Landing gear is one of the simplest aircraft components. Its maintenance process is also simple and good management will lead to economic costs per flight hour. Airlines should be aware of what affects the economics of landing gear maintenance.

The economics of landing gear maintenance

Maintenance for an entire aircraft can broadly be divided into the three categories of airframe, engine and components. The category of components can be then sub-divided into smaller constituents. These include heavy components maintained on a programme independent of airframe checks. One of these components is landing gear. The process, costs and economics of maintaining landing gear for all major jet types is analysed here.

Landing gear component

Landing gear is often viewed as being the leg assemblies for mounting wheel and brake units and the hydraulic system for raising and lowering them into the aircraft. In fact, the entire landing gear system comes under air transport association (ATA) chapter 32. “ATA chapter 32 includes everything that is required to activate the whole of the landing gear system,” explains Richard Fortner, president and general manager at AAR Landing Gear Services (LGS). “This includes the actual legs, steering mechanisms, wheel brake actuators and anti-skid system, landing lights, hydraulic and electric harnesses, retraction mechanism and the wiring and relevant controls on the flightdeck. Modern aircraft types also have tyre pressure indicating systems, and this is part of ATA Chapter 32”.

These components can be broken down into three broad categories of the airframe structures, accessories and electrical systems. “The airframe structures include the legs and they are highly critical to the safety of the aircraft, but they also very safe because of their strength and structural integrity. Accessories are the items of landing lights, steering, braking and hydraulic actuating which are condition-monitored. Electrical components are wiring and sensors.

Landing gear system design is controlled by the airframe manufacturers, but sub-contracted to specialist landing gear manufacturers. Messier Dowty performs the Airbus landing gear design; BFGoodrich is a sub-vendor to Boeing. These specialist manufacturers also have repair and overhaul capability for landing gear. There are also airline and other independent landing gear shops.

Overhaul process

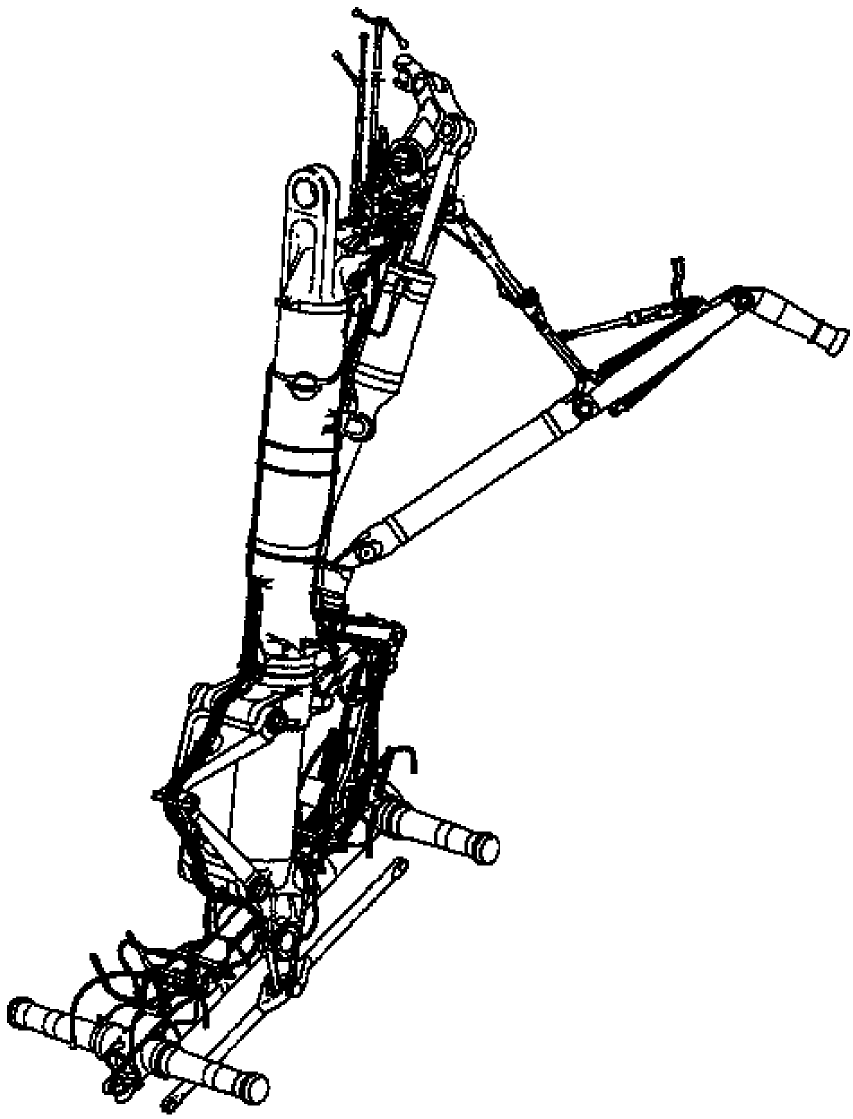
Landing gear repair intervals for most aircraft types are calendar and flight cycle (FC) limited. Limits and intervals used by airlines for most jet types are eight to 10 years.

