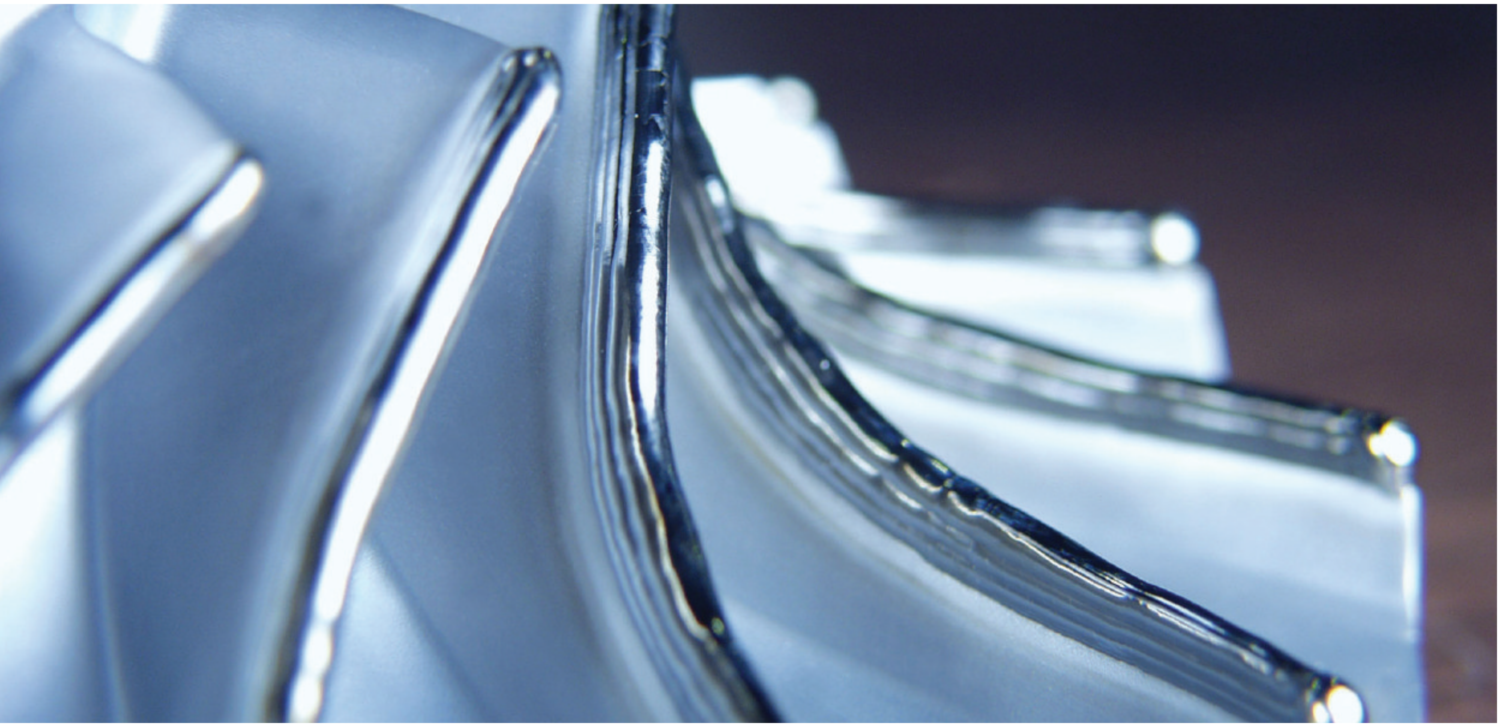


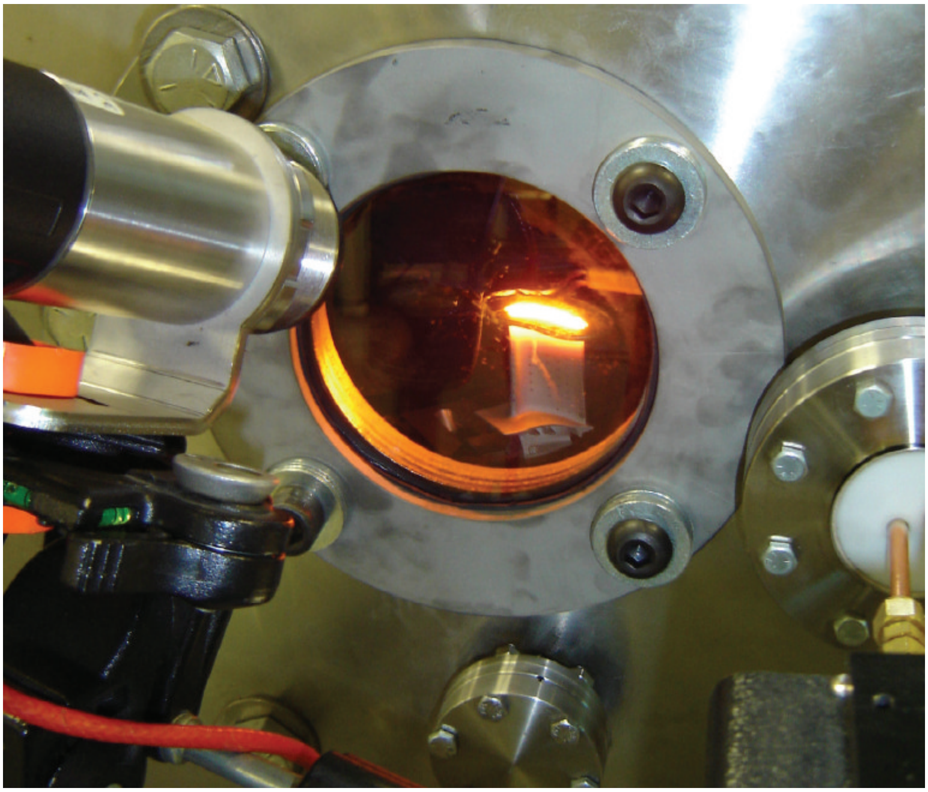
# Specialist repairs — the market, the statistics and the strategies

**Aero-engine specialist repairs provide the opportunity for airlines to save money and for independent and airline engine MROs to successfully compete with the OEMs. Moreover, they can be instrumental in extending engine life and reducing scrap rates. *Aircraft Technology* reports.**

Over the last 25 years there has been significant change in the engine MRO business. Where many airlines previously had overhaul shops, some such as British Airways switched from being service providers to totally outsourcing engine MRO work. To a large extent this followed the Southwest Airlines model, whereby work of non-strategic airline importance was outsourced.

The majority of the engine shops which remained operative effectively became 'module tear down and outsourcing shops', with a few notable exceptions. This allowed specialist companies such as ATS, Chromalloy, TSS, SIFCO, Howmet, MTU, TOS and so on, to thrive in their preferred activities of fan blade, compressor blade, stator vane, nozzle guide vane, turbine blade and air seal repair. Most airline and independent shops retained strong capabilities in applying plasma coatings, performing sheet metalwork, repairing large engine cases, life limited parts and non-core engine modules.

By the early to mid 1990s the major OEMs had all decided to become more strongly involved with their respective aftermarkets. Indeed, some started to overhaul the engines of competing OEMs. According to the OEMs this business requirement came about as a result of their need to seek supplemental income after selling their new engines at heavily discounted prices to airlines. Where GE took the acquisition route and bought-up many independent and airline engine shops, Rolls-Royce took the partnership approach and set up joint ventures such as HAESL, TAESL and SAESL. Over time, the latter approach proved to be more successful, since some airlines which had traditionally offered their overhaul services to third parties considered the new OEM competition to justify a change of direction during the engine selection process.



