Chapter I

1.0 Introduction

1.1 Landing gear.

The landing gear is one of the main parts of an aircraft, from the weight point of view it can represent a share of 3 to 7% of the maximum weight of the aircraft at take-off and from 15 to 20% of the empty one, depending on the category of aircraft, also from the economic point of view the landing gear has a significant percentage from the total cost of the aircraft.
The landing gear is made up of some main components:

- kinematics for extraction / retraction.
- Shock absorber.
- Brake.
- Wheels and tires.
- Sensors.
- Actuators for steering and the positioning.

The landing gear represents a typical example of an on-board system that has heavy interference with the structure, aerodynamics, systems and flight mechanics. The design of the landing gear system for a given aircraft requires both the development of ad hoc components and the use of standardized components, with greater or lesser importance of the two depending on the type of aircraft and its distribution.
The conceptual and preliminary project is normally developed simultaneously with that of the entire aircraft, while the detailed design and components are often delegated to specialized companies.
Introduction

1.2 Landing gear MRO

Landing Gears Are very Expensive, a set of Landing Gears for an Airbus 320 cost around 1.8 million USD increasing to 5.0 million USD for Airbus 330/340 and upwards of 7.0 million USD for B777. Clearly then a significant cost which needs to be managed, as a rule a Landing Gear Overhaul can cost between 10% & 20% of the price of a full set. Then you need to take into consideration some extra work These include:

- Additional customer requests,
- Optional Service Bulletins,
- Missing or abused parts,
- Replacement of life-limited parts,
- Technical Support Engineering Charges,

2.0 Purpose of the work

Landing gear MRO is very important due to many technical and economical aspects. After knowing how huge of an impact it has over the aircraft industry, since there is no landing gear MRO plant in North Africa and the Middle-East is costing the airplane companies a lot of time and money because then they have to dismount and ship the landing gear overseas to be maintained, repaired and overhauled, having such a plant in the Middle-East will save so much money and time, since also the idea was having a plant based in Egypt where the technology and the knowledge is available also with a relatively low cost labor and renting space

3.0 Statement of purpose

The aim of this work is having a feasible study on making a landing gear MRO plant, while taking into consideration the technical and the economical aspects the aim of the thesis is to plan an achievable landing gear MRO plant in the Middle-East that serve both

the Middle-East and North Africa, taking into consideration all the dimensions to make it profitable and practicable

Chapter 2.0

Technical

1.1 Landing gear MRO facility

1.1.1 Landing gear

Landing Gear systems is one of the critical subsystems of an aircraft that is often configured along with the aircraft structure because of its important impact over the aircraft structure. Landing gear detail design is taken up early in the aircraft design cycle due to its long product development cycle time. The need to design landing gear with minimum weight, minimum volume, reduced life cycle cost, and short development cycle time, is a challenge to landing gear designers and specialist. These challenges must be met by applying advanced technologies, analysis methods, processes, materials and production methods. Various designs and analysis tools have been developed over the years and are still being developed.

The purpose of the landing gear in an aircraft is to aid braking of the aircraft using a wheel braking system and provides directional control of the aircraft on ground using a wheel steering system. It is often made retractable to minimize the aerodynamic drag on the aircraft while flying. The landing gear also provides a suspension system during on land maneuver, take-off and landing. It is designed to absorb and dissipate the kinetic energy of landing impact, thereby lower the impact loads transmitted to the structure.

The landing gear design considers various requirements of stability, strength, ground clearance, stiffness, control and damping under all possible ground types of the aircraft. These requirements are guaranteed by the Airworthiness Regulations to meet

operational requirements and safety. The landing gear should occupy minimum volume in order to reduce the storage space requirement in the aircraft. Further, weight should be at minimum to increase the performance of the aircraft. The service life of the landing gears should be same as that of the aircraft.
A Landing Gear system (Figure 1) comprises of many structural and system components. The structural components include:

- Main fitting,
- Shock absorber,
- Bogie beam/ Trailing arm,
- Axle,
- Torque links,
- Drag/ Side braces,
- Retraction actuator,
- Down lock mechanism,
- Up lock,
- Wheels,
- Tire etc. ‘

The system components are:

- Brake unit,
- Antiskid system,
- retraction system components.

Typical Main Landing Gear (MLG) and Nose Landing Gear (NLG) are shown in Figure 2 and Figure 3 respectively . The nose gear will have additional elements like steering actuator and steering mechanism.