“Many aircraft types are permitted eight year intervals by aviation authorities, but then have these extended to 10,” explains Benoit Gosset, senior vice-president and chief operating officer at Messier Services. “Airlines can also get their interval extended. Removal interval is also affected by the practical considerations of fleet delivery profile and aircraft age”.

Flight hours (FH) accumulated since last overhaul or since new is not an interval determinant. The number of FH between removals can therefore vary for a fixed calendar period. FC and calendar removal intervals are determined by the need to avoid excessive wear, cracks and corrosion. The corrosion prevention and control programme (CPCP) generally puts the maximum interval, or time between overhaul (TBO) at 10 years, irrespective of FCs accumulated.

Landing gear shops find that while airlines may prefer a removal interval of 10 years in an attempt to minimise cost per FH or FC, a higher level of corrosion and rate of component scrap and replacement is experienced than if a removal interval of eight years is used. Corrosion increases exponentially from eight years. “At eight years the amount of scrapped parts might only have a value of $3,000 per leg,” says Fortner. “This can increase to a level of about $45,000 if removed at 10 years”. This usually means it is more economic, in terms of cost per FH or FC, to use an interval of eight years.

Although intervals are independent of all other aircraft maintenance activities, removals are scheduled to coincide with airframe checks. This is because of the downtime and manpower required to remove an expired gear and install a replacement set.



Configuration sheets provide a guide to what constitutes an entire landing gear. Missing parts have to be replaced, increasing overhaul costs.

Many airlines that operated their own landing gear shops and kept inventories of spare gear sets have divested their facilities. They now have gears maintained and spare sets supplied by third-party contracts. This simplifies organisation of maintenance and avoids the need to carry spare landing gear sets.

Overhaul process

"Landing gear is the one aircraft component that performs just as well after overhaul as it did when new," says Fortner. "Overhaul is based around ensuring structural integrity and operational reliability. The process therefore starts with complete disassembly to bare metal and piece parts".

One initial step is to check the inventory of parts supplied. Some airlines may not send the entire landing gear assembly, leaving some hydraulic control lines or wiring assemblies. Checks can be made against configuration sheets.

"The main part of landing gear maintenance is the removal and replacement of bushings. Bushings are some of the most important components and they are subject to corrosion and wear. Bushings are removed and all parts have paint and cadmium finishings stripped", says Fortner.

All individual parts are then inspected and listed. The incoming inspection of all parts reports their condition. It identifies components that have to be replaced, measures dimensions of all parts, lists those which are outside dimensional limits, and performed and outstanding service bulletins (SBs) on each part. It also checks for corrosion.

Initial inspection determines the work required on each part and the whole landing gear set. "The overhaul process and workscope is computerised by AAR, and this is based on the incoming inspection report, which determines what is required to bring each part back into compliance," says Fortner. "This could be just re-plating and painting of parts, or re-work to get back within dimensional limits. This will involve special repairs and will lengthen the workscope. Major components are, however, rarely worn beyond reworkable limits".

Parts that have been subject to structural stress have to go through non-destructive testing (NDT). This uses magnetic particle inspections to detect cracks. The same parts are then de-stressed, either by an oven baking or shot peening. "High-strength components in many landing gears are made with 300M carbon steel. This is strong, but subject to corrosion. Boeing has recently used titanium, which does not rust, but has the same strength qualities," explains Fortner.

