HINDUSTAN AERONAUTICS LIMITED
HELICOPTER DIVISION
Bengaluru 560075

INDUSTRIAL TRAINING REPORT

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PREFACE

Industrial Training, which has to be carried out outside the university, is part of the curriculum. For us, this was a great opportunity to go to HAL, apply our knowledge in a practical environment and to increase our competences.

Our assignment was to detail study the various operations followed for manufacturing a helicopter. Mr. Mallikarjuna, our supervisor at the Hindustan Aeronautics Limited, guided us very well in what contributed to the results we have obtained.

Looking back from our training, we can say that it has been a valuable and truly amazing experience. The working environment and the people at the Programme Engineering Department as well as from the other Departments are really great, which makes all the difference. This industrial training has inculcated us with immense knowledge and the experience is something that we'll reminisce forever.

ACKNOWLEDGEMENT

We would like to take this opportunity to thank all the people who have helped in the completion of this industrial training (Internship) at HAL Bangalore. At the very outlet, we convey our sincere gratitude to all people in HAL Helicopter Division for their co-operation during my industrial training period of one month. Towards the successful completion of the training, we would like to acknowledge our debt to our advisors. The training work would not have been possible without their support, encouragement and constructive comments we received from them. We also thank our coordinator Manager (ALH FA) N Mallikarjuna for his support and guidance.

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1.INTRODUCTION

1.1 ABOUT HAL

Hindustan Aeronautics Limited (**HAL**) based in Bangalore, India, is one of Asia's largest aerospace companies. Under the management of the Indian Ministry of Defence, this state-owned company is mainly involved in aerospace industry, which includes manufacturing and assembling aircraft, navigation and related communication equipment, as well as operating airports.

HAL built the first military aircraft in South Asia and is currently involved in the design, fabrication and assembly of aircraft, jet engines, and helicopters, as well as their components and spares. It has several facilities spread across several states in India including Nasik, Korwa, Kanpur, Koraput, Lucknow, Bangalore and Hyderabad. The German engineer Kurt Tank designed the HF-24 Marut fighter-bomber, the first fighter aircraft made in India.

Hindustan Aeronautics has a long history of collaboration with several other international and domestic aerospace agencies such as Airbus, Boeing, Lockheed Martin, Sukhoi Aviation Corporation, Elbit Systems, Israel Aircraft Industries, RSK MiG, BAE Systems, Rolls-Royce plc, Dassault Aviation, MBDA, EADS, Dornier Flugzeugwerke, the Indian Aeronautical Development Agency and the Indian Space Research Organisation.

HAL has 20 production divisions for manufacture and overhaul of aircraft, helicopters, engine and accessories. 10 co-located R&D Canter's to give a thrust to research & development. Which again are divided into various complexes. Each complex is headed by a Managing Director (MD).

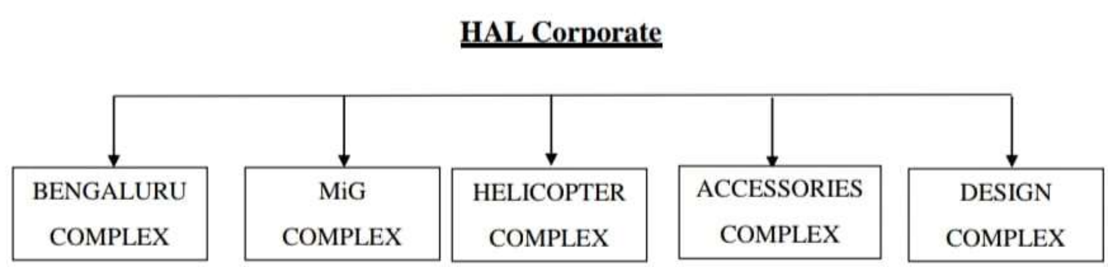


Figure 1: HAL Corporate

HAL has its five complex and several divisions in Bengaluru, Nasik, Hyderabad, Kasargod, Lucknow, Kanpur, Korwa, Barrackpore, Koraput and Liaison, and offices in Delhi, Chennai, and Visakhapatnam. HAL Nasik and HAL Koraput come under MiG Complex.

1.2 HISTORY

The Company which had its origin as Hindustan Aircraft Limited was incorporated on 23 Dec 1940 at Bangalore by Shri Walchand Hirachand, a farsighted visionary, in association with the then Government of Mysore, with the aim of manufacturing aircraft in India.

In March 1941, the Government of India became one of the shareholders in the Company and subsequently took over its management in 1942. In collaboration with the Inter-Continental Aircraft Company of USA, the Company commenced its business of manufacturing of Aircraft. In January 1951, Hindustan Aircraft Limited was placed under the administrative control of Ministry of Defence, Government of India. Dr. V.M. Ghatge flew for the first time. Over 150 Trainers were manufactured and supplied to the Indian Air Force and other customers. With the gradual building up of its design capability, the company successfully designed and developed four other aircraft i.e., two-seater 'Pushpak' suitable for flying clubs, ‘Krishak' for Air Observatory Post (AOP) role, HF-24 Jet Fighter '(Marut)' and the HJT-16 Basic Jet Trainer '(Kiran)'.

Hindustan Aircraft Limited and Aeronautics India Limited was brought about on 1st Oct 1964 by an Amalgamation Order issued by the Government of India and the Company after the amalgamation was named as "Hindustan Aeronautics Limited (HAL)" with its principal business being design, development, manufacture, repair and overhaul of aircraft, helicopters, engines and related systems like avionics, instruments and accessories.

In 1970, a separate division was set up exclusively for manufacture of 'Chetak' and 'Cheetah' Helicopters in Bangalore under licence from M/s SNIAS, France.

Design and Development of Basant agricultural aircraft was undertaken between 1970 and 1974 and design and development of Ajeet, an improved version of Gnat, was undertaken between 1972 and 1980. In 1976, projects were sanctioned for design & development of the HPT-32 elementary piston engine trainer, Kiran MK II (an improved version of Kiran MK I / IA) and Ajeet Trainer as well as for Advanced Light Helicopter.

In order to facilitate Helicopter Division, Bangalore to dedicate itself exclusively for ALH manufacture, the manufacturing and repair / overhaul activities of Chetak and Cheetah helicopters and their variants were transferred to the Barrackpore unit. A new MRO Division was created at Bangalore to carry out ALH Overhaul activities in 2006 Composites material is being used extensively in aircraft manufacturing for its low weight. A new Aircraft Composite Division (ACD) was formed in Mar 2007 with a dedicated manufacturing facility for composite materials for projects such as ALH, LCA. Facilities Management Division was created in Dec 2007 for effective and focused attention towards the common services at Bangalore.