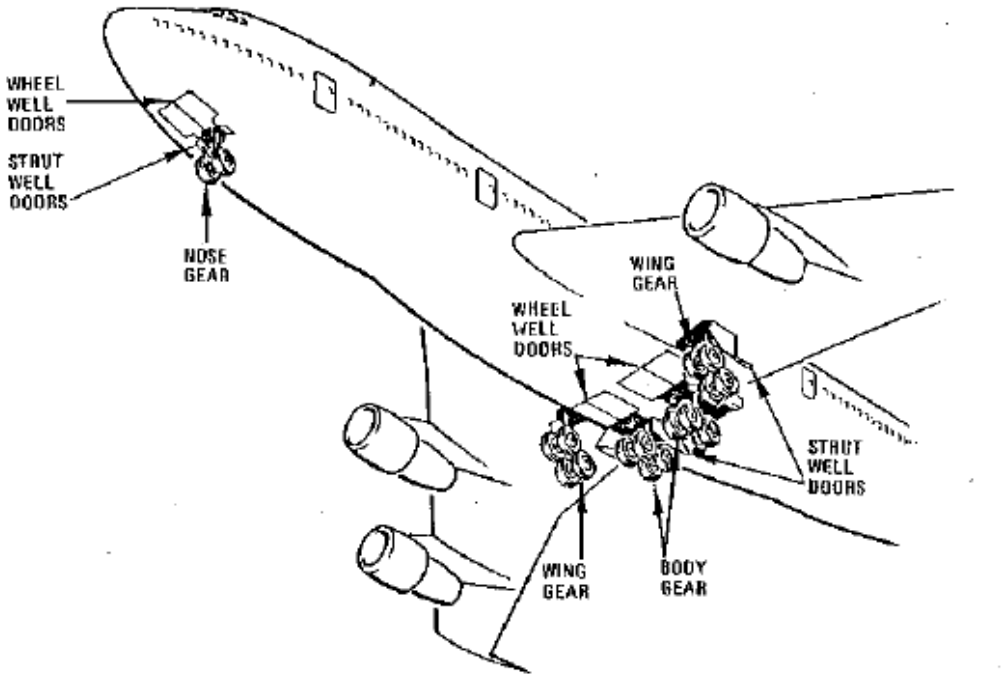

Figure 1: Landing gears in aircraft.

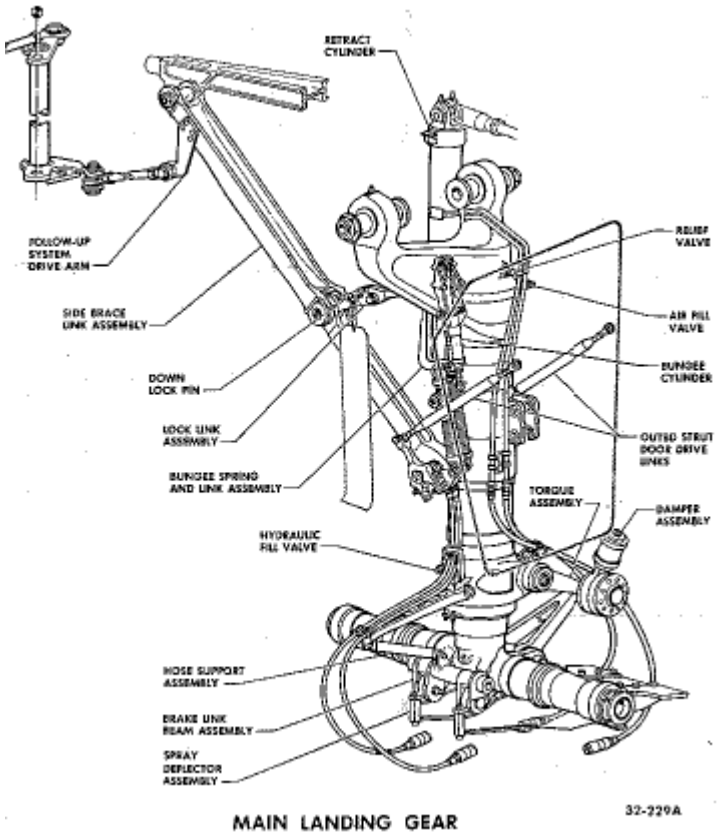

Figure 3 : Main landing gear.

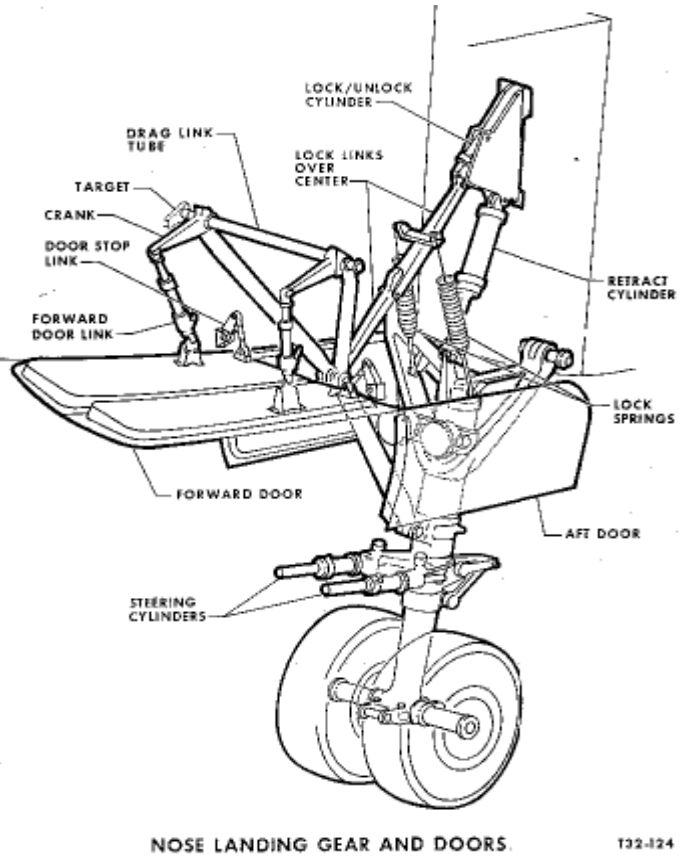

Figure 2 : Nose landing gear.

1.1.2 An Overview of Landing Gear Design

The landing gear design and integration process gathers knowledge of many engineering areas such as dynamics, structures, fluid mechanics, kinematics, and runway flotation.

The geometry, mission requirements, flotation requirements and operational requirements of the aircraft manage the landing gear configurations. The configuration design includes choice of number of tire sizes, pressures, landing gear layout, type of shock absorbers, wheels and retraction kinematics.