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This new OEM position in the aftermarket combined with various different 'cost-per-hour' programmes provided the OEMs significant MRO aftermarket share. Whilst this suited many airline CFOs, with MRO costs becoming totally predictable, it did mean that some airlines scaled down the capabilities of their technical departments. This in turn led to a loss of technical knowledge which meant stronger dependence on OEMs.

Meantime, some highly technically capable airline MROs with strong third-party businesses such as Lufthansa Technik and Delta TechOps noted the growing strength of the OEMs and decided that they needed to have more weapons in their armoury. The development of more non-OEM repairs and the growing use of PMA parts were two of the key strategic initiatives they put in place. Indeed, both Lufthansa Technik and Delta TechOps have actively encouraged the manufacture of PMA parts, the former through a shareholding in HEICO and the latter through a more recent agreement with Chromalloy.

## Repairs history

Twenty-five years ago, it was normal for OEMs to publish all standard repair schemes in engine manuals. This permitted most airlines to have free-of-charge access to the repairs required. However, as new engines came into service, OEMs introduced licenses and royalties to control who could carry out various repairs. Apart from acting as a supplemental source of income for the OEMs, it also created barriers to market entry, a requirement for outsourcing of certain repairs and gave the OEMs more control of their aftermarkets. What was more, increasing levels of sophistication in the design and manufacture of new engine components meant that non-OEM repairs were increasingly more difficult to originate and certify.

Some airlines have reacted to this situation by insisting that they have free-of-charge access to all repair schemes prior to agreeing to a new engine purchase. Moreover, airline shops such as Lufthansa Technik and Delta TechOps that retain strong technological capabilities, developed their own FAA-designated engineering representative (DER) repairs. These repairs, which are intended to be as good as or better than the OEM repairs, together with PMA parts have lead to significant opportunities for cost reduction relative to OEM offerings. Indeed, some would argue that the pendulum has swung too far in the favour of the engine OEMs and that DER repairs and PMA parts assist in redressing the balance.

The vast majority of high-tech blade and vane repairs are performed by highly automated, high-volume shops, some of which will process millions of blades in a year. Several of these shops are positioned in Asia-Pacific, where there is little union resistance to efficiency and profitability as compared with some older union-dominated shops in parts of Europe which still use manual techniques. Many of the automated repair shops are joint ventures between airline and independent MROs as well as OEMs.

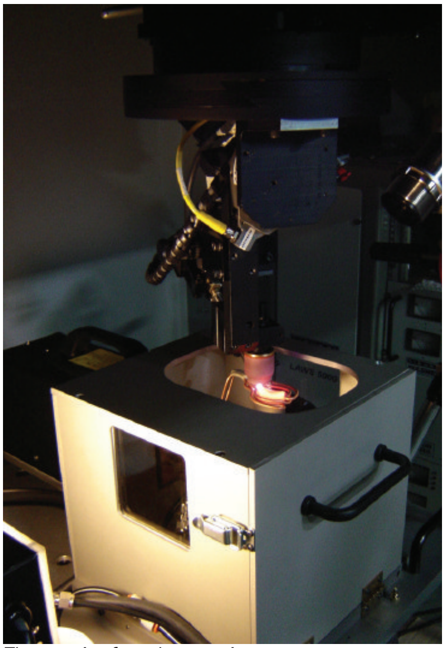
Specialist automated shops not only bring down the costs of repair, but also improve the process time and reduce the scrap rates. Considering an APU impeller which has a highly complex shape and requires between 16 and 24 hours for manual repair, only three hours might be required for automated repair. Moreover scrap rates move down from 10-15 per cent using manual methods to something more in the region of five per cent when using an automated system. This adds up to be significant when such parts cost as much as $30,000 each.

Turn around time is of great significance when it comes to parts repair since it affects the total inventory required to support a particular engine type or delays the production of an engine. Robert Tollett, director of marketing at Liburdi, reckons that good turn times for specialist repair in his market sector are 15-25 days compared with some shops which might take 60 to 90 days. These times exclude the time required for shipping and customs-clearance and this can be of importance when setting inventory levels. Of course, there is the option of accepting parts from spares pools but this usually increases costs, and some airlines will refuse to pool some or all parts in view of the possibility of diluting quality standards.