The in-house development of Light Combat Aircraft (LCA) will give major boost to the modernization program of our Defence Services. For production of LCA, a separate LCA Tejas division was established at Bangalore in march 2014.

A new integrated facility for manufacturing of indigenous Light Utility Helicopter (LUH) is coming up at Tumakuru near Bengaluru for which the foundation stone was laid on 3rd January 2016. HAL has successfully flown Light Utility Helicopter (LUH) from the Greenfield Helicopter Manufacturing facility, Tumakuru on 29th Dec 2018.

2. ALH TRAINING

2.1 Role of Helicopters

Few roles of helicopter are as follows: -

- Patrolling
- Army troops transportation
- Warfare
- Air Ambulance
- Rescue operations

2.2 Advanced Light Helicopter (ALH- DHRUV)

The Advanced Light Helicopter (ALH-DHRUV) is a twin engine, multi-role, multi-mission new generation helicopter in the 5.5-ton weight class. The basic Helicopter is produced in skid version and wheeled version. Dhruv is “type –Certified” for Military operations by the Centre for Military Airworthiness Certification (CEMILAC) and civil operations by the Directorate General of Civil Aviation (DGCA).

2.3 Features of ALH

Features of ALH are as follows: -

- 4-Axis digital Automatic Flight Control System
- Advanced Cockpit
- Hinge less main motor
- 6-Axis freedom
- Anti-resonance isolation system
- Bearing less rear motor

2.4 Role of ALH Training

Roles of ALH training are as follows: -

- Training to newly inducted training personnel
- Familiarization of maintenance

- Pre-flight and ground training to pilots

2.5 Customers

Customers of HAL which use ALH are IAF, Navy, Army, Coast guards, Border security force, Govt. of Jharkhand, ONGC, GSI, Mauritius, Nepal, Afghanistan, Maldives, Namibia, Suriname and Ecuador

2.6 ALH Training Classification

- **Airframe:** The airframe of an aircraft is its mechanical structure. It is typically considered to include fuselage, wings and undercarriage and exclude the propulsion system. Airframe design is a field of aerospace engineering that combines aerodynamics, materials technology and manufacturing methods to achieve balances of performance, reliability and cost.
- **Power plant:** Two types of power plants used in ALH are following: -

  1. TM 333-2B2 (for DHRUV MK-I and MK-II) & ARDIDEN 1H1 SHAKTI (for DHRUV MK-III & MK-IV)

  2. Max power is 801 KW

- **Electrical**: ALH is equipped with two electrical systems both DC and AC

  1. **DC:** The DC power specifications is 28A, The DC generator also charges a 24V generator also charges a 24V battery that provides a stand by time of 30min.

  2. **AC:** 115/200V, 3-phase, 400Hz, AC power is generated by an alternator coupled to the main gear box.

- **Instruments:** There are two types of instruments system: -

  1. Direct sensing type: The measured data reaches the system directly from the sensor module.

  2. Remote sensing type: The measured data from sensor is stored and converted in a sub system and then further retried.

- **Avionics:** Avionics are the electronic systems used on aircraft, artificial satellites, and spacecraft. Avionic systems include communications, navigation, the display and management of multiple systems, and the hundreds of systems that are fitted to aircraft to perform individual functions.

3. MACHINE SHOP

A machine shop is a room or building where machining is done. In a machine shop. machinists use machine tools and cutting tools to make parts, usually of metal or plastic (but sometimes of other materials such as glass or wood). The parts produced can be the end product of the factory, to be sold to customers in the machine industry, the car industry, the aircraft industry, or others. In other cases, companies in those fields have their own machine shops

The production can consist of cutting, shaping, drilling, finishing and other processes. The machine tools typically include metal lathes, milling machines, machining centers, multitasking machines, drill presses, or grinding machines, many controlled with CNC. Other processes, such as heat treating, electroplating, or painting of the parts before or after machining, are often done in a separate facility. A machine shop can contain some raw materials (such as bar stock for machining) and an inventory of finished parts. These items are often stored in a warehouse.

3.1 Operations in Machine Shop

Various types of operations performed in machine shop are following: -

- Turning
- Grinding
- Taper Turning
- Gear Cutting
- Milling
- Drilling
- Boring

3.1.1 Turning

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helix toolpath by moving more or less linearly while the workpiece rotates. The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear (in the non-mathematical sense). The cutting of faces on the workpiece (that is, surfaces perpendicular to its rotating axis), whether with a turning tool, is called "facing", and may be lumped into either category as a subset.

3.1.2 Grinding

Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool. A wide variety of machines are used for grinding are: -

- Hand-cranked knife-sharpening stones (grindstones)
- Handheld power tools such as angle grinders and die grinders
- Various kinds of expensive industrial machine tools called grinding machines
- Bench grinders often found in residential garages and basements

3.1.3 Taper Turning

When the diameter of a piece changes uniformly, from one end to the other, the piece is said to be tapered. Taper turning as a machining operation is the gradual reduction in diameter from one part of a cylindrical workpiece to another part. Tapers can be either external or internal.

3.1.4 Gear Cutting

Gear cutting is any machining process for creating a gear. The most common gear-cutting processes include hobbing, broaching, milling, and grinding. Such cutting operations may occur either after or instead of forming processes such as forging, extruding, investment casting, or sand casting.

3.1.5 Milling

Milling is the machining process of using rotary cutters to remove material from a workpiece by advancing (or feeding) in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

Milling machines are of three types: -

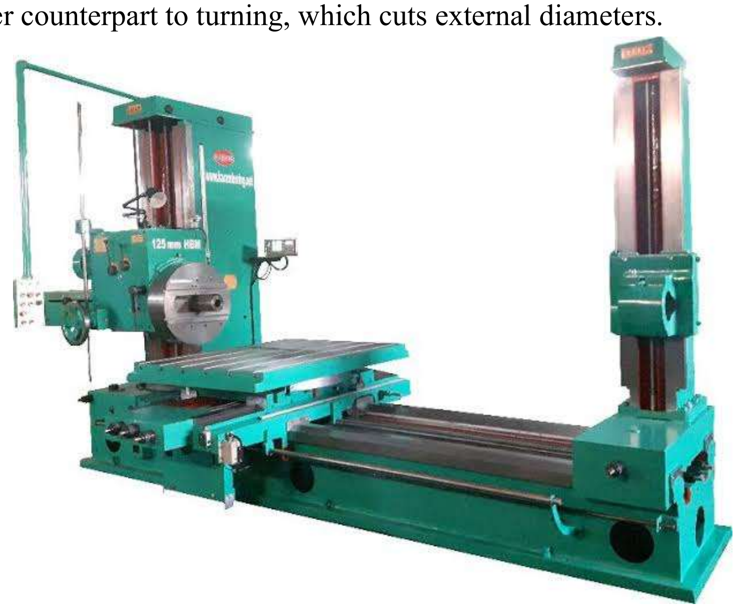
- Horizontal Milling Machine
- 2. Vertical Milling Machine
- 3. Universal Milling Machine

3.1.6 Drilling

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multipoint. The bit is pressed against the workpiece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the workpiece, cutting off chips (swarf) from the hole as it is drilled.

