Engine maintenance involves several levels of shop visit workscope. Each stage of an engine shop visit has to be carefully planned so that the entire process can be completed in the shortest time. A detailed examination of every element of a full overhaul is made.

Analysing the engine shop visit process

Every engine needs shop visits at regular intervals. Engine shop visit workscopes fall into the following broad categories: a light visit: performance restoration; hot section inspection; light overhaul; or full overhaul. Most only involve disassembly and repair work on a few modules, and only a full overhaul is likely to involve work on all modules. This article analyses the entire engine shop visit process, and examines the different stages involved in a full overhaul of each module.

The complete engine comprises several modules, with the actual number depending on design and configuration. Most commercial jet types are two-shaft engines, with a fan, combustor, low pressure compressor (LPC), high pressure compressor (HPC), high pressure turbine (HPT), and low pressure turbine (LPT). The low pressure (LP) system includes the fan, LPC and LPT that rotate on the LP shaft. The high pressure (HP) system includes the HPC and HPT that rotate on the HP shaft. The LP shaft runs through the HP shaft. The LP shaft is supported by the number 1 and number 4 bearings, while the HP shaft is supported by the number 2 and number 3 bearings.

They will also have a quick engine change (QEC) kit and electrics, various accessories and line replaceable units (LRUs), external gearbox, and mounts for mounting the aircraft structure. The external gearbox is connected to the internal gearbox, usually located within the LPC, via transmission shafts.

The Rolls-Royce RB211 and Trent family engines are three-shaft designs, and therefore contain more modules than a two-shaft engine. The modules include the fan, intermediate pressure compressor (IPC), HPC, combustor, HPT and LPT.

Engine workscopes

Engines are removed for several reasons, including expiry of life limited parts (LLPs), loss of performance and exhaust gas temperature (EGT) margin, oil leaks, vibration or foreign object damage (FOD). The engine's deteriorating performance will have different symptoms depending on the reason, thereby determining the depth of disassembly and workscope needed. "For example, high EGT means that HPC and HPT section blades and vanes need refurbishing," explains Serkan Ertekin, engine workshop director at MyTechnic. LLP expiry in a particular module will require its full disassembly. Modules can sometimes require partial or light workscopes, but those that have to be fully disassembled to piece-part level require a full workscope and an inspection and repair of all parts.

Engine maintenance is performed on an on-condition basis, except for LLP expiry. This means that each module will be visually inspected and have borescope inspections when the engine enters the shop. This is considered together with factors like the engine's EGT margin, its time on-wing since its last shop visit, and the previous shop visit workscope. Some modules may not have any work performed, while others are disassembled and repaired. The decision to work on a module and on an individual part or component is partially determined by guidelines in the engine shop visit manual. After disassembly parts and components may need no work on them, or may be repaired or replaced.

Workscopes that include all modules have the longest time in the shop. A full shop visit can generally take up to 60 days according to Jan Steenbock, vice president of customer service at MTU Maintenance.

Incoming Inspection

The shop visit process starts with the incoming inspection. "We call this first part of the shop visit the induction process," says Frank Walschot, head of engine maintenance engine services at SR Technics. "The engine arrives with its documentation sent separately. We perform a pre-induction inspection that includes visually inspecting the external accessories and LRUs, checking for missing items, photographing the engine, and checking the modification status of the LRUs.

"We have a computerised tracking system provided by SAP for the engines we manage," continues Walschot. "This monitors engine utilisation, LLP life, the serial and part numbers of the engine's components, the status of airworthiness directives (ADs) and service bulletins (SBs) performed, and the workscopes of each shop visit the engine has had. This provides a complete database of the engine's history. This includes a complete configuration of the engine, so it tells us when parts were installed or how many times they have been repaired, and how many engine flight hours (EFH) and engine flight cycles (EFC) they have accumulated. All this information helps our engineering group determine the likely workscope that will be required."

When an engine arrives at the shop the physical condition of its interior will also have to be assessed prior to disassembly. "We therefore do borescope inspections on the HPC, HPT, combustor and LPT. We also do an oil chip detection in the gearbox and at specific filters. This information is compared to what we already have," says Walschot.