## Repair statistics

The value of the worldwide aero-engine MRO business in 2008, as estimated by AeroStrategy, was approximately $16.3bn, representing approximately 35 per cent of total MRO spend. As fleets expand and the MRO requirement increases, average total MRO costs will grow on average by 3.6 per cent over the next decade and engine MRO costs will grow by an average of 4.5 per cent. This will mean that in 10 years time engine MRO costs will represent closer to 45 per cent of total MRO spend.

As one would expect, the cost of parts accounts for the highest proportion of engine MRO costs — 60 per cent of total spend or $9.8bn. In comparison, parts repair represents approximately 25 per cent of the total annual spend or $4.1bn. The remaining 15 per cent is attributable to the labour required for disassembly, assembly and test, plus test cell running costs.



*The repair of modern engines presents greater technological challenges.*

There are differences between engine types, however, so that the ratio of spending on parts, repairs and labour will be different on older, more mature engines as compared with newer engines. In fact, older engines such as the CFM56-3 and the JT8D-200 will require more money spent on repairs (31 per cent of total spend) as compared with newer engines such as the CFM56-5B or the V2500-A5 (24 per cent of total spend). The equivalent materials costs are 57 per cent on older engines and 66 per cent on newer engines.

Modern engines have parts made from highly sophisticated materials and feature more advanced and complex designs and coatings. Whilst they have greater durability and offer higher on-wing potential, the technological challenges involved in repairing the parts is greater. Deeper knowledge is required and more significant investment in repair process development is necessary. Indeed, many repairs are licensed by OEMs which can prevent access to such repairs and/or further increase the associated costs. The alternative for independent and airline MROs is DER repairs but this requires high levels of technical expertise and significant investment.

When looking at the costs of repairing different parts of an engine, the approximate breakdowns are as follows, as a percentage of the total engine repair cost: aerofoils 45 per cent; stationary parts 20 per cent; accessories 15 per cent; rotating parts 10 per cent; seals five per cent; and combustors five per cent. Of all these repairs it is believed that only 25 per cent are authorised by DERs with the remaining 75 per cent having OEM origin.

To a large extent, outsourcing policies on such parts are affected by the nature of the repairs required. For example, repairs to compressor blades can frequently require more labour cost than material and process cost, which means that the availability of reasonably priced labour is a determining factor. In comparison, on HP turbine blades the material and process costs are much higher than the labour costs which means that the availability of high technology equipment and the relevant approvals is more important. As always, the selection of a repair specialist will come down to a number of factors with quality, turn time and cost being the most significant. Inventory management and spares logistics

would be secondary considerations.

As things stand, approximately 70 per cent of engine MRO is outsourced although AeroStrategy expects this to grow to 80 per cent over the next decade. OEMs are expected to be the largest beneficiaries of such growth as they expand their market share (inclusive of joint ventures) from the current 44 per cent to an expected 50 per cent. This will be driven by their respective full service packages: OnPoint for GE; Global Service Partners for Pratt & Whitney; and Total Care for Rolls-Royce.

## Repair strategies

Compressors: At an AIG conference in March 2008 Tollett explained that there are three primary reasons for compressor deterioration: erosion; corrosion; and foreign object damage (FOD). Erosion of compressor components is typically caused by sand, dust and water cavitation whereas corrosion is usually limited to low-altitude turboprop operations, particularly on inter-island routes.

At an engine shop visit, the primary focus when it comes to the compressor is blade chord loss and tip wear. Whilst there are variations between engine types and their operating environments, 60 per cent of blades typically require repair, and erosion is the primary cause of blades being scrapped (up to 30 per cent of blades). Erosion causes blade chord to reduce and thereby causes changes to the blade mean angle of attack, thereby reducing aerodynamic performance.