3.1.7 Boring

In machining, boring is the process of enlarging a hole that has already been drilled (or cast) by means of a single-point cutting tool (or of a boring head containing several such tools), such as in boring a gun barrel or an engine cylinder. Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole. Boring can be viewed as the internal-diameter counterpart to turning, which cuts external diameters.



4. HEAT TREATMENT SHOP

4.1 Heat treatment

Heat treatment is the process of heating the metal, holding it at that temperature, and then cooling it back. During the process, the metal part will undergo changes in its mechanical properties. This is because the high temperature alters the microstructure of the metal. Heat treatment involves the use of heating or chilling, normally to extreme temperatures, to achieve a desired result such as hardening or softening of a material.

4.2 Heat treatment techniques

The heat treatment techniques are as follows: -

Annealing: Annealing is a process by which the properties of steel are enhanced to meet machinability requirements. Annealing is a process of heating the steel slightly above the critical temperature of steel (723 degrees Centigrade) and allowing it to cool down very slowly.

Case hardening (Carburizing): Case-hardening or surface hardening is the process of hardening the surface of a metal object while allowing the metal deeper underneath to remain soft, thus forming a thin layer of harder metal (called the "case") at the surface.

Precipitation strengthening: Precipitation hardening, also called age hardening or particle hardening, is a heat treatment technique used to increase the yield strength of malleable materials, including most structural alloys of aluminium, magnesium, nickel, titanium, and some steels and stainless steels. In super alloys, it is known to cause yield strength anomaly providing excellent high-temperature strength.

Tempering: Tempering is a process of heat treating, which is used to increase the toughness of iron-based alloys. Tempering is usually performed after hardening, to reduce some of the excess hardness, and is done by heating the metal to some temperature below the critical point for a certain period of time, then allowing it to cool in still air.

Normalizing: Normalization is a process of heat treatment that relieves stress on steel this improves ductility and toughness in steels that may harden after the cold working process.

Quenching: Quenching is the rapid cooling of a workpiece to obtain certain material properties. A type of heat treating, quenching prevents undesired low-temperature processes, such as phase transformations, from occurring.

4.3 Furnace Types

Furnaces used in heat treatment process are following

Box-type furnace: Many basic box type furnaces have been upgraded to a semi-continuous batch furnace with the addition of integrated quench tanks and slow-cool chambers. These upgraded furnaces are a very commonly used piece of equipment for heat-treating.

Pit furnaces: Furnaces which are constructed in a pit and extend to floor level or slightly above are called pit furnaces. Workpieces can be suspended from fixtures, held in baskets or placed on bases in the furnace. Pit furnaces are suited to heating long tubes, shafts and rods by holding them in a vertical position.

Salt bath furnaces: Salt baths are used in a wide variety of heat treatment processes including neutral hardening, liquid carburizing, liquid nitriding, austempering, martempering and tempering. Parts are loaded into a pot of molten salt where they are heated by conduction, giving a very readily available source of heat. The core temperature of a part rises in temperature at approximately the same rate as its surface in a salt bath.

Vacuum furnaces: A vacuum furnace is a type of furnace in which the product in the furnace is surrounded by a vacuum during processing. The absence of air or other gases prevents oxidation, heat loss from the product through convection, and removes a source of contamination. This enables the furnace to heat materials to temperatures as high as 3,000 °C with select materials.

Muffle Furnace- A muffle furnace (sometimes retort furnace in historical usage) is a furnace in which the subject material is isolated from the fuel and all of the products of combustion, including gases and flying ash.

5. PROCESS SHOP

The surface finishing processes are been covered in process shop.

Surface finishing is a broad range of industrial processes that alter the surface of a manufactured item to achieve a certain property. Finishing processes may be employed to: improve appearance, adhesion or wettability, solderability, corrosion resistance, tarnish resistance, chemical resistance, wear resistance, hardness, modify electrical conductivity, remove burrs and other surface flaws, and control the surface friction.

5.1 Surface finishing processes

- **Metal Plating**: Metal plating machines use a chemical bath to coat or alter the surface of a substrate with a thin layer of metal, such as nickel, silver, copper & cadmium. The electroplating method generates an electric current to coat the substrate, while electrolyte plating employs an autocatalytic process in which the substrate catalyses the reaction. Metal plating provides a number of advantages as a finishing process. It can improve a product's durability, corrosion resistance, surface friction, and exterior appearance. It is also a useful option for coating other metals. In high-volume production runs, a barrel-finishing machine is a fast and efficient plating solution. However, plating machines are generally not suited for smoothing out surface defects.
- **Anodizing:** Anodizing is an electrochemical process that converts the metal surface into a decorative, durable, corrosion-resistant, anodic oxide finish. Aluminium is ideally suited to anodizing, although other nonferrous metals, such as magnesium and titanium, also can be anodized. The anodic oxide structure originates from the aluminium substrate and is composed entirely of aluminium oxide. This aluminium oxide is not applied to the surface like paint or plating, but is fully integrated with the underlying aluminium substrate, so it cannot chip or peel. It has a highly ordered, porous structure that allows for secondary processes such as colouring and sealing.
- **Pickling:** Pickling is a metal surface treatment used to remove impurities, such as stains, inorganic contaminants, rust or scale from ferrous metals, copper, precious metals and aluminium alloys. A solution called pickle liquor, which contains strong acids, is used to remove the surface impurities. It is commonly used to descale or clean steel in various steelmaking processes.
- **Powder coating:** Powder coating applies a decorative finish that is similar to paint, but with greater durability. The process involves melting dry plastic powder onto the metal

to produce a textured, matte, or glossy coating. A textured powder-coating machine is also highly effective in removing surface defects.

- **Abrasive blasting:** Abrasive blasting is the operation of forcibly propelling a stream of abrasive material against a surface under high pressure to smooth a rough surface, roughen a smooth surface, shape a surface, or remove surface contaminants. A pressurized fluid, typically compressed air, or a centrifugal wheel is used to propel the blasting material.