All this information is collated and forms the basis for the initial shop visit workscope definition. This workscope is then put forward to the customer. "The workscope can usually be pre-defined once we have the removal cause and the EFH and EFC time since the last shop visit," says Walschot. "It is not possible to have a definite idea of the critical paths or the largest repair processes of the shop visit until the workscope is defined."

The first few stages of engine disassembly include removal of fan blades and separation of the fan module and LPC.

Once everything is agreed, the pre-defined workscope is finalised and the engine is fully inducted into its shop visit. This pre-induction and workscope defining process can take 2-14 days. The longer length of time will be required if the customer does not agree with the initial workscope proposal, and it has to be reassessed one or more times.

Engine disassembly

When the engine is actually on the shop floor it starts its shop visit and a set series of processes. The first process in this system is to disassemble the engine into its modules. The modules themselves can and will be broken down into their smallest parts if a full workscope on the module is required.

"The initial disassembly of a CFM56-5C can take up to four days," says Walschot, "and involves clearly pre-determined sequences. The first is to remove the front and rear mounts. The fan spinner and fan blades are then removed, and can be sent to the inspection and repair area. The LPT is then removed, after which the rest of the fan module and LPC are disassembled and the number 1 and number 2 bearing supports are taken out." This is echoed by Steenbock who says that MTU Maintenance sets aside three to four days for disassembling the engine.

"The core engine is then split into its modules in the module shop," continues Walschot. "During the disassembly process, the QEC and electrical components are disassembled, and accessories, harnesses and tubes are sent to various repair shops. This whole induction and disassembly process takes us eight shifts, which is four days. Modules can then be worked on in parallel. Many LRUs and accessories may remain on the fan case. This leaves the gantry free for the next inducted engine."

Each module is then disassembled in the relevant module repair shop or area. "Most modules take less than one shift to be disassembled," says Walschot. "The core module usually requires two shifts and the LPT three, because its complex construction and number of stages make it delicate, and removing all the blades and vanes takes a lot of time."

Some engine shops only disassemble the engine into modules, and then sub-contract the repair of the module and components to shops with more specialist capabilities. One example is PAS Technologies. "We overhaul complete modules, and also carry out specialised parts repairs," says Dan Fayer, vice president of quality process engineering and lean, at PSA Technologies. The company has capabilities for the JT8D, JT9D, PW2000, PW4000, CF6 family, CFM56-3/-5/-7, and some Rolls-Royce RB211 and Trent family members.

"Most turbomachinery or gas path parts have protective coatings to protect them from the high temperatures and pressures in the engine, so they are first sent for cleaning," continues Walschot. "Some tubes, brackets, and nuts and bolts are also sent for cleaning. This involves chemical cleaning in many cases, or plastic or water blasting."

If the engine shop does not have the capability to repair a part, it is packed and sent to a specialist provider to be cleaned, inspected and repaired if required. All parts are therefore cleaned first and inspected.

SR Technics, for example, does not have repair capability for LPT airfoils, so these are sent to SR Technics' sister facility in Cork, Ireland. Repaired parts are sent back to SR Technics and placed in a holding area until the module is reassembled.

Parts inspection

Once the module parts and components have been cleaned, they are inspected, with the method used depending on the material and the manual instructions. These inspections are mainly to detect cracks, erosion and other physical damage.

Non-destructive tests (NDT) are used on most parts. This can involve a fluorescent penetrant inspection (FPI) for non-ferrous parts, which uses ultraviolet (UV) or infrared light to reveal any cracks after the part has been dipped in a fluorescent liquid. Magnetic resonance NDT tests are used for ferrous parts.

Dimensional checks are carried out on blades, vanes, seals and cases after NDT inspection. These involve taking precise measurements of each part's dimensions and contours to assess if it is within manual limits that allow repairs, or if the part has to be scrapped. "There are three basic possibilities for a part," says Ertekin. "The first is that the part has no cracks or physical damage and is within dimensional limits and so does not require any work. The second possibility is that the part has some damage and/or its dimensions differ from specification, but it is within manual repair limits and so can be repaired. The third is that the physical damage and the part's dimensions are out of manual limits, so it has to be scrapped and replaced."