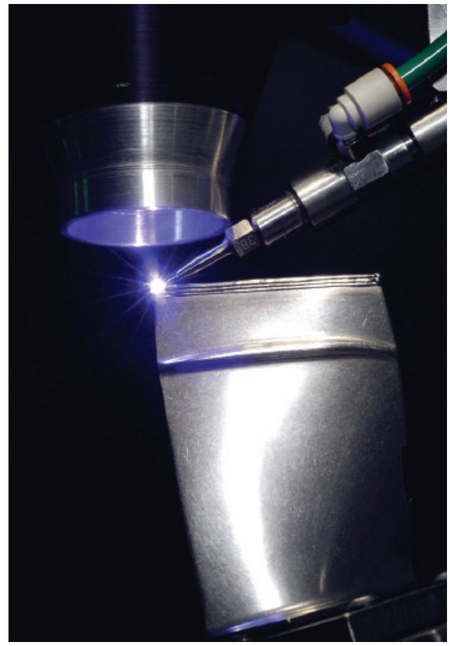
Apart from the operating environment, fundamental aircraft design can affect compressor damage, with the fan blades of the rear-mounted JT8D-219 engines of the MD-80 being susceptible to leading edge cavitation caused by water ingestion from the landing gears. In comparison, FOD has been a more significant problem on large wing-mounted engines. What is more, blade wear characteristics vary depending on whether they are close to the front or nearer the rear of the compressor section, with those at the front suffering greater leading edge erosion and those at the rear suffering more trailing edge erosion.

The frequency of compressor refurbishment will vary from airline to airline, depending upon the soft lives specified in the operator's 'engine maintenance programme'. This will also specify the repair requirements and tip clearances and these too will differ between operators depending upon their particular operational experience, business models and technical expertise.

Fans of traditional manufacture will be visually and dimensionally inspected. Depending on damage and wear they will either be blended, repaired using a weld bead on weld bead process or repaired using a suitable coupon. They will then be machined and polished, leading edges will be re-profiled and blade roots will be recoated. Low-pressure compressor blades and vanes are treated in a similar manner. Hollow titanium and composite fan blades will require specialist repair if they have suffered anything more than superficial damage.

HP compressor blades and vanes will be visually and dimensionally inspected and then blended or repaired. Repair will normally be required on blade tips, leading edges and trailing edges. Blade leading edges will normally be re-contoured and blades will frequently be coated with anti-erosion coatings, which can also designed to improve surface finish and engine efficiency.

Automatic machines will typically be used for blade welding, milling, grinding and leading edge profile restoration. Coatings will typically be applied using plasma vapour deposition (PVD) techniques to deposit a thin film of TiN material to between five and 20 microns thickness. The quality of the surface finish of



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this coating can affect engine performance by between one and two per cent.

Combustors: Where the majority of compressor blade repairs are outsourced, over 60 per cent of combustor repairs are insourced. At AIG's March 2008 conference Luc Bornard, CEO of CRMA, advised that combustors have significant effects on fuel burn, emissions, on-wing life potential and the subsequent costs of engine maintenance. Their reliability is affected by numerous factors including: the quality and repair specification of the last shop visit; environmental conditions including sand and dust pollution; and other factors such as fuel quality and water washing.

Engine types incorporate different designs and materials and have differing deterioration characteristics. However, every annular combustor will suffer deterioration of the inner and outer liners as well as the dome (or head) which incorporates the fuel swirlers at fuel spray nozzle locations. The degree of deterioration to these components and the consequent requirement for repair and replacement will vary significantly between engine types.

Within CRMA the CFM56-3 has a zero scrap rate for the dome and inner wall and only a one to two per cent scrap rate on the outer liner. Repairs are typically performed by direct or patch welding or the replacement of component parts. In comparison, the CFM56-5A/-7B has a zero scrap rate for the inner liner, a two per cent scrap rate for the dome and a 10 to 18 per cent scrap rate for the outer liner.