5.2 Choosing a Metal Finishing Process

There are a few considerations that can help to narrow the choices in selecting a metal finishing technique suitable for the project. Some helpful things to keep in mind are: -

- Production speed & Process speed
- Cost-effectiveness: Certain finishing machines (such as vibratory tumblers) can be expensive, but may compensate for their price by delivering faster cycle rates
- Metal hardness: Harder metals usually require more intense finishing techniques, like grinding, or may need tougher abrasives than those used on softer materials

6. WELDING & SHEET METAL SHOP

6.1 Welding

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing fusion. In addition to melting the base metal, a filler material is typically added to the joint to form a pool of molten material (the weld pool) that cools to form a joint that is usually stronger than the base material. Pressure may also be used in conjunction with heat, or by itself, to produce a weld.

Manufacturing nearly any modern product involves joining various separate components. When a permanent joint is required, welding is commonly used.

Different types of energy sources can be used for welding includes gas flames, electric arc, laser, electron beam, friction & ultrasound.

There are two categories of welding process:

Fusion welding: The surface of two components to be joined are cleaned placed close together and heated, forming a pool of molten metal that connects the components. A filler rod may be used to add metal to the joint.

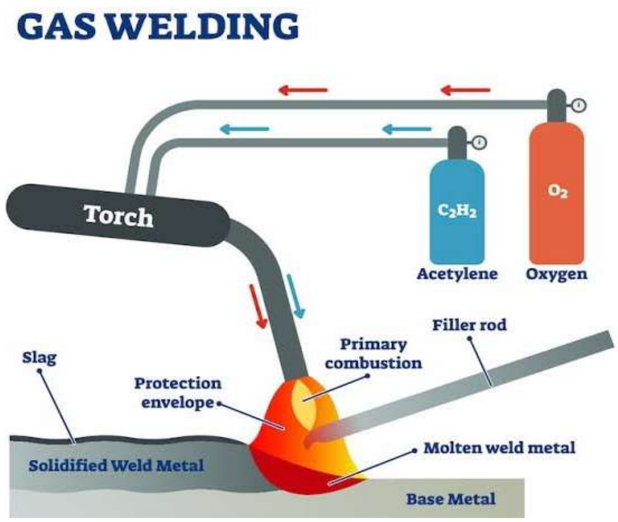
Pressure welding: A pressure welding process in which macro deformation of the base material to produce coalescence results from the application of heat and pressure. Pressure welding usually involves heating the surfaces to a plastic state and then forcing the metal together. The heating can be by electric current of by friction resulting from moving one surface relative to the other.

6.1.1 Types of welding

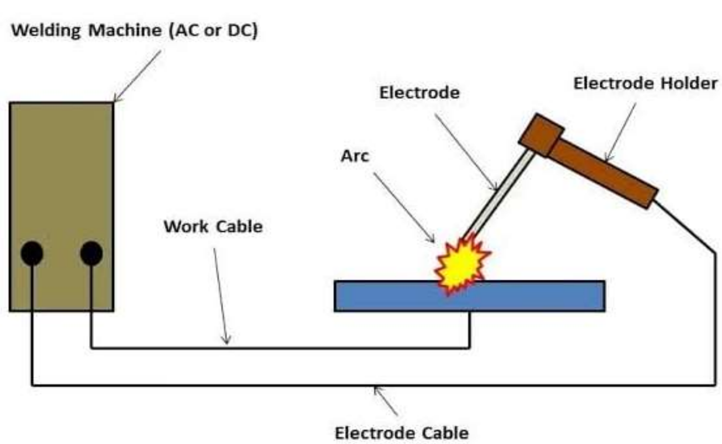
Types of welding which are available in HAL are:

- Gas welding
- Electric Arc Welding
- TIG (Tungsten Inert Gas) Welding
- Spot Welding

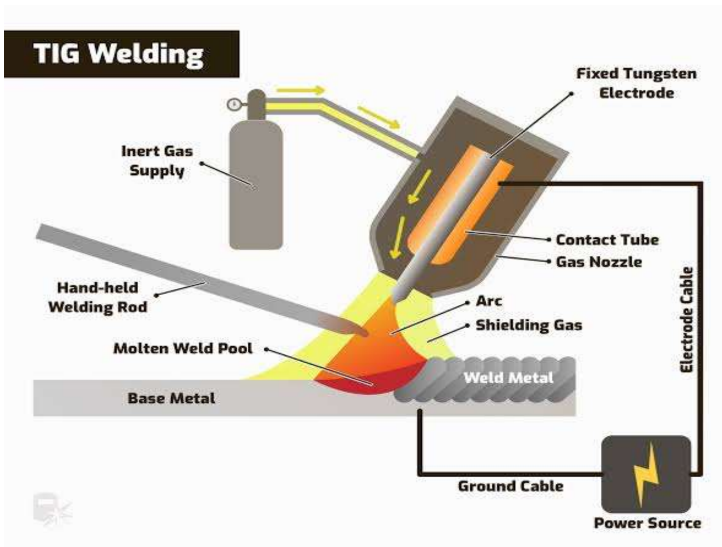
Gas Welding: Oxy-fuel welding (commonly called oxyacetylene welding, oxy welding, or gas welding in the U.S.) and oxy-fuel cutting are processes that use fuel gases and oxygen to weld and cut metals. In oxy-fuel welding, a welding torch is used to weld metals. Welding metal results when two pieces are heated to a temperature that produces a shared pool of molten metal. The molten pool is generally supplied with additional metal called filler. Filler material depends upon the metals to be welded. Oxy-fuel processes may use a variety of fuel gases, the most common being acetylene. Other gases that may be used are propylene, liquefied petroleum gas (LPG), propane, natural gas, hydrogen, and MAPP gas. Many brands use different kinds of gases in their mixes.



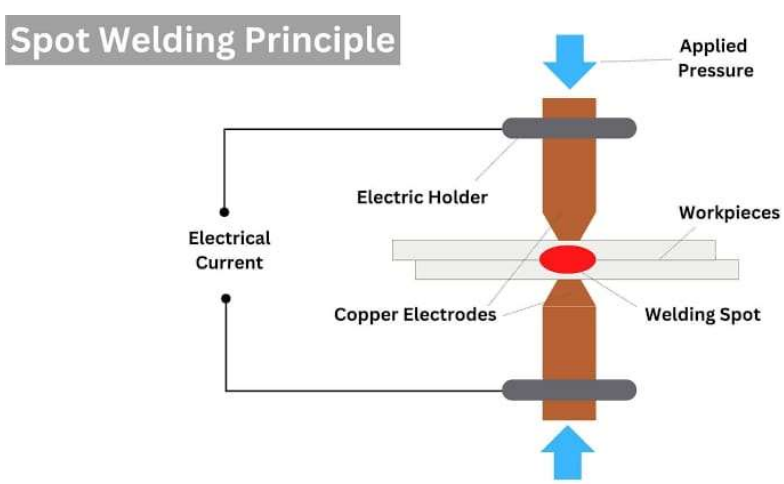
Electric Arc Welding: Arc welding is a process that is used to join metal to metal by using electricity to create enough heat to melt metal, and the melted metals when cool result in a binding of the metals. It is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes.