Examples of parts beyond repair limits include a rotating seal that has worn away, or a blade tip or leading edge that has deteriorated.

SR Technics estimates that within 15 days of the engine's induction, all parts will be cleaned, inspected and ready for repair.

When a part is sent to its relevant repair shop, again a set of pre-defined steps is followed to ensure that the part is effectively repaired and the quality is suitable for all concerned. At every stage of a part's repair, further inspections will be undertaken and, if at any point a part fails, it will go to the beginning of the process again until it is within engine manual limits.

"If the item is close to repair and damage limits, then the shop will need to

The HPC module is comprised of stators and rotors. Variable stator vane controls are some of the more complex stator parts, and require extensive repairs.

gain special permission from the original equipment manufacturer (OEM) to do the repair," says Steenbock. "A reference number has to be issued every time that permission is granted for a part that is borderline, which can be time consuming.

"The repair of a specific part is pre-defined in the engine shop visit manual, and our SAP system has documents to perform these repairs," says Walschot. An inspector determines what repairs are required and looks at a menu of repairs in the SAP system. For example, a weld repair on an HPT blade tip is complex since it can involve about 60 steps. It takes 25-28 days, excluding transport time, to repair and is a limiting factor for the shop visit process time. Some parts are not repairable within the total turn time of 60 days for a full shop visit, so these parts have to be exchanged.

There are several specialist repair providers. Airfoil Technologies offers fan blade and HPC blade and vane repairs for the RB211 and Trent families, CF6 and CF34 families, and V2500.

PAS Technologies provides repairs for blades and vanes in the fan, LPC, LPT, HPC and HPT modules of the engines listed. It also repairs rotating airseals in the HPC and HPT. These repairs include capabilities for plasma spray coatings, chrome plating, tungsten inert gas (TIG) welding, electron beam welding, and electrical discharge machining.

Fan & LPC module

The fan module is disassembled into piece parts. "The main components in the fan module are the spinner, fan blades, fan disk and the fan case," explains Steenbock. "Disassembly starts with removing the spinner, annulus fillers between the fan blades, fan blades and the retaining plate. This leaves the fan disk, LPC and fan case.

"All the parts are then cleaned simultaneously before inspection. The coatings will also need to be stripped off the blades and damper pads," continues Steenbock. "The root area of fan blades and coating layers has to be inspected, and can be removed with blasting if necessary. The blades then have a chemical clean and a detailed visual inspection. Dimensions of the blades are checked, particularly the length and the chord. The tips may need repairing and grinding. The FPI and ultrasonic NDT inspections follow. The engine shop manual gives damage and repair limits for each part."

Damage on the surface can be repaired with blending techniques, and shot peening is applied to create a compressive layer on the surface to increase resistance to cracking.

Ultrasonic testing is used for hollow blades used on engines such as the V2500. Blending is not always an easy option for hollow blades, as some blades are made from composite materials, which makes them life-limited.

Airfoil Technologies is a specialist parts repair provider for fan and HPC blades. It repairs fan blades for the major Rolls-Royce engines, the CF6, CF34, CFM56-3 and V2500. "Fan blade repair takes about 21 days," says Pete Wride, regional sales manager at Airfoil Technologies. "Most fan blade repairs are light blending for dents and 'nicks'. Severe damage can be cut out on solid blades, when within manual limits, and replaced by a patch of solid material which is electro-beam welded, and then machined back to manual dimensions. The last item is replacing root pressure face coatings. Few repairs can be done to hollow and composite fan blades except for leading edge strip."

Once the blades are repaired, they are cleaned again and polished. Lubricants are applied on dovetails and damper pads reinstalled. Then there is the final inspection and certification.

The remainder of the fan module mainly consists of the fan disk and shaft, and stators. "The stators are the case, struts and airflow areas. These have a detailed visual inspection for damage and deterioration. The integrity of nuts and bolts is also checked. Only major problems with the fan case require a disassembly," says Ertekin.

The shop will inspect inside the fan case to ensure that the acoustic liners and anti-ice panels are intact, and clean and repair the inside surfaces. The fan case, comprising the fan frame, the driveshaft to the gearbox and bearing, and the plumbing, can be fully disassembled. "The remaining rotor parts are: the fan disk, LPC rotor drum, the internal gearboxes; and the bearings," says Steenbock.

