A Report on Industrial Training
Undertaken at Foundry & Forge Division, HAL (BC)

In partial fulfillment of the requirement for the award of the Degree of Bachelor of Technology in Metallurgical & Materials Engineering from National Institute of Technology Karnataka- Surathkal (NITK).

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CONTENTS

OVERVIEW

The foundry and Forge division at Bangalore was established in 1974 for meeting the requirements of components for aircraft and engines manufactured under licence as well as indigenous design and development programs. Today, The Foundry and Forge Division at HAL Bangalore Complex, manufactures various products by different techniques like Castings, Forgings etc. which manufactures products like Brake pads, Rubber items and Seamless Rings, mainly for aircraft applications. Various materials like Steels, Aluminium alloys, Magnesium alloys, Nickel alloys, Titanium alloys are used for these purposes. The division is an ISO 9002 Company, with the seal of approval from NADCAP, DGCA, DGAQA, Rolls Royce, BAE Systems, Garrett and Schweizer, USA.

PRODUCTION SHOPS:

- Powder Metallurgy
- Ferrous Foundry
- Non ferrous foundry
- Pattern shop
- Rubber shop
- Ring rolling
- Magnesium foundry
- Precision foundry
- General forge
- Die shop

- Machine shop
- Precision forge
- Shape memory

OTHER DEPARTMENTS:

- CMPL (LAB)
- Quality control
- Development department
- HR
- Marketing & Stores

POWDER METALLURGY SHOP

INTRODUCTION

The Powder Metallurgy Shop of the division manufactures Copper and Iron-based brake pads and bimetallic anti-friction bushes for aircraft. The unit has the capability to design, develop, manufacture and test military and Civilian Aircraft brake pads. The DGAQA and DGCA have approved the unit for the design, development, manufacture, and testing of military and civilian aircraft brake pads.The powder selected undergo heat treatment and purity tests

In HAL three types of brake pads are manufactured

Iron type – has more life and is used in heavy aircrafts

Copper – used in high-temperature conditions and has the ability to withstand high kinetic energy.

Organic / non-metal – Used in lighter aircrafts

STEPS IN POWDER METALLURGY

Basically, there are 4 different steps in powder metallurgy:

- Blending (mixing)
- Solidification (compaction)
- Sintering
- Finishing

1. BLENDING: It is defined as the thorough intermingling or mixing of powders of the same nominal composition. The implication with blending is that the constituents in the vessel are virtually identical except for some minor physical characteristics This is done using a double cone mixer. Blending can take anywhere from 6 to 8hrs. This yields a necessity to choose an optimum blending time for any particular case of the mixture to provide a compromise between the mixture homogeneity and mean fibre length. 2.COMPACTION: The friction material powder is pressed or compacted in 250 Ton press various parameters are considered while solidification such as load. application tool used and type of machine used.

3.SINTERING: It is a heat treatment applied to a powder compact in order to impart strength and integrity. The temperature used for sintering is below the melting point of the major constituent of the Powder Metallurgy material, during this operation density and bonding improved

. Hydrogen pusher furnace for powder reduction and bulk sintering is used

· For loose sintering Loading of charge boats in pusher furnace

· Stacking of green friction compacts and backing frames for pressure sintering

· Heating hood of furnace lifted after sintering

4. FINISHING – It is the process of removal of unwanted materials from the product. This is done by Coining or warpage removal and Dimension control machine.

The advantages of powder metallurgy over casting or forging is that it involves less machining and alloys of any composition can be used since dissolution is not involved.

MIG 27 Aircraft (Nose wheel)

Max energy – 12MJ Life – 250 landings.

FERROUS FOUNDRY

INTRODUCTION

Ferrous Foundry is specialized in the production of the bimetallic brake sector for the MIG21 project through the CO_2 mold process. The shop has a capacity of 200 tonnes of metal melt capacity per annum per shift on an operational basis.

PROCESS

- **SAND PREPARATION**: The first stage of the process was to mix the sand required to produce the casting. This started by mixing dry silica sand along with tetra amine and dextrin used as a releasing and binding agent respectively. These chemicals were then placed in a rotating mixer to form a uniform sand mix. To this mix was added sodium silicate, sodium silicate has a unique binding quality when exposed to carbon dioxide gas thus helping in the production of a stronger mold. The mix produced was then placed into a specially designed mold box with the pattern of the casting placed in it; holes were then made through the sand (called vent holes). Through these holes, carbon dioxide gas was passed, as explained above the presence of sodium silicate caused the sand to warp and become strong and stiff. The main form of pattern used was a single pattern and there were two mold boxes one containing the shape required and the other the means required for the flow of the liquid metal.

- **CASTING PROCESS**: The basic process of casting is to pour molten metal into a mold of a certain shape and dimension to produce the same shape of the mold. As seen above the mold required was set and then we learned of the method used for producing the molten metal. Molten metal is basically or commonly known as liquid metal, in the foundry we saw that the molten metal was produced by the use of an induction furnace, the induction furnace works on the principle of electrical induction through the use of coils, through which heat is produced which then causes the metal to melt. To the furnace

was an added raw piece of pig iron which was melted and to which various chemicals were added to get the required amount of carbon in the metal. When the metal had reached the required temperature for pouring (found to be about 1540ºC) the mold boxes were laid out and were pre-baked using an open flame passed into the boxes.

- To produce the bimetallic pads pre-manufactured steel plates were placed into the molds over which the molten metal would be poured.
- Once the metal and the molds were ready for pouring with the help of a ladle the metal was poured into the mold boxes through the gating systems provided in the boxes. The metal was then allowed to rest in an open environment and allowed to cool back to room temperature. Once this was done the mold box was broken open and the solid metal that remained was extracted. By the use of fettling tools, the excess sand and material on the cast were removed and a rough cast plate was found, the plate was then sandblasted (the process of producing a smooth surface by jetting sand at high velocities to impinge on the surface of the cast thus producing a smooth finish), sandblasting help in preventing the new cast from gathering rust from the