Airworthiness regulations play a crucial role in the landing gear configuration, such as allowable load factors, sink rate and ground maneuvering conditions, designate in the applicable airworthiness regulations. A brief summary of various life cycle stages of landing gear design and development are described below:

- **Concept Design:**

The concept design begins with a study of all design specs and airworthiness regulations. A concept is then evolved while meeting the practical and regulatory requirements. Major design points are performance, safety, cost, time frame and technology. The landing gear location is established, and type of landing gear is selected. The landing gear geometry is defined along with kinematics. Steering concepts are also identified in this phase. The ground loads are estimated using dynamic simulations for material selection and preliminary sizing of components. The actuation mechanisms and loads are also developed in this phase. Various arrangement studies are performed to enhance volume, weight and cost. Based on these arrangement studies, a best concept is selected.

- **Preliminary Design:**

In the preliminary design phase, dynamic simulations are carried out for landing, take off and retraction kinematics to arrive to the data required for sizing the components and material selection. Preliminary design of components is performed and weight estimates are established.

- **Detailed Design:**

In this phase the detailed design of all the landing gear components is performed and an integrated landing gear system is defined with all interfaces and associated systems. Component loads are estimated, and material selection and sizing are done in this phase. Reduction in part count by making closed die forgings for complex shapes is done through 3D CAD modeling that enable computer-controlled 3D machining. Dynamic analysis and simulation are carried out to fine tune certain design parameters for energy absorption, shimmy suppression and retraction/extension. In this phase digital mock-up of the landing gear is developed. All lessons are learned and best practices evolved over the years are utilized in the detail design to realize a reliable design.

- **Stress & Fatigue Analysis:**

Finite element modeling (FEM) and conventional hand calculation methods are used for landing gear stress analysis. Landing gear is designed as a safe life system and fatigue analysis methods are used to predict the life. Safe life requirements demand as

high as 60,000 landings for a commercial aircraft landing gear, high stress fatigue analysis is applied for landing gear life evaluation to be detected by present day NDT techniques.

- **Reliability & Maintainability Analysis:**

Proper failure mode effect and criticality analysis (FMECA) is performed to assess reliability. Data on failure modes and failure rate are collected from previous designs to conduct this analysis and reliability is predicted before the design. Quality, reliability and maintainability are important to cut down operational costs and to ensure aircraft availability for service. The design aims at increased mean time between failures (MTBF) and reduced mean time to repair (MTTR). Periodic preventive maintenance schedules and on-condition maintenance requirements are specified as required. Various best practices evolved are followed in design to ensure good maintainability. Health monitoring systems are being evolved to move towards condition-based maintenance practice from scheduled maintenance practice, which will lead to enhanced safety and a reduction in maintenance costs.

- **Manufacturing & Assembly:**

The landing gear manufacturing involves development of many closed die forgings, machined components from ultra-high strength steels, titanium and aluminum alloys. Precision tolerances are required for components like piston, shock absorber parts, actuator cylinder and axle. Heat treatment of parts is performed after rough machining followed by final machining, plating and painting. Reliability of the product is enhanced through stringent quality assurance requirements.

1.1.3 Landing Gear Technologies

Landing gear technologies are in continuous development. Some of these important technologies are presented below:

- **Steering System.**

Steering control systems are moving towards electronic control systems replacing hydro-mechanical systems. The main advantage with electronic control system is its accuracy.

- **Corrosion protection.**

  Good corrosion protection is important for the landing gear components as they are susceptible for wear. Apart from normal electrolytic finishes like cadmium plating, hard chromium plating, HVOF etc. epoxy or polyurethane primer and polyurethane top coats are applied for the exposed landing gear parts. Use of corrosion resistant materials is also becoming increasingly popular.

- **Tires.**

  Radial tire is one of the advanced technologies employed in aircraft for the past 25 years. Landing gear radial tires offer lighter tires with longer life.

- **Actuation System.**

  In actuation systems, partially electric or all electric systems are replacing the conventional hydraulic systems. The electric systems offered today have become weight competitive with use of brushless high-power motors. Further, electric systems help to overcome problems of fire hazard and leakages.

- **Up-locks.**

  Hydro-mechanical locking systems and proximity switches are replacing mechanical locks and micro-switches because their higher reliability.

- **Brake system.**

  Electronically controlled antiskid brake systems are replacing old mechanical or electric antiskid systems. Electronic systems are more efficient and trouble free.

- **Materials.**

  Composites are being used in some components of landing gear because of their superior specific strength and stiffness properties. They are relatively expensive

which is the one disadvantage in using them, which is now being overcome with improved manufacturing techniques. Ultra-high strength steels are used due to its high strength to weight ratio and size advantage. The choice of material for a landing gear component is decided depending on its application and this requires study of strength, stiffness and cost to arrive at the optimal choice. Fatigue and fracture toughness properties and aspects like protection against stress, corrosion, wear and reliability in service etc. are other considerations in the selection of material for the landing gear. Carbon composite brake offers reduced weight, longer life and maintenance free wheel brakes thereby reducing the cost per landing gear.

- **CAX Technologies.**

  Many commercially available CAD/ CAM/CAE/CFD and Dynamic Simulation software tools are used in the design and development of landing gear. These tools have helped in virtual product development of landing gear before actual prototype is being fabricated. These help to improve designs with reduced cycle time and cost. Check table (1).