TIG Welding: Tungsten Inert Gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area and electrode is protected from oxidation or other atmospheric contamination by an inert shielding gas. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapours known as a plasma.



Spot welding: Resistance spot welding (RSW) is a process in which contacting metal surfaces are joined by the heat obtained from resistance to electric current. Work-pieces are held together under pressure exerted by electrodes. The process uses two shaped copper alloy electrodes to concentrate welding current into a small "spot" and to simultaneously clamp the sheets together. Forcing a large current through the spot will melt the metal and form the weld.



6.2 Sheet Metal

Sheet metal is metal formed by an industrial process into thin, flat pieces. It is one of the fundamental forms used in metalworking and it can be cut and bent into a variety of shapes. Countless everyday objects are fabricated from sheet metal. Thicknesses can vary significantly; extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.

There are different types of sheet metal processes available in HAL Bangalore are:-

Bending: Bending is a manufacturing process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials.

Punching: Punching is performed by placing the sheet of metal stock between a punch and a die mounted in a press. The punch and die are made of hardened steel and are the same shape. The punch is sized to be a very close fit in the die. The press pushes the punch against and into the die with enough force to cut a hole in the stock.

7. BLADE SHOP

Blade shop consist of the following: -

- Manufacturing of MRB and TRB
- Repairing of MRB and TRB
- Static balancing tests for MRB and TRB

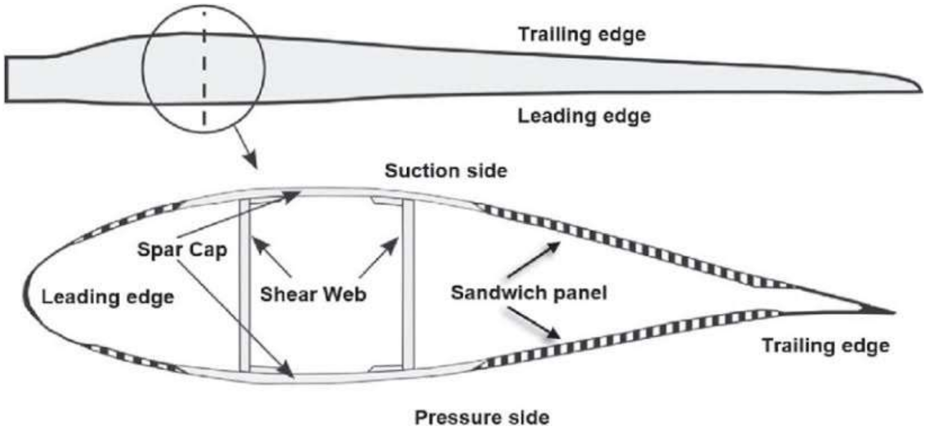
7.1 Procedure for Blade Manufacturing

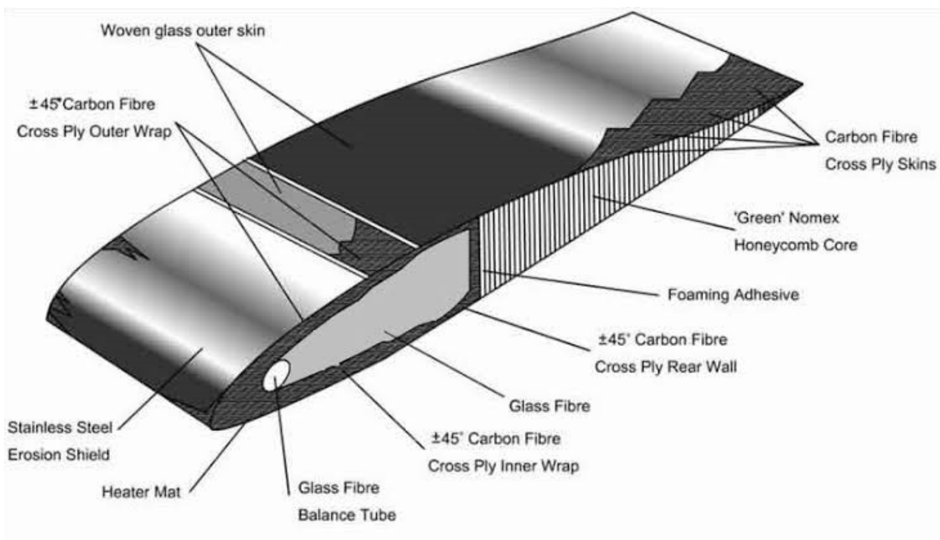
The MRB & TGB for Cheetah and Cheetal (further modification of Cheetah Helicopter) are been manufactured and repaired for these Aircrafts.

The process of manufacturing of MRB is described in steps below: -

- 0.4 mm thick sheet of Aluminium alloy (having **ASTM B289**)
- Vapour Blasting with air, water, sand.
- **Sulfochromic pickling** to remove excess water, sand, oil or grease.
- Folding the sheet into desired shape (symmetric airfoil-**NACA0012**) with the help of jigs and a mechanical press (using dead weight).
- Adding steel cuff and spar with the help of adhesive filling and heating it at 60°C for 15 min.
- Filling the inner space with **moltoprene** foam material.
- Applying liquid **araldite** at the opening and let it heat at 165°C for 2 hours in oven for bonding,
- Let it cool and get riveted and for providing the twist angle (6°) again heat it at 60°C for 5 hours with the help of UV bulbs in a specific mould.
- Paint will be done after letting the blade cool.
- After paint static balancing will be done and some weight will be added at the tips of the blades (4gm to 40gm each).
- Protective casing will be added and all the screws and rivets are applied and sent for the dynamic test.
- For dynamic test the blade will be mounted on the transmission test unit and vibration tests will be performed and some free weight will be added on the certain points.

- Now the last part of blade manufacturing the necessary markings will be done to denote the blade type and design year and manufacturer logo.





7.2 Servicing

The ideal life of a single blade is about 6000 hours or 20 years but need to check after 4-5 years.

In repairing of the blades static and dynamic test takes place if the blades are been having any inner problems the disassembly of the blades takes place and the whole procedure mentioned above is repeated.

8. STRUCTRAL ASSEMBLY

8.1 Types of Helicopter Construction

It can be divided into 3 categories such as

- Tubular construction
- Stressed construction
- Bonded construction

8.1.1 Tubular Construction

This type of structure is still in use in many lightweight aircraft using welded steel tube trusses. A box truss fuselage structure can also be built out of wood—often covered with plywood. Simple box structures may be rounded by the addition of supported lightweight stringers, allowing the fabric covering to form a more aerodynamic shape, or one more pleasing to the eye. E.g., Cheetah, Cheetal.

