts that would otherwise have been "easily and economically repaired" are now having to be scrapped, meaning that new assemblies must be purchased from the OEM.

"The trend with electrical harnesses seems to be that the industry is forced by the OEM's to replace and scrap a defective harnesses rather than repair them even though a repair is technically feasible. This attitude of replace rather than repair will increase the cost of ownership and the carbon footprint of the aircraft in the mid to long-term life of the airframes," he adds.

It seems that while many nacelle OEMs are actively collaborating with MRO providers on some maintenance activities, that the introduction of the next generation of aircraft is also being used as an opportunity to expand their share in the aftermarket.