CAD Tools	CATIA V5, UG, Solid works,
CAE Tools	NASTRAN, ABAQUS, ANSYS, Hypermesh, Optistruct
Dynamic Simulation Tools	MATLAB, SIMULINK, ADAMS
CFD Tools	Flow works, Ansys- Fluent, Ansys-CFX, Star – CD
Kinematics	CATIA V5, UG, Solid works

Table 1 CAX Tools

- **Knowledge Based Engineering (KBE).**

Knowledge Based Engineering (KBE) tools and information intelligence tools are being developed and used by landing gear designers to automate many engineering processes while retaining company specific knowledge. These tools lead to reduction in development cycle time, reduction in human errors, ability to redesign iteratively and capturing organizational knowledge. Few of these tools include:

- Tools for selection of number of tires and pressures taking the ground flotation requirement
- Shimmy analysis tools
- Ground load estimation tools
- Tools to compute axle travels requirements
- Shock absorber performance optimization tools
- Rake and Trail requirements analysis tools
- Tools to analyze retraction actuation
- Wheel / Brake sizing tools

- **Health monitoring**

Landing gear is a maintenance intensive system of the aircraft. Health monitoring of landing gear is very important as suitable sensors and processing units are available today. Wireless sensor network and RFID technologies are being employed in health management of aircraft systems and structures including landing gear. Health monitoring not only improves the safety and reduces both operational and maintenance costs, but also helps in extending the life of the landing gear beyond designed service life.

- **Dynamic Simulation.**

Dynamic simulation helps to predict the performance of a component and the assembly operation. The results of these simulations will be more accurate compared to manual calculations. The landing gear shock absorber performance is evaluated by a dynamic simulation of the landing and taxing. This considers the hydraulic damping, air spring characteristics and friction effects and structural flexibility in the landing gear. Using the computer models developed for this purpose the shock absorber parameters are enhanced to maximize its efficiency and peak reaction behavior.

1.1.4 Landing gear MRO procedures

Giving an overview about the most important parts to be carried out for landing gear by a MRO facility working under EASA regulations you have to consider:

- **Overhaul Considerations**

  There is an old adage in aviation: "Take offs are optional and landings are mandatory." Landing gear supports the aircraft at rest and during the landing where the most pressure and stresses occurs. The shock absorber absorbs and dissipate the initial shock of the landing. In order to assure safe operation of the landing gear, most aircraft manufacturers have specific overhaul limits established, as well as life limits established on the landing gear assemblies, or on parts within the assembly.
  To overhaul a set of gears can take about 6 weeks (or more) so from a maintenance planning perspective the landing gear creates many issues which need to be managed. A typical overhaul of the landing gear will take place at around 10 Years. The landing gears are thoroughly cleaned and then disassembled into little components, which are then individually cleaned. Paint is then removed from the components using either chemical or mechanical processes. All components are then inspected using a number of non-destructive test processes (NDT), as well as optical checks to check defects. As well as checks for corrosion and fractures, checkups are performed to ensure the dimensions and coated surfaces of all components are within limits.
  The following article is based on some of the procedures used by most MRO facilities when performing landing gear overhauls.

  Incoming inspection

  Components receive NDT inspections upon arrival, a visual inspection is conducted for obvious damage and missing parts. A complete inventory of the landing gear assemblies is performed. Taking care of missing parts quickly keeps the work on schedule and avoids unnecessary cost.

  Disassembly

  the gear is disassembled, and the parts are then cleaned and prepared for inspection. Landing gears are subject to rough service. Dirt, brake dust, grease, and oil, in addition to paint and primer, must be removed and cleaned. A variety of approved cleaning methods are employed including solvents, steam, soap and other cleaning agents, and blasting. When using media blasting, plastic blast media is used on non-ferrous material such as aluminum and magnesium, and

glass blast media is used on ferrous material such as steel. Ferrous and non-ferrous materials and their blast media are kept separated to prevent contamination and dissimilar metal corrosion. Once the parts are clean, they are ready for inspection.

Evaluation

The evaluation process involves inspecting the landing gear per the manufacturer's overhaul or inspection requirements. The general objective is to inspect the gear for wear, corrosion and damage. Fits and clearances of major parts are measured for wear tolerances. Dimensional inspections are performed using precision measuring equipment, a geometrical check of the gear's major parts is performed to assure proper alignment and confirm the landing gear was not bent or overstressed.
Parts that require non-destructive testing (NDT) are sent to the NDT department for the inspections required. Magnetic Particle, Dye Penetrant or Eddy Current inspection of all parts requiring NDT are accomplished. Parts with indications of cracks or defects are noted for further evaluation, repair or replacement.
During the evaluation phase. For maximum reliability, manufacturer service bulletins and other improvements to aircraft landing gear should always be incorporated per the aircraft and component manufacturer's instructions. Many of these bulletins are interrelated with each other as well as with the overhaul manuals and aircraft maintenance schedule.

Corrosion

Corrosion is one of the major problems to landing gear safety. The time between overhaul, different climates and conditions that aircraft are operated in, and how often the lubrication and pressure washing of the landing gear is applied all may result in corrosion damage to various parts. Corrosion weakens critical structural members of the landing gear, concentrating points of stress that can lead to failure. Corroded surfaces in sealing areas cause hydraulic and nitrogen leaks and interfere with the smooth and proper operation of mechanisms.

Repair

A list of all the necessary repairs are initiated and all maintenance is performed using the manufacturer's maintenance instructions, EAA, EASA Approved Repairs.

Bearings

Bearings are inspected and can be reconditioned and reused in some cases. Bushings are normally worn and must be replaced. The bushing bores are inspected and reworked if needed. Replacement of bushings and bearings is precision, close tolerance work. In many cases, these parts carry the weight of the aircraft and the shock of landing. Many bushing and bearing installations are interference, or pinch fit. Sometimes these parts are assembled by differential temperature method. This involves heating the bore, observing a temperature that does not affect the base metal temper or heat treat, and chilling the part by immersing it in liquid nitrogen or a slurry of dry ice and alcohol. Many times, the manufacturer specifies that these parts are installed with some type of protective coating between them and the bore. In all cases, great care must be taken when assembling close tolerance parts to avoid damage to the assembly.