8.1.2 Stressed Skin Construction

High strength to weight ratio than tubular construction.

Semi-monocoque: It consists of frameworks of vertical and horizontal members covered with metal skin. Vertical members are called bulkhead and formers provide the shape of fuselage. Longerons provide the primary strength while Stiffeners gives mean of attaching and stiffening the skin.

Monocoque: Its construction involves the construction of tubes and cones without internal structural members. It's is necessary to have formers to maintain the shape but it's the stressed skin that carries the principle stress imposed upon the structure. E.g., Chetak, Chetan.

8.1.3 Bonded construction

In this type of construction, the structural parts are joined together by the chemical methods. Fibre glass, honeycombs and other composite materials that are used in the structure by the use of adhesive, heat and pressure. E.g., Dhruv, LCH

8.2 Different sections of helicopter structure

Body structure: It is the main structural member of the fuselage. It does not only carry the load and thrust but also the landing load. It supports all other member directly or indirectly. Transmission assembly main rotor is also support by this. In the middle of this structure fuel tank is placed.

Bottom structure: It's made up of two cantilevered beams extending from the box to the cross members of the box. The two beams carry the weight of the cabin and transmit it to the box. The cabin section is directly attached to the floor.

Cabin section: It's made almost entirely from synthetic material. Its heat moulded and assembled by ultra-sonic spot welding or riveted to the cabin floor and bulkhead.

Rear section: Connects to the body section. It's made up of 3 frames connected by the beam to the body section. This frame covered with firewall material and act as an attachment point of the engine. Tail boom section is also bolted to the rear section.

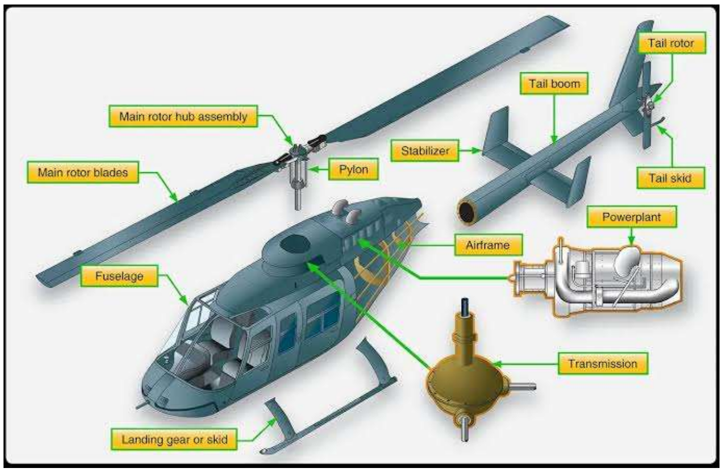
Tail boom section: It consists of tail rotor which provides both the anti-torque and direction. It also includes the drive shaft, tail gear box, vertical fins, horizontal stabilizers, and tail skid. It's of conventional design-circular frames, longerons and outer skins.

Vertical and Horizontal Stabilizers: Fin is bolted to the tail boom at leading edge and spar of section of the fin. It is protected by the tail rotor guard.

Horizontal stabilizers produce downward forces to keep the helicopter level in forward flight. It passes through slot and in the tail boom and bolted on each side.

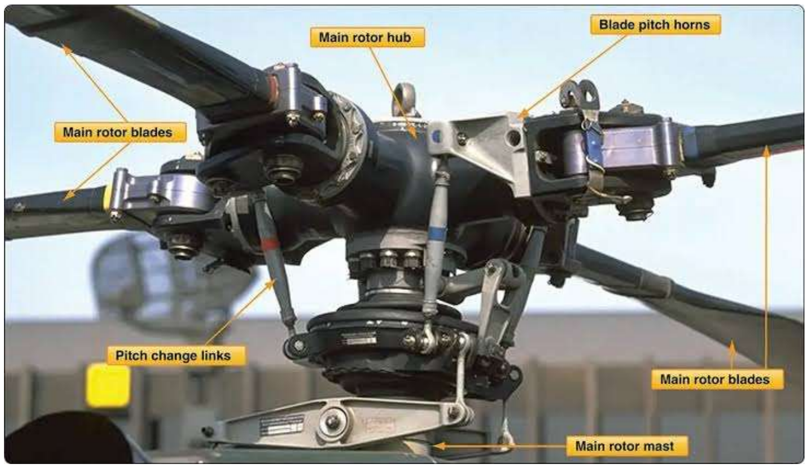
9. TRANSMISSION ASSEMBLY

The transmission system transfers power from the engine to the main rotor, tail rotor, and other accessories. The main components of the transmission system are the main rotor transmission, tail rotor drive system, clutch, and freewheeling unit. Helicopter transmissions are normally lubricated and cooled with their own oil supply. A sight gauge is provided to check the oil level. Some transmissions have chip detectors located in the sump. These detectors are wired to warning lights located on the pilot's instrument panel that illuminate in the event of an metal shavings are detected, indicating an internal problem.