NDT inspections are then done on the fan disk. The dovetail slots on the fan disk have a similar coating to the fan blade roots, and this coating has to be inspected and removed. The bore area where the shaft goes through also has to be checked for cracks and distress that could have been caused by the centrifugal force. The bolt holes where the disks are connected are another critical area.

The major parts of the LPC are: the booster drum, which is usually 3-5 stages; blades; vanes; and the casing. The inner wall of the case has rub strips which form a seal against the LPC blade tips.

"Disks in the LPC have platings in dovetail areas. These platings have to be removed. There is an NDT inspection, after which molycote is applied and the disks are balanced prior to reassembly," says Ertekin.

The LPC blades are first cleaned and have coatings removed. They are then visually examined, to see if they have reached the limit of erosion, and have NDT inspections. "They are scrapped if outside limits, but tip welding can be used to extend their length, while blending and contouring will soften any nicks or dents. Tip welding is limited for leading and trailing edges, since material

The HPC case consists of two halves. The rotor and stator can be ground simultaneously during reassembly to get the best blade and vane clearances.

is thinner here. Once blades are repaired their coating is reapplied before being inserted in the disks and drum," says Steenbock. "The LPC and blades are then ground down to the correct dimensions with a laser that measures the blade length to within a thousandth of a millimetre. First they grind the rotor blades and then the stator blades on the same machine, which completes the job with balancing in mind."

The casing is then reassembled and the module stored for engine reassembly.

HPC

The HPC is worked on during performance restorations and full overhauls. "The HPC is inspected as a whole, and then removed either horizontally or vertically," says Stephan Drewes, vice president of engine service at Lufthansa Technik. "This is disassembled into rotor and stator parts. The stator parts are the outside case, fixed or variable stator vanes (VSVs), seals on the inner case, and mechanisms on the outside of the case for moving the VSVs. The rotor parts are the shaft, disks and blades".

Many engines have disks joined as drums. The rotor is the drum and disks, the abradable knife-edge seals between disks, and the blades. The stator consists of two halves of the case which are removed from either side of the rotor. Once removed, the first visual inspection on the vanes can be done.

"The blades and vanes are first cleaned. There are 16 different baths that can be used, and each chemical is used to remove a specific type of coating if one is present," says Drewes.

The HPC blades will be assessed to see if they have reached the limit of erosion. They are scrapped if they are outside the limits. Tip welding or laser material build-up can be used to extend the length of HPC blades, while blending and contouring will soften any nicks and dents. One blade has to be recontoured at a time. "The bulk of the HPC blade repair process is dimensional checks, but virtually all HPC blades require tip welding to restore their length," says Wride. "If the blade chordal width is low, the leading and trailing edges can be welded in all cases and machined back to blueprint dimensions. This is a manual or automated process, depending on the volumes involved. This all has to be done within the contracted turnaround time, so a maximum of 17 days can be allowed for the repair of blades." The final step in an HPC blade repair is a Sweco clean.

Blades are then inspected again, which may lead to another repair. Once parts have passed inspections, coatings are re-applied or the parts receive oven treatment, before being inspected again.

"Vanes go through a similar repair process to blades," says Wride. "The removal of coatings and dimensional checks is critical. Vanes demand heavy welding to restore blueprint dimensions. This is normally done manually due to the complexity of shape and form."

"The last part is for every blade to be weighed and a set is made up for each disk," says Drewes. "Weighing is important for balancing and forming a complete set. The dimensions of blades within a set are different, and it is important that all the blades make up a tight-fitting set on each disc."

The large parts of the casings are repaired in parallel to the blades and vanes. "The parts are cleaned and then inspected using X-ray or FPI, depending on the part," continues Drewes. "Cases are X-rayed. Depending on the findings, it will be serviceable, be sent for repair, or be scrapped."

"Parts are then recontoured, inspected and recoated. This can involve replating, such as chrome being reapplied in some cases. Few parts in the HPC casing require replating," continues Drewes.

HPCs on most modern engines have variable stator vanes, so cases, flanges, lever arms and bushings have to be inspected for cracking and wear. Bushing holes can be re-drilled.