Platings and coatings

Chrome-plated surfaces are inspected and replated with the correct specification process if needed. All protective processes such as cadmium plating, black oxide coatings, primer and paint are renewed, even when this is not required by the manufacturer's instructions. Primer and paint, when specified, is always applied prior to assembly for complete protection against corrosion.
The landing gear assembly procedure is inspected, both in process and during final assembly, by the Inspection Department. Special tools and assembly fixtures are often used during the assembly process to ensure the correct fit and operation of parts. Wiring harnesses for position indicating, weight on wells, brake anti-skid and nose-wheel steering are completely overhauled and thoroughly tested for proper operation upon installation. Wheel brake and nose-steering and rigid hydraulic lines are inspected and tested. Flexible lines are replaced. All the landing gear hydraulic system components are tested at final assembly.
The shock absorber and other hydraulic components are serviced with hydraulic oil and dry nitrogen (always use dry nitrogen to inhibit corrosion of internal components). The landing gear/shock absorber is put in a special hydraulic press to compress the shock for testing proposes for proper operation, internal friction, correct service pressures and leakage. After the testing procedure, the shock absorber is deflated to a reduced pressure..

- **Re- Assembly and Final Test**

After cleaning, inspection and repair, the several thousand components are reassembled into a full working system. Rig testing is performed followed by return to the aircraft.

1.2 Machines & Tools

1.2.1 - Machines

Regarding the: MRO (Maintenance Repair Overhaul), it is possible to use a certain number of auxiliary machineries for the task that will be carried out, below all the necessary machinery will be reported. The machines are: CNC Toolroom Lathe with 16 "x 48" max capacity, External / Internal grinding machine (manual), Blasting cabin for paint removal, shot peening, Painting cabin, Airmix 20.25 Pump - Stainless Steel, Electrostatic guns

a) CNC Machine.

About the CNC machine, it is one of the most multiuse machines in the mechanical field, it allows components to be machined through the use of an external computer which is used to be able to control the activity of the machine. The machining is performed with specialized internal and external binders in combination with boring mills, lathes, CNC machines and vertical mills with narrow body and wide body capacity provided by the best world manufacturers.

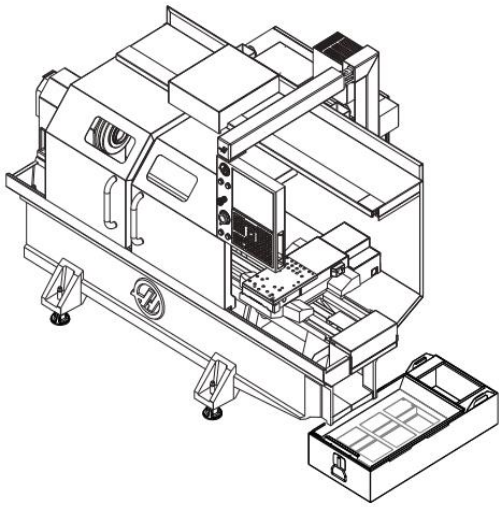

Figure 4 – CNC

b) External/ Internal grinding machine (manual).

The following machine allows the removal of material both internal to the component and external through abrasion.

Figure 5 - External/ Internal grinding machine

c) Blasting cabin for paint removal and painting.

The manual shot blasting chamber is the room where one operator carries out the blasting operation by ejecting abrasive media through a special nozzle. The aim of this job is to prepare the surface of the materials for further operations, such as panting, galvanizing, paint reconditioning.
The installation will be finished with a coat of antirust primer and a coat of final paint: colors as per requirements.

Figure 6 - (3 x 3 x 3)mt. R.R.T.

d) Shot peening.

This shot penning unit type “AC2 TRE PR1”: is suitable for the housing for the bearing cup. The treatment is obtained by the abrasive effect of the media ejected by 1 pressure nozzle, fed by a blasting unit. The machine mainly consists of a motorized rotary table and one support on upper side where it is fixed an arm with one nozzle for shot-penning the housing for the bearing cup.

The pressure nozzle, located in the blasting station, is installed onto a vertical support with fixed position, the rotation of the table ensures the treatment of the part.

Therefore, the machine has one peening positions, where the operator can load and offload the part according to the pre-fixed blasting time. This position has the speed rotation controlled by encoder and can be adjusted through a PLC. This unit does not require any preparation work (foundations are not required) for the installation and is complete with all technical devices to collect and separate the recycled steel media, consisting of buckets elevator, abrasive separator and shots reservoir.

Figure 7 – SHOT PEENING UNIT TYPE “AC2 TRE PR1”

e) Electrostatic gun.

It is used to get as much coating material on the part as possible, this is achieved by negatively charging atomizes paint particles so that they are attracted to the grounded work-pieces.

Figure 8: electrostatic gun

f) AIRMIX® PUMP 20.25 + Xcite™120 GUN.

True accelerator of performance for your AIRMIX® Xcite™ gun, the high flow & well-proven technology of the 20.25 pump combines a robust design & high efficiency Large diameter suction rod & high compression ratio can be used with a wide range of materials. Stainless steel desig**n** compatible with water-based materials.

Figure 9: PUMP 20.25 + Xcite™120 GUN

g) Plating.

The in-house plating capabilities encompasses deep and shallow tanks for wide body and narrow body Landing Gears. Specialized processes such as out of tank plating and special anode technology will place us among the best in producing the highest quality product.