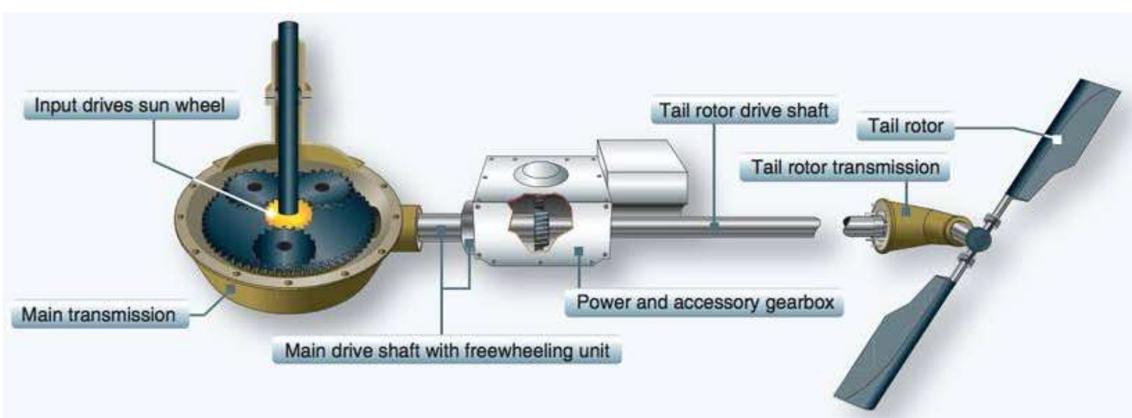
9.1 Main Rotor Transmission

The primary purpose of the main rotor transmission is to reduce engine output RPM to optimum rotor RPM. Suppose the engine speed of a specific helicopter is 2,700 RPM. Achieving a rotor speed of 450 RPM would require a 6 to 1 reduction. A 9 to 1 reduction would mean the rotor would turn at 300 RPM. Most helicopters use a dual-needle tachometer to show both engine and rotor RPM or a percentage of engine and rotor RPM. The rotor RPM needle normally is used mostly during clutch engagement to monitor rotor acceleration and in autorotation to maintain RPM within prescribed limits. See figure 3-1. In helicopters with horizontally mounted engines, another purpose of the main rotor transmission is to change the axis of rotation from the horizontal axis of the engine to the vertical axis of the rotor shaft. The primary purpose of the main rotor transmission is to reduce engine output RPM to optimum rotor RPM. Suppose the engine speed of a specific helicopter is 2,700 RPM. Achieving a rotor speed of 450 RPM would require a 6 to 1 reduction. A 9 to 1 reduction would mean the rotor would turn at 300 RPM. Most helicopters use a dual-needle tachometer to show both engine and rotor RPM or a percentage of engine and rotor RPM. The rotor RPM needle normally is used mostly during clutch engagement to monitor rotor acceleration and in autorotation to maintain RPM within prescribed limits. See figure 24. In helicopters with horizontally mounted engines, another purpose of the main rotor transmission is to change the axis of rotation from the horizontal axis of the engine to the vertical axis of the rotor shaft.



9.2 Tail Rotor Drive System

The tail rotor drive system consists of a tail rotor drive shaft powered from the main transmission and a tail rotor transmission mounted at the end of the tail boom. The drive shaft may consist of one long shaft or a series of shorter shafts connected at both ends with flexible couplings. This allows the drive shaft to flex with the tail boom. The tail rotor transmission provides a right-angle drive for the tail rotor and may also include gearing to adjust the output to optimum tail rotor RPM.



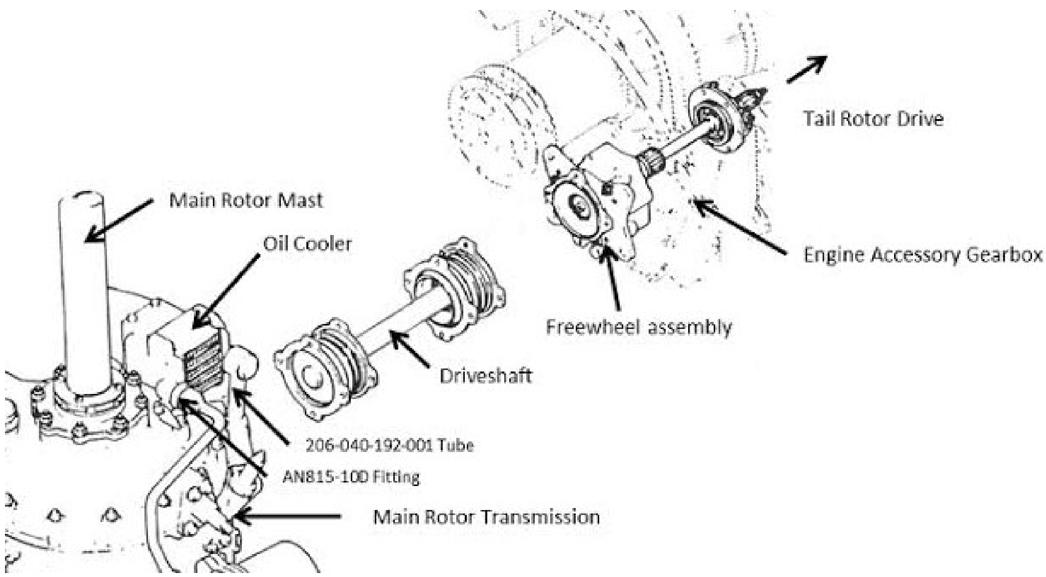
9.3 Clutch

Owing to the greater weight of a rotor in relation to the power of the engine, as compared to the weight of a propeller and the power in an airplane, the rotor must be disconnected from the engine when you engage the starter. A clutch allows the engine to be started and then gradually pick up the load of the rotor. On free turbine engines, no clutch is required, as the gas producer turbine is essentially disconnected from the power turbine. When the engine is started, there is little resistance from the power turbine. This enables the gas producer turbine to accelerate to normal idle speed without the load of the transmission and rotor system dragging it down. As the gas pressure increases through the power turbine, the rotor blades begin to turn, slowly at first and then gradually accelerate to normal operating RPM. On reciprocating helicopters, the two main types of clutches are the centrifugal clutch and the belt drive clutch.

- **Centrifugal Clutch**: The centrifugal clutch is made up of an inner assembly and an outer drum. The inner assembly, which is connected to the engine driveshaft, consists of shoes lined with material similar to automotive brake linings. At low engine speeds, springs hold the shoes in, so there is no contact with the outer drum, which is attached to the transmission input shaft. As engine speed increases, centrifugal force causes the clutch shoes to move outward and begin sliding against the outer drum. The transmission input shaft begins to rotate, causing the rotor to turn, slowly at first, but increases as the friction between the clutch shoes and transmission drum increases. As rotor speed increases, the rotor tachometer needle shows an increase by moving toward the engine tachometer needle. When the two needles are superimposed, the engine and the rotor are synchronized, indicating the clutch is fully engaged and there is no further slippage of the clutch shoes.
- **Belt Drive Clutch**: Some helicopters utilize a belt drive to transmit power from the engine to the transmission. A belt drive consists of a lower pulley attached to the engine, an upper pulley attached to the transmission input shaft, a belt or a series of V-belts, and some means of applying tension to the belts. The belts fit loosely over the upper and lower pulley when there is no tension on the belts. This allows the engine to be started without any load from the transmission. Once the engine is running, tension on the belts is gradually increased. When the rotor and engine tachometer needles are superimposed, the rotor and the engine are synchronized, and the clutch is then fully engaged. Advantages of this system include vibration isolation, simple maintenance, and the ability to start and warm up the engine without engaging the rotor.

9.4 Freewheeling Unit

Since lift in a helicopter is provided by rotating air foils, these air foils must be free to rotate if the engine fails. The freewheeling unit automatically disengages the engine from the main rotor when engine RPM is less than main rotor RPM. This allows the main rotor to continue turning at normal in-flight speeds. The most common freewheeling unit assembly consists of a one-way "sprag" clutch located between the engine and main rotor transmission. This is usually in the upper pulley in a piston helicopter or mounted on the engine gearbox in a turbine helicopter. When the engine is driving the rotor, inclined surfaces in the sprag clutch force rollers against an outer drum. This prevents the engine from exceeding transmission RPM. If the engine fails, the rollers move inward, allowing the outer drum to exceed the speed of the inner portion. The transmission can then exceed the speed of the engine. In this condition, engine speed is less than that of the drive system, and the helicopter is in an autorotative state.