While vanes are being repaired, the VSV assemblies are dismantled after the stator casings are opened. Pads and bushings are replaced, while the lever arms are cleaned. Wear on the lever arms can be built up with HPOF thermal spray, and then ground back to original dimensions. The parts are then reassembled when the vanes and casings have been repaired and the stator parts are ready for reassembly.

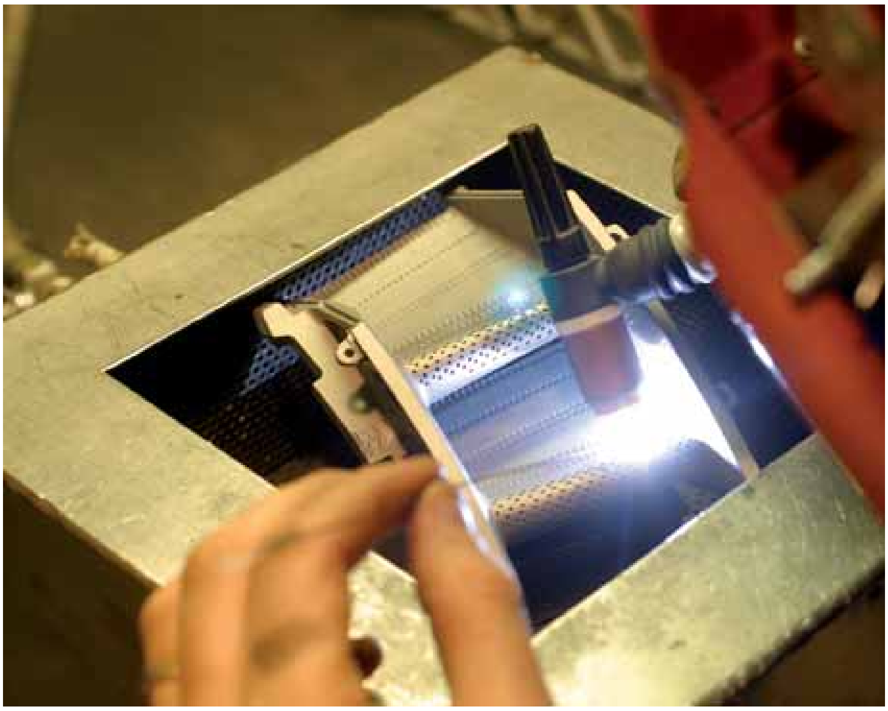
"Reassembly of the HPC follows a final inspection," continues Drewes. "In parallel to repairs and inspections there is the supply of replaced parts. The rotor and stator components are reassembled at the same time. The vanes are fitted to the inside of the cases, and the blades to the disks." The rotor and stator blades are balanced and lengths adjusted by high-speed grinding. Lufthansa Technik is one of the few facilities that has the machine to grind the rotor and stator at high speed to get the best clearances on blade and vane tips thus providing best engine performance."

"If reassembly is done incorrectly it has to be done all over again, requiring engine disassembly" says Ertekin. "Dimensional measurements and balancing are therefore critical." The completed HPC is sent to storage to await the full engine assembly.

Combustor

Located in the central part of the core engine, the combustor is often one of the last items to be removed and one of the first to be fitted back in the engine during reassembly, so it is one of the most time-critical parts to repair.

There are two main types of combustor in engines. Older generation types have multiple tubo-annular combustion chambers. Each chamber



One of the most complex repair processes in engine maintenance is the laser drilling of cooling holes in nozzle guide vanes, HPT blades and LPT blades. The number of providers of this specialist technique is relatively small.

tube has its own flame. Newer engine types have continuous annular combustion chambers, which have a single flame tube. The chamber is completely open at the front to the HPC nozzle guide vanes (NGVs) and at the rear to the turbine NGVs.

"The main components of the combustion chambers are the compressor rear frame, which has the fuel nozzles outside, and the combustion liner," says Ertekin. "The first step is to take out the combustion liner, remove the fuel nozzles and inspect the compressor rear frame.