Our plating process will include: Sulfamate Nickel, Black Electroless Nickel Plating, Alodine, Passivate, Hard Chrome.

Complete automatic plating system with nickel sulphamate plating line, black electroless nickel plating line, chemical conversion - Alodine, hard chrome plating line, waste water treatment system, laboratory equipment

One of the companies that was contacted was ZINI and they were very clear with their offer.

h) NDT (Non-Destructive Test).

Equipment and tooling to ensure complete crack detection with specialized Level III personnel and state of the art equipment ranging from magnetic particle, fluorescent penetrate, x-ray, eddy current and ultrasonic.

i) X Rays generator.

An X-ray generator is a device that produces X-rays. Together with an X-ray detector.

Figure 10: Comet X-ray generator

j) X Rays display.

Figure 11: CARESTREAM HPX1-Plus

k) Ultrasonic flaw detector.

Flaw detection propagation of sound waves through solid materials have been used to detect hidden cracks, voids, porosity, and other internal discontinuities in metals, composites, plastics, and ceramics. High frequency sound waves reflect from flaws in predictable ways, producing distinctive echo patterns that can be displayed and recorded by portable instruments. Ultrasonic testing is completely nondestructive and safe, and it is a well-established test method in many basic manufacturing, process, and service industries.

Figure 12: OLYMPUS OMNISCAN MX2

Figure 13: GENERAL ELECTRIC Flaw detector transducers

l) Eddy current.

Is used for flaw detection of holes (EPOCH659) and flat surfaces (NORTEC 600 D).

Figure 14: OLYMPUS EPOCH 650

Figure 15OLYMPUS NORTEC 600 D

m) Magnetic particles.

Magnetic Particle Inspection is a non-destructive process used for the detection of surface and near-surface flaws or defects in ferromagnetic (ferrous) materials. An externally applied magnetic field is directed to the test subject. If the material is without defect, most of the magnetic flux remains below the material's surface. Magnetic flux is distorted or will leave the part at any flawed area due to interaction with the magnetic field.

Figure 16: CGM D-2060

n) Dye penetrant crack detection.

This is method of detecting surface-breaking flaws such as cracks, laps, porosity, etc. To be detected, the flaw must reach the surface to be tested. The principle of liquid penetrant testing is that the liquid penetrant is drawn into the surface-breaking crack by capillary action and excess surface penetrant is then removed; a developer (typically a dry powder) is then applied to the surface, to draw out the penetrant in the crack and produce a surface indication. The indications produced are much broader than the actual flaw and are therefore more easily visible.

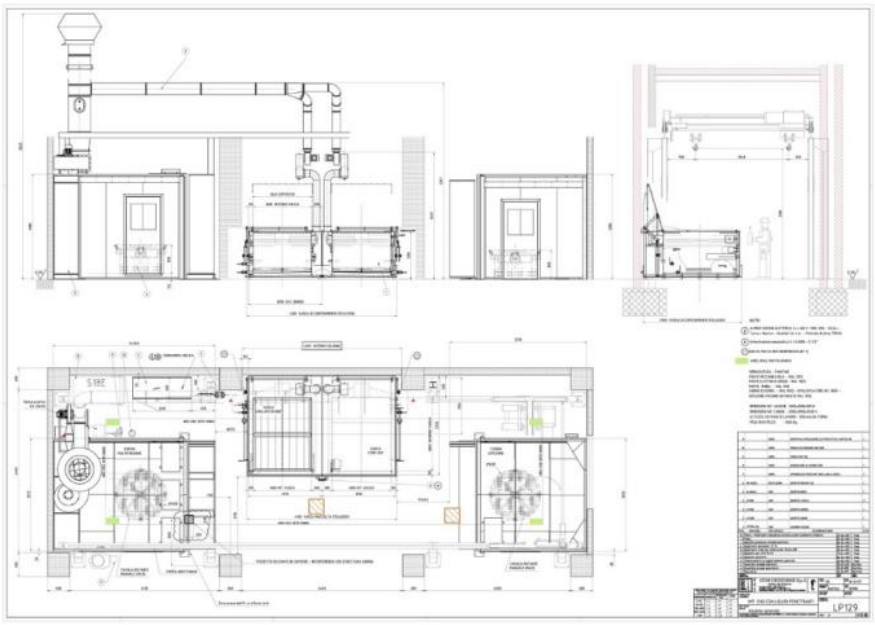

Figure 17: CGM LP

o) Chemical Laboratory.

A complete in house chemical and material mechanical testing laboratories will insure the optimum quality of the supplied products: processes that most major overhaul facilities and OEM's source out for testing such as: Boeing Porosity Meter, Failure Analysis, Metallurgical Analysis, Notch Tensile, Adhesion, Salt Spray.

From the file the data acquired are about: Thickness detection, Surface Roughness tester, Automatic Coordinate measuring machine.

p) Thickness detection.

Regarding the following apparatus of the supplied material there are two types of equipment:

- ARW 8812

This instrument allows the detection of thicknesses in various materials, steel, cast iron, aluminum, copper, brass, zinc, glass, polyethylene, pvc, etc. with the simple support of the probe on the piece. Ideal for measuring pipes, tanks and in any situation, it is not possible to access the measured object from both sides. Particularly suitable for corrosion control, quality control, material acceptance and maintenance of civil and industrial systems.

Figure 18: ARW 8812

- ARW-N

Portable digital ultrasonic thickness gauge for measuring material thickness. Ergonomically designed for comfortable positioning in your hands, the ARW N brings together all the functions necessary to meet any need. Equipped with internal data memory and a built-in calibration plate for calibration, it allows a fast and precise measurement both on a single point and in continuous mode with the SCAN function. Comes complete with a 5 MHz probe and delivered in a sturdy carrying case.