Each operator and MRO will specify its own requirements for post repair on-wing life potential and this will affect combustor modification, repair and parts replacement strategies. Indeed, these will often be dependent on the availability of modifications and upgrades. When undergoing repair, welding of the combustor will be accomplished both automatically and manually. The re-application of thermal barrier coatings is standard.

Turbines: Maintenance costs associated with the turbine section are significantly higher than any other part of the engine. At AIG's March 2008 conference, Bernd Kriegl director engineering commercial MRO, MTU Aero Engines, pointed out that first stage HP turbine blades account for the largest portion of these costs, followed by the second stage turbine blades, the first stage nozzle guide vanes and the second stage nozzle guide vanes.

However, there are many variables within the cost calculations and these are not all controlled by the airline operator and its engine MRO provider. Other influencing factors include lessor requirements (lease return conditions and the acceptance of DER repairs and PMA parts), regulatory requirements (airworthiness directive compliance and DER/PMA acceptance) and OEM performance (the availability of repairs and spare parts, engine upgrade options and design issues affected by modifications). Some of these influences will act in sympathy with airline and engine MRO objectives and others will not.

Airlines and their engine MROs have three primary goals: to reduce engine removals; to optimise workscopes and to reduce shop visit costs. On occasions these objectives will also not be in sympathy. For example, if one continues to extend engine life on wing then costs per flight hour will ultimately start to go up as damage done to hot end components causes scrap rates to rise.

Like many other engineering problems, it is a matter of finding a compromise solution where the workscope at a shop visit is deemed to produce an engine with good reliability and performance potential at an acceptable cost. Indeed, the ultimate objective has to be to lower the engine costs per flight hour and extend the time between shop visits. Where this is not possible, it may be preferable to remove an engine prematurely to reduce the scrap rate of turbine components.

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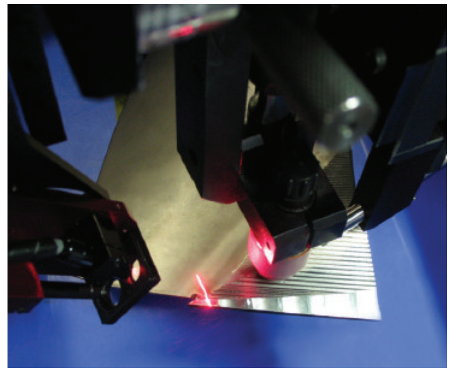

*Many engine MROs have introduced repairs which significantly reduce the scrap rate.*

The alternative solution from the engine MRO's perspective is to introduce repairs which can significantly reduce the scrap rate, or originate repairs which can substantially extend engine life, preferably both. In certain areas MTU Aero Engines has achieved both of these goals. For example, it recently originated a new DER repair for stage one and two HP turbine blades on the V2500 whereby deep multiple cracking and oxidation on blade tips is cut out and filled with laser cladding. The blade is then restored to its original shape. The MTU repair permits five such cracks to be repaired where alternative repairs only permit the removal of three cracks.

An example of a repair which MTU Aero Engines developed to extend engine life is also to be found on V2500 stage one and two HP turbine blades. Basically, it has originated a new abrasive tip coating which is more resistant to oxidation. It also has the advantage of an efficient and robust production process and a significant reduction in turn around time. The repair is achieved through the use of a high temperature vacuum induction brazing process which is computer controlled and fully automated.

MTU Aero Engines has developed numerous other repairs for other engine types and these also work on the philosophy of extending both the life potential of components and reducing the associated scrap rates.

As technology develops, more repair processes will become available. Laser peening, laser welding and waterjet coating removal techniques are relatively new to the market and have yet to be properly established as mainstream repair processes. In the short- to medium term, computer modelling of parts is likely to come about and further down the road the repair of engine components made from ceramics and composites will have to be contemplated.