"The compressor rear frame undergoes visual and NDT inspections," continues Ertekin. "The fuel nozzles are taken out and have a bench test. The combustion liners have a chemical clean, and then a detailed visual inspection. At this point there are findings, since the combustion liners experience the highest temperatures in the engine. These findings lead to specialist repairs being needed. The coating is first stripped, and then weld repairs are made, followed by braze repairs. These repairs often change the shape and cause some stress to the liners, so they are heat-treated to bring them back to their original shape. The liners are then re-contoured.

"Combustion liners may need detailed repairs, so they are separated into three parts: the inner liner, outer liner and dome section. Continuous annular combustors of modern engines do not have dome sections," continues Ertekin. "There are also mounting pins and holes that install the combustion chambers on the compressor rear frame. The bushing holes for the mounting pins are also re-drilled and bushings put back in. There is also often wear to the swirler cups, the area where the fuel and air is mixed. All the repairs to the combustion liners take about one week, and then parts are ready for reassembly. Combustion liners are usually exchanged, rather than the original repaired parts being reinstalled on the same engine."

HPT

Like the HPC, the HPT can be divided into large and small parts. "Examples of large parts are the disks, shaft and cases, while the airfoils are small but high-cost parts. These are the nozzle guide vanes (NGVs) which are the stators and the rotating HPT blades. The HPT shrouds which seal the clearance between the blade tips and inner wall of the case are also a major contributor to the material cost," says Matthias Malina, vice president of engine parts and accessory repair at Lufthansa Technik. HPT modules either have one or two HPT stages, depending on the engine type, with a corresponding number of sets of NGVs, HPT blades and shrouds."

Some Rolls-Royce engines have shrouds at the top of the HPT blades, and these join together to effectively form a ring. The top of these shrouds rub against a seal on the inner wall of the case.

During overhaul the parts are disassembled from the module. Due to the cost of the HPT airfoils the shop will always try to repair them if possible. "The first HPT stage on a CF6-80C2 engine has 80 blades, and these have a list price of $8,000 each so the shipset will be about $600,000. Also, a set of HPT shrouds has a list price of $100,000 per stage," explains Malina. "Multiply these figures by two stages and it becomes clear why it is important to repair parts instead of replacing them with new ones."

Repairs to the HPT blade and NGV are complex, as some of these parts have cooling holes, which lengthen the repair process. As with all other blades and vanes, they are first cleaned and their coatings are removed in various chemical baths. They are then visually inspected and their dimensions are checked to determine if they need to be repaired. Many shops will then have to send the blades for repair, since their complexity means that few shops have all the capabilities required to repair them.

"We often send HPT blades to specialist shops in Asia or the US to be repaired. HPT blades can have 60 steps to their repair process and take up to 28 days. Since it can take up to 10 days just to transport parts, it is essential that they are sent as soon as possible, so that they can be inspected, repaired and returned in time for the reassembly of the engine within the 60-day turnaround time," explains Walschot.

Some engine shops have a rotable exchange pool available to speed up the process, but there is a charge for this. Walschot adds that many of SR Technics' customers in fact prefer to have their own blades reinstalled into the module so that their history is known. Efficient repair is therefore the only answer in many cases.

"If cracks are found on the blade platforms at inspection, they may have to be scrapped with certain models," adds Walschot.

After cleaning and stripping, blades are checked for dimensions and cracks. These checks usually involve NDT inspections such as FPI and X-ray. "An airflow measurement test performed at the end of the repair process makes sure that the cooling holes provide a sufficient airflow to protect the airflow surface from the heat of the hot gas flow, while avoiding a loss of engine efficiency due to excessive cooling air," says Malina.

The main repair for HPT blades is tip weld repairs to restore tip length, but this is only for blades without shrouds. Other damage results in blades being scrapped. After this a thermal barrier coating has to be applied by plasma spray. Once this stage is completed the cooling holes have to be re-drilled, usually automatically by a robotic laser (the holes are small in diameter and several hundred or thousand are present on each blade). Blades that have had minor repairs have cooling holes re-drilled manually.

"As seals, shrouds on the inner case

Reassembly of the LPT module is completed one stage at a time. Replacement honeycomb seals have a tight clearance with blade shrouds, so the LPT is rotated while closing the case.

wall need to have their rub strip replaced. The new rub coat is typically attached to the backing strip by a brazing process in a high-temperature vacuum furnace. Alternative repairs with plasma spray help to extend the life of certain highly stressed shroud types," says Malina.