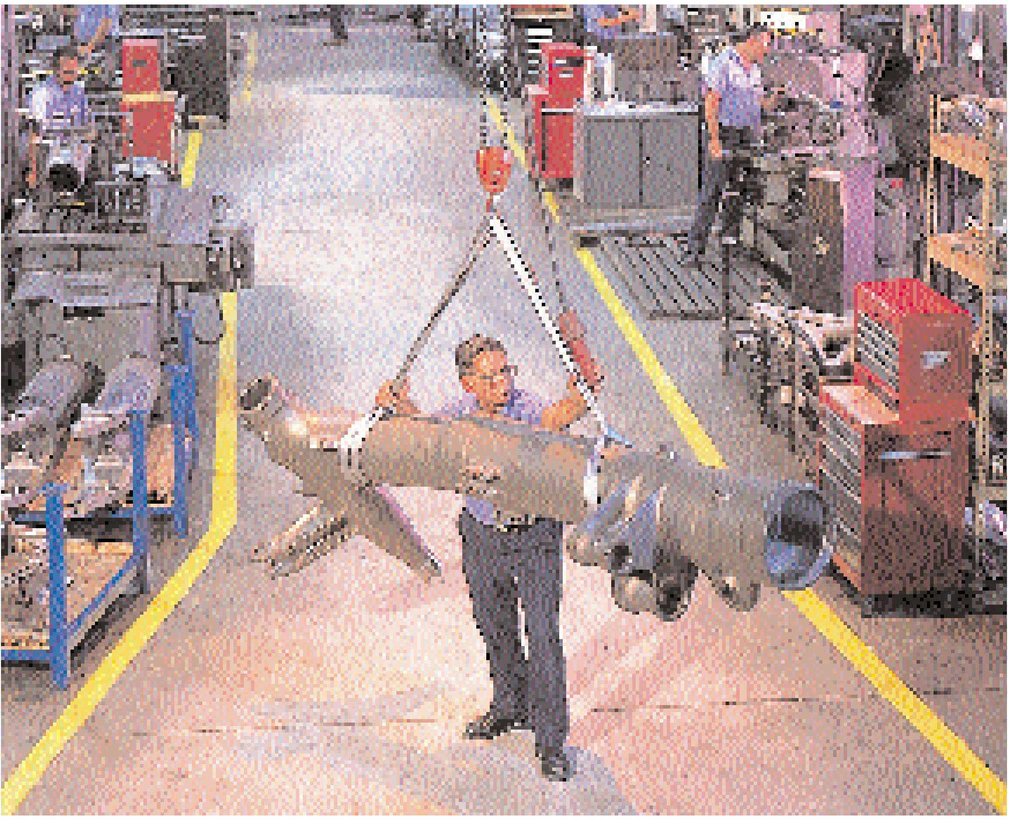
Following de-stress corrosion is removed and dimensional checks are made. This process of NDT, de-stressing, corrosion removal and dimensional checking will bring components to a condition at which their required overhaul process can be determined.

Small defects, less serious than cracks, can be dealt with by polishing and grinding. The TBO will influence the level of corrosion, although aircraft type and style of operation will also have an effect. "Because of this it is better to perform an initial inspection at five years to check for corrosion, rather than wait until removal at 10 years to find a high level," Fortner advises. "Many airlines are doing a sampling programme at five years to detect corrosion. The degree of corrosion and its detection is important, because it affects the number of parts that have to be scrapped.

The actual repair and overhaul process of many parts is no more than stripping, grinding, inspecting for damage and then re-plating and re-painting. Once inspections have been completed, parts can be painted and re-plated. Painting is preceded by a vapour degreasing process.

Components that are beyond dimensional limits have to be re-plated to re-attain correct dimensions. Following inspection and repair to re-attain correct dimensions, cadmium plating is applied and parts given a post-bake cadmium dip to restore a protective finish.

Bushings are then replaced and any SBs required are incorporated. Prior to re-assembly all parts are inspected.



Exchange fees and repair costs can be standardised. Unpredictable extra costs come from scrap parts. Maintenance practices which detect and prevent corrosion will minimise scrap costs, resulting in the lowest costs per flight hour.

Plumbing and wiring is re-installed and the full landing gear set is tested.

The parts used in the overhaul process can be grouped into standard replacement parts (that is, parts which always require replacing), consumables and major parts that may or may not have to be replaced subject to their incoming inspection.

"Downtime for this process is about six weeks for a 747 shipset and down to about three weeks for a smaller type like the 737. Most types have a downtime of four or five weeks," says Gosset.