10. FINAL ASSEMBLY

Final Assembly is the final stage in the manufacture of a helicopter. During final assembly, subassemblies and other components are installed into the airframe. These parts come from internal and 17 external suppliers around the world. Quality checks and operational checks are performed as assembly progresses. Flight operations include painting defueling of the aircraft, performing a ground run to ensure proper operation of aircraft systems prior to flight, and passing flight acceptance tests.

Final assembly begins with receipt of the airframe. The airframe is the basic fuselage structure of the aircraft and is constructed of sheet metal or, in some cases, composite materials. During final assembly, subassemblies and other components are installed into the airframe. Systems installed include the wiring, tail rotor pylon, exhaust systems, engines, transmission, oil cooler, control systems, and avionics. The final assembly build is comprised of hundreds of installations to install these systems into the helicopter. Each installation is called an AOS (Assembly Operation Sequence). Each AOS consists of many operations that must be followed to ensure proper assembly of the helicopter. These include quality checks performed by the Quality Assurance (QA) department. If there is a problem with the installation of a component, QA inspectors record the problem, and it must be fixed before that operation can be completed and signed off.

The structure of the helicopter is installed with the various systems such as transmission, electrical, avionics, automatic flight control system, missile system integration and weapon system integration.

It also includes the mounting of the helicopter blades.

Final paint job and finishing of the helicopter is done as per the requirements of the customer.

10.1 Electrical System

- There are 3 main system for electrical power- EPR (electrical power receptacle), generators and battery.
- EPR provide power to helicopter externally when it is on the ground.
- Generators is the primary source for 28 V DC power and also charges the batteries.
- It is also including the various lighting installed on the helicopter.
- Integrated Architectural Display has two DMC (display management computer), two DIU (digital interface unit), two CDS (cockpit display unit) and four MFDs (main flight display).

- FADEC (fully authority digital engine control) controls the sequence for engine starting engine idling and engine shutdown. The ALH FADEC control also comes with auto reflight features which is a system that executes the start up when a previous attempt has failed, usually used for cold starts.

10.2 Avionics

- Intercom which enables the communication between the pilot and the co-pilot.
- HFSSB (high frequency single sideband) communication is used to send messages over long distances but is rarely used due to excessive interference.
- V/UHF is used to enable the communication exterior to the aircraft.
- IFF (identification of friend and foe) is a system that transmit a coded message that contains the information about the pilot, the squadron he’s flying. A friend aircraft will have the same system transmit back a message of the same format and a foe aircraft will not.
- MADRAS also known black box contains two module FDR (flight data recorder) and CVR (cockpit voice recorder). It can withstand up to 3400g, 260°C for 10 hours and 1100°C for 1 hour.

10.3 AFCS (Automatic flight control system)

- It contains a PCU (pilot control unit), AFSC computer, AHRS (attitude and heading reference system), ADU (air data unit), Vertical Gyro and Magnetometer.
- The AFCS has a control module in the cockpit that has the following functions: hold height, hover height, airspeed, turn coordinator and heading.

10.4 MSI (Mission system integration)

- EW (electronic warfare) Suite contains the three sensors i.e. missile, laser and radar in four quadrants. It can detect an approaching missile radar tracking signal and laser tracking signals falling on the helicopter.
- FCD (flare and chaff dispenser) is a counter measure system that dispenses high temperature flares or metallic chaffs, to divert heat sinking and metal seeing missiles respectively.

- HPS (helmet pointing system) comes in the form of HUD (head up display) manufactured by IAI (Israel aerospace industries).The system comprises of a set of cameras and laser device that scan the retina of the eye and project a virtual screen.
- EO (electro optical) pod is a spherical module that contains two cameras, one for day time use and one for night vision.

10.5 WSI (Weapon system integration)

- Weapon Jettison is a system to designed to dispense all weapons when a crash landing might occur.
- Turret gun is a gun of capable of firing 300 round at once.
- ALH is capable of carrying the four missiles. The missile firing system is at a default to fire the outboard missiles first.
- ALH can also carry four rocket launchers that can house 12 rockets.
- Fixed Sight is a system used to guide the missiles. It uses EO pod to pin point the target and guide the missiles.

11. CIVIL HELICOPTERS

To exploit the national and international market potential in the 4–5-ton weight class, Civil Variant of ALH was taken up. It is mainly intended to be used in the transport role, commuter, offshore as well as VIP roles. Additional roles such as emergency medical service, rescue, utility, law enforcement is also envisaged. First flight of ALH civil variant was carried out successfully on 6th Mar'2002 & demonstrated at Aero-India 2003 and 2005. Certification for Civil wheel version was obtained in Oct.'03 and for civil Skid Version obtained in Jul.'04. PT-2 basic version was converted to Air Ambulance version and demonstrated during Aero India 2001. Further, ALH capabilities were successfully demonstrated in Chile with IAI-LAHAV's centralized avionics package. After the successful Type certification of ALH civil variant up to five ALH civil helicopters are in service with various operators like ONGC, IAI, BSF, GSI and Govt. of Jharkhand.

The revalidation of ALH civil variant Type Certificate with DGAC, Chile has been completed in April 2007. This is the first re-validation accorded by any foreign airworthiness authority to an Indian Aircraft.

The certification with EASA is under progress and FAA is being pursued

MK-I

It is a Utility Version with Conventional Cockpit & 2B2 Engine, its specifications are described below:

- Max take-off Weight: 5500 Kg
- Fuel Capacity: 1055 Kg
- Useful Load: 2490 Kg
- Never exceed speed: 295 km/h
- Service Ceiling: 6500 m
- Under Slung: 1500 Kg

Mk-II

It is a Utility Version with Glass Cockpit & 2B2 Engine, its specifications are described below:

- Max take-off Weight: 5500 Kg
- Fuel Capacity: 1055 Kg
- Never exceed speed: 292 km/h
- Useful Load: 2100 Kg
- Service Ceiling: 6500 m
- Under Slung: 1500 Kg

MK I

MK II

MK III

MK IV

Civil variants

Dhruv (C): Also known as ALH-Civil, a Turbomeca TM333-2B2-powered 12-seat helicopter, type certificate issued on 31 October 2003.

Dhruv (CFW): A Turbomeca TM333-2B2-powered 12-seat helicopter fitted with wheels, type certificate issued on 20 April 2005.

Dhruv (CS): A Turbomeca TM333-2B2-powered 12-seat helicopter fitted with skids, type certificate issued on 30 July 2004.

Garuda Vasudha: A Dhruv outfitted with a heliborne geophysical survey system (HGSS).

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