HPT blades typically wear out where they rub against the shrouds during engine operation. Consequently the repair concentrates on welding and contouring the tip of the blade. NGVs are made of similar materials to HPT blades and also have cooling holes. The NGVs do not rotate. Between an inner and an outer platform is the airfoil, often enough in a cluster configuration of two airfoils in one part. They do not have tips that need to be rewelded. "NGVs are first cleaned and stripped with a DFIC bath," says Malina. "They are then inspected and have dimensional checks. Small cracks can be repaired by using a brazing paste, and then being treated in a vacuum furnace. In case of more severe damage the airfoil of the NGV can be replaced. An FPI NDT follows to ensure cracks are repaired. Cooling holes are then re-drilled, and then coatings are re-applied. Blades and NGVs are then reinstalled in disks ready for grinding and module reassembly."

The discs, shaft and case are all dealt with in similar ways. Once they have been cleaned and had coatings removed, they are given an FPI NDT inspection. The inner case surfaces are examined to see if they have worn out and need re-building using plasma. "The dimensions are checked and measured, and tests are made for tears and to see if the shaft is bent," says Malina. "X-ray, eddy current and FPI tests are also carried out on these large parts to check for cracks and damage. Plasma spray is used to re-build parts and bushing holes are re-drilled. Sections of damaged cases can be replaced in some circumstances. A new case has a list price of $300,000-400,000. Blend and weld repairs can also be used.

"The parts are then inspected again and have new coatings applied. Some parts need treatment with galvanic processes, like nickel plating. It goes without saying that again no part is certified as serviceable without detailed dimensional checks," continues Malina.

Once all parts have been repaired, the module can be reassembled and the blade tips ground to the right dimensions.

LPT

The LPT is a delicate module, and has to be disassembled carefully. "Each stage of rotors and stators has to be disassembled separately and one at a time. This requires a special fixture for disassembling the module vertically," explains Ertekin. "Blades and vanes are then removed from each stage. After they have been chemically cleaned, there is a detailed visual inspection and dimension check. LPT blades are shrouded, and clearances between blade tips and honeycomb seals on the inner case wall are important to maintain EGT margin.

"Good blades and vanes are Sweco cleaned to polish them. The most important repairs are to the clearances, and the honeycomb seals have to be replaced to maintain these clearances," continues Ertekin. "Repairs are not often required on LPT airfoils, although some blending repairs are used. Cracked blades and vanes have to be replaced. A Sweco clean is used before reassembly."

The turbine rear frame may also be repaired after a visual inspection. Cracks require weld repairs, followed by heat treatment and a dimensional inspection.

"Once all parts have been repaired, the module has to be reassembled starting with the turbine rear frame," says Ertekin. "Each stage is then added one at a time. The critical issue is that the replacement honeycomb seals have a very tight clearance with the blade shrouds, so the LPT has to be rotated while closing the case so that shrouds and seals wear down to get a perfect fit."

Reassembly & test

Once all the piece parts have been inspected, repaired and certified, the modules are re-assembled.

"The re-build of modules typically starts five to six days before the engine is re-assembled," says Walschot. "The HPC module is usually the first to be built, since it requires machining of the compressor blades for tip clearance to matching the seals on the inner case. Several modules or sub-assemblies need to be dynamically balanced, before the engine is rebuilt."

It generally takes SR Technics about four working days to complete the assembly of all the modules, in parallel, with the HPC taking the longest because of the grinding process.

The completed engine will then need to have all its documents updated and checked. "This includes notification of work completed and the status of the SBs and ADs, which is legally required to declare the engine serviceable again," says Walschot.

"External piping is checked for leaking," adds Ertekin "and the engine is tested on-wing or in a test cell for performance, vibration, acceleration and fuel-oil leaks." The test cell run of the engine is completed to ensure that it is running to its optimum. This is then followed by a basic or video borescope inspection.

Walschot says that the rebuild process, from the start of the module reassembly to the completion of the final testing and paperwork, generally takes about 15 days. The engine is now ready to be shipped to the customer. AC

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