Sub-contract deals

Few airlines have their own gear shops and inventories of spare shipsets. Few airlines have enough annual removals and shop throughput to financially justify having a gear overhaul shop. The same applies to inventory.

Most airlines use third-party specialist landing gear overhaul facilities, such as AAR LGS, American Aircarriers Landing gear Services and Messier Services.

AAR LGS is one of the few shops that repairs the complete landing gear system and also all Airbus, Boeing McDonnell Douglas and all major regional aircraft types. Messier Services has the same capability for all airliner types.

Most third-party landing gear overhaul contracts are based on an exchange system. Removed gears are exchanged for a freshly overhauled set with a repair facility. This system avoids the need for any airline to keep an inventory. It also minimises a shop's inventory level, since it can anticipate shop throughput. By managing and forecasting the throughput it can minimise the number of spare sets by always having a freshly overhauled set ready just days prior to shipping and receiving a removed set.

"This system is alright if we get a gear that has not been in an incident and has traceability," says Bob Bierk, president and general manager, American Air Carriers Support Landing Gear Services. "We will only take a gear that has accumulated less than 65% of its full life limit. This is because we do not want to accept a shipset of low value, because it becomes hard to sell".

These exchange systems have fixed fees with several cost elements. The first is an exchange fee, which has a cost element to cover the ownership or inventory cost of the landing gear shipset being supplied. That is, the number of removals a shipset will have during its life can be estimated and the cost of acquisition and interest amortised over the estimated number of removals.

Another element, often fixed, is the cost of repairs that can be predicted with a fair degree of accuracy. This will be a fixed number of man-hours (MH) and a standard bill of materials. This includes 100% replacement parts and all bushings and other parts known to be required. Many shops offer a fixed price for these elements, whatever the condition of the gear. Further features are warranties. AAR, for example, provides a warranty for the first five years after overhaul.

There are three basic ways the overhaul cost can be charged. The first is straight MH and material, the second a fixed fee based on average MH, and the third a fixed fee per aircraft type.

"Pricing landing gear is very complicated," explains Fortner. "It is hard to keep track of the various options that relate to pricing, since each shop has different ways of quoting". Shops can, for example, exclude labour for SB incorporation, which will be an additional cost above quoted fixed prices.

Fortner advises airlines to set up a standard configuration of each gear so that it can compare offers made by each overhaul shop. These configurations are taken from illustrated parts catalogues. Airlines should then get shops to quote at the same level. Airlines should be clear about exactly what is included in the pricing from each shop. A man-hour rate needs to be clarified in terms of the number of man-hours that are expected to be used. Some shops quote a total fixed labour cost.

The third element, which is less predictable, is replacement of scrap parts. "We cannot control the number of parts that are missing and scrap," says Fortner. "Pistons and cylinders, the most expensive parts, rarely scrap. Most of scrap comes from corrosion and bad handling at removal and shipping".

These are complex components, such as those with screw threads, bushings and areas where moisture accumulates. Some airlines prefer a fixed exchange and overhaul price and a separate invoice for scrap parts.

"Modifications for SBs, new parts and exceptional MHs for upgrades and expensive components, also have to be invoiced separately," says Gosset.

"In the past, shops just charged for MH and material used," says Fortner. "Although it is more simple to have fixed rates for the exchange fee and MH and material, the actual size of the overhaul is affected by what we receive. We sometimes receive an incomplete gear from an airline, which effectively increases the number of missing parts. We try to get airlines to match the gear sets they send us with configuration sheets. If airlines send us the complete gear shipset then they can get a fixed exchange fee and overhaul price. Shipsets can also get damaged in transit,

SUMMARY OF EXCHANGE FEES, OVERHAUL COSTS & ADDITIONAL COSTS

Aircraft type	Exchange fee $	Average overhaul fixed cost $	Average extra costs $	Total costs $
A300B2/4	55,000	350,000	175,000	580,000
A300-600	100,000	335,000	85,000	520,000
A310	100,000	335,000	85,000	520,000
A310-300	130,000	335,000	85,000	550,000
A320	50,000	230,000	60,000	340,000
A330	220,000	450,000	130,000	800,000
A340	235,000	500,000	125,000	860,000
707	25,000	193,000	95,000	313,000
727-200	25,000	148,000	30,000	203,000
737 series	25,000	115,000	17,000	157,000
747-200/-300	90,000	400,000	100,000	590,000
747-400	130,000	480,000	120,000	730,000
757-200	40,000	240,000	60,000	340,000
767-200/-300	75,000	290,000	75,000	440,000
DC-9	30,000	145,000	35,000	210,000
MD-80	30,000	145,000	35,000	210,000
DC-10	75,000	260,000	65,000	400,000
MD-11	100,000	275,000	70,000	445,000

so we video shipsets when they first arrive to record damage".