Figure 19: ARW-N

q) Surface Roughness tester (ARW 100).

The Barcol durometer is a hardness tester based on a simple and quick non-destructive. The test is carried out by measuring the resistance to penetration of a steel needle pushed by a spring, the sample is placed under the needle of the instrument and a uniform pressure is applied to the sample until the indicator reaches a value. The depth of the penetration is converted into the Barcol hardness value on a scale from 0 to 100

Application: The Barcol hardness tester is mainly used to check the hardness of aluminum alloys, it also finds its place for measuring the hardness in the plastic products, glass fiber and coatings, such as paint.

Figure 20: ARW-100

r) Automatic Coordinate measuring machine.

This is Mitutoyo's manual floating bridge type coordinate measuring machines designed to give you very high accuracy in a wide range of applications. CRYSTA-PLUS M is the intelligent alternative to the complex, cost-intensive measuring equipment with conventional multi-point measuring devices. These CMM's will introduce you into the world of 3D measurement and will demonstrates its strengths wherever the measuring tasks are constantly changing, different work pieces are involved, and random measurements are needed.

Figure 21: Mitutoyo crysta-plus 7106

1.3 Legalization & Regulations

Introduction

The objective of the following preliminary work is acquisition of data in such a way to understand how a maintenance company operates, in particular to know what are the regulations to be used, the necessary equipment to perform the requested operations and the request of these activities based on the fleet that will have to use them.
The first step was the acquisition of information related to the aviation legislation in Egypt, in particular what are the procedures and certifications of a maintenance company (Part 145 ECAA).
The authority that manages the legislation in Egypt is the ECAA (Egyptian Civil Aviation Authority).
Thanks to the B737 manual provided, it was possible to know the equipment needed to perform maintenance on landing gear. Having to take into account how the machines shown in the chapter works, the questions asked: when it is necessary to use the following equipment? Or rather, what are the limits and the constrains to be followed to carry out a landing gear MRO? With this, it was necessary to understand the time within which maintenance should be performed.

Using the information acquired in this thesis, two measuring instruments have been identified allowing us to understand when it is necessary to perform a total maintenance for the landing gear, wither after 18000 cycles or 10 years. This topic is discussed in more details in the chapter 3 part fleet ... introducing the fleet of the two companies and a preliminary statistical study was carried out allowing us an approximate understanding of every time an aircraft goes into maintenance.
In order to acquire a more accurate information regarding maintenance times, it is necessary to have the maintenance programs of each aircraft.
Regarding the information related to the maintenance of a landing gear, the manual of B 737-300 / 400/500 was provided, a list of the consumable materials and equipment that can be used to carry out a full maintenance were identified.

The MRO facility that was supposed to be held in Egypt for the company Egypt Air, will be established in accordance to Part 145. The organization is headed to the accountable manager and Part 145 is apply to the whole organization. It is important to highlight the purpose of this Part which is the safety during the maintenance, in fact it explains for example, how to store the component, how to store the file data and the software to preserve the information.
It is important to understand the concept and the titles of the people that are part of the organization, because there is a specific role for each one, and the roles are designed by the ECAA.

AMO: this is the acronym of "approved maintenance organization"

Accountable manager: is the manager that control the maintenance process, because it is important that the maintenance operations are made in accordance of standard ECAA. The accountable manager is necessary for a maintenance organization, in fact if there is an absence for a long time, to prevent this problem another person is delegate to cover this position.

Maintenance: this word covers all parts of overhaul.

Certifying staff: are all the workers approved by the AMO, in accordance with the ECAA, that provide to make it in service an aircraft or aircraft component .

Authorization board: it is the approved staff in an approved maintenance organization that provide to maintenance or other work that support it and the organization. This board is delegate from ECAA to release authorization for the staff.

Accreditation body: are the other maintenance organization "third-party".

ILAC: The international Laboratory Accreditation Cooperation.

Accreditation Laboratory: means a laboratory which is accredited by an accreditation body.

Before explication about applicability of this part is important to assert that:

- Aircraft that are used for commercial air transport they can't fly without a maintenance release to service issued by an approved organization, this is valid for aircraft and aircraft component.

- No organization can release the maintenance certificates if it hasn't the authority of these Part. It is possible to be issued and authorisd to fly if this aircraft is covered by this Part or working under a quality system of an AMO.

- A maintenance organization can be approved to do maintenance for an aircraft or an aircraft component.

Application of Part 145

This Part can be applied for different organizations that carry out base maintenance, line maintenance, engine maintenance and maintenance on aircraft components.

The organization can maintain aircraft with maximum take-off weight above 5700 kg, less or helicopter.

For an organization to run maintenance it must reach a certificate released by ECAA. The certification will give the extent of approval and the type of work that the organization will accomplish.

A. If a maintenance organization want to acquire the approval to operate, the request shall be made in a form that is acceptable for the ECAA, the form must be completed by the accountable manager or the responsible if there isn't the accountable manager. They must submit three copies of the MOPM and MOE, and it is necessary to duplicate the following copies:

    - Safety management system manual

- A list maintenance function that to be performed for it, under contract, by another agency (in the appendix A are reported the list of operational maintenance for each class)
- In case of an applicant of a rating 2 (propeller rating), it is necessary a list of accessories used to undergo the maintenance on the propeller.