Deals can be structured in other ways. "Customers can maintain ownership of their gears and get their own shipsets back," says Bierk. "Complications arise when the complete configuration of a gear is not known, or part numbers which determine an aircraft's maximum take-off weight (MTOW) do not match the MTOW an airline requires. If the MTOW is limited then parts have to be changed, increasing cost".

Some authorities have regulations which stipulate that an airline gets its own gear back from the shop, which is inefficient in terms of inventory. This also means the airline has to lease spare sets while their own is being overhauled, rather than accepting an exchanged set.

Economics of overhaul

Typical industry rates for the exchange fee, standard overhaul cost and possible additional costs for scrap parts and other items are summarised *(see table, this page)*.

The total costs for types of similar size vary. The MD-11 has a total cost of $445,000 and the A340 $860,000.

This difference is due to the disparity in exchange fees. One factor is that the MD-11, being no longer manufactured and less popular than the A340, will have low demand and a higher number of gears on the market. The MD-11 may also be more durable, and so have lower overhaul and scrap costs. Additional costs for scrap parts will also be lower, because of market excess.

"The biggest factor, which generally makes the total cost for Airbus aircraft more expensive than either Boeing or McDonnell Douglas aircraft, is the design," explains Gosset. "Boeing and MDC aircraft have simpler landing gears which are more durable by being heavier. This simplicity reduces both acquisition and repair costs. Airbus gears are designed to a weight limit. Their inherent complexity makes them more expensive to manufacture and repair".

Other factors that affect exchange fees and parts prices are the penetration of a type in the used market. Many Airbus types are uncommon in the secondary market and the majority of parts controlled by Airbus Industrie. Few are held by independent suppliers. This was illustrated by the price of parts for the A300B2/4 when it entered the secondary market following freight conversion. First-user inventories were acquired by the aftermarket and market prices fell.

Since the A340 entered service in 1991 few landing gears will have been removed, while many MD-11s will have had their first-gear overhaul, putting some parts on the market. Of all the types in the table, the A330 and A340 will have had the smallest number of removals across their fleet compared with all other types.

The same factors result in the wide difference between the MD-80, 737 series and A320 family.

Older types, which have been operational for many years, will have had a high number of removals. This effect, combined with a deeper penetration in the used market by older types, means parts and exchange fees will be lower for the 737 compared with the A320. Again, complexity of Airbus landing gears also increases their exchange fees.

In some cases similar sized types, such as the A300, A310 and 767, have similar costs.

On the basis that the average TBO is eight years, the costs in the table are equal to about $100,000 per year for the A330/340; $90,000 per year for the 747-400; $55,000 for the 767 and $42,000 for the A320 family.

Annual utilisations for the A330 and 767 will be about 3,000FH, and so a reserve for overhaul will be $33 and $18 per FH. The 747-400 and A340 can be expected to generate 4,500FH per year and so have a reserve of $20 and $24 per FH. The A320 will generate about 2,500FH per year and so a reserve of about $17 per FH would be appropriate.

"The overall economics depends on the condition of the gears and airline's style of operation and quality of maintenance," explains Gosset. "It is possible to get huge differences because of maintenance practices. That is, frequent greasing, lubrication and inspection are necessary because it is almost impossible to detect corrosion. It is possible to visually detect bushing migration and sealant breakage. Some airlines use high-pressure cleaning techniques and this increases moisture in the bushings and the chance of corrosion. A salty operating environment also increases corrosion risk".

High scrap rates and costs can be avoided by good maintenance practices. "If high costs occur because of extended TBOs and higher scrap rates, then it is advisable for an airline to revert back to short intervals. This will actually reduce cost per FH and FC," explains Gosset. "Airlines seeking cheap maintenance often wait until the removal and then ask for a quote, but they will only get what is available in terms of capacity. Airlines should take a preventative and long-term view. Many carriers are also often unaware of what the life limits are on their gear components, or do not have the records to prove the limits. Either way, parts have to be replaced, increasing the cost. The biggest contribution an airline can make to improving its costs are understanding what affects the economics". AC