B. An organization that respect the requests of this Part and has paid all the related fees, in the approval document there must be:

   a. The organization's name
   b. Location
   c. Date of issue period of validity
   d. Terms of approval

C. From January 2020, an applicant who satisfy the requirements of Appendix (C) about this Part and paid all fees, in the approval document he has to put:

   a. The organization's name
   b. Location
   c. Date of issue period of validity
   d. Terms of approval

D. A certified AMO, which decides to renew the contract after the expiration at the end of the 12 months, can do so. The AMO must request renewal at the end of the 12 months and continue to carry out maintenance according to Part 145.

E. An AMO has the certificate expiration at the end of the 12 months, unless the latter has been revoked, suspended or blocked. The certificate of the foreign organization must be in accordance with the Egyptian certification, otherwise it will be suspended.

F. The certificate, if it has expired, has been revoked, etc., must be returned to the ECAA.

Extension of approval

The release of the approval to an organization indicates the guarantee by the ECAA. The approval certificate will specify the extension of the approval and the display by the maintenance organization must specify the scope of the work that will be used, which constitutes the approval.

Structure requirements

A. The designated structures must be appropriately protected as they could be degraded due to the atmospheric agents present, in particular, workshops and specialized housings must be appropriately separated so as to prevent any contamination of the workplace.

1. For basic maintenance, the hangar must be available and large enough to accommodate both aircraft and components. The hangar used by an organization may not belong to the latter, in which case it is necessary to demonstrate the lease of the environment. It is necessary to demonstrate the activity of the hangar, in particular the latter's ability to accommodate aircraft for maintenance. In the case in which the maintenance will have to be carried out on aircraft it is necessary to bring back the aircraft in the plant. In the case of maintenance on individual components, the workshops must be large enough.

2. The hangar must be designed according to a standard, which guarantees protection from local meteorological phenomena that can occur during the 12 months. Aircraft hangar and component maintenance workshops must be properly sealed to prevent dust from proliferating.

3. If a line maintenance is to be carried out, it is not necessary to use the hangar, in any case it is always necessary to guarantee entry into the hangar in the event that there are adverse weather conditions or in the case where must carry out scheduled maintenance or rectification of defects.

B. The offices must have an appropriate configuration for the management referred to in the paragraph (accountable manager), the planned work includes in particular the quality control planning and technical documentation.

1. "Offices" means a place where suitable personnel for planning, quality control, technical documentation, etc. can continue the work related to aircraft maintenance in an appropriate manner. In particular, certified maintenance personnel must have a place where they can study the maintenance to be carried out and fill in the maintenance records correctly

2. As far as the previous point is concerned, it is possible to assemble it all in one single office, the important thing is that the designated personnel have enough space to perform the tasks.

C. The work environment must comply with certain standards, in particular, the latter must not be compromised.

Hangars where aircraft and offices are located must have a configuration so that staff can carry out the activity effectively

1. The temperature must be such as to guarantee the continuous activity with a given comfort.

2. Dust should never exceed a certain level, so as to prevent contamination of aircraft and components.

3. The light must have a level that guarantees every inspection and maintenance in the most appropriate way possible.

4. During the inspections, the noise must never reach levels such as to cause distractions to the personnel, in the event that the aforementioned inconvenience occurs, the personnel must act with appropriate equipment to be able to control it.

5. Usually a maintenance task may require the application of specific environmental conditions different from those previously applied, in any case what has been said must be done and the procedure to be followed is reported in the approved maintenance manuals.

6. The work environment must have a configuration such as to be able to carry out maintenance activities without distractions, in particular, if the deterioration of the working environment occurs below a certain level, ie in the case where has contamination of air, rain, snow, ice, dust, etc. maintenance activity must be suspended.

7. Both for basic and line maintenance, in the event that dust or other types of factors capable of contaminating the air reach a high level, all systems susceptible to these phenomena must be sealed until suitable conditions are established.

D. The systems dedicated to the storage of components, equipment and equipment must be able to guarantee the safety of the parts that can be put into service and the latter separated from those that cannot be used, or rather, out of service. These environments must in particular guarantee the integrity of the components mentioned in order to prevent any deterioration of the latter.

    1. So storage is necessary for components in service, compared to those not in service, in any case the storage of components that cannot be put into service is required anyway.

    2. The systems for the storage of components that can be put into service must be ventilated, dry, etc. In any case, the required environmental standard must be seen for each specific component.

    3. Storage shelves must be adequately sized based on the component you are going to place, and the latter will not be distorted during storage.

    4. All components, when possible, during storage should remain packaged so as to prevent damage and corrosion as much as possible.

    5. All components must be marked.

E. A AMO, which has different requirements than those reported in paragraph 145.49, must comply with the following requirements.
    1. The one who is requesting must provide suitable:
        i. Location for necessary equipment and materials.
        ii. Space for work based on membership rating for necessary equipment and materials.
        iii. Storage warehouses must properly separate and protect materials and components.
        iv. Structures to properly protect parts and sub-assemblies during disassembly, cleaning, inspection, repair and assembly; so that the work done is protected from atmospheric agents, dust and heat. Workers are protected so that work is not compromised by their physical efficiency; and maintenance operations have efficient and adequate facilities.

    2. The applicant must have a shop space, where the machines and crews are maintained to carry out the bench work. Every time the machinery must be kept closed when:
        i. The machines or work of the wood are close to assembly areas, so parts can be inadvertently dropped into the following parts to be assembled.

ii. Non-partitioned cleaning units are near other operations.
iii. Factory work is done in areas where there is oil and grease.
iv. The painting is done in such a way that the powder produced by the latter does not fall into disassembled parts.
v. Painting carried out near testing operation may compromise the accuracy of the equipment used.
vi. In any case, ECAA determines the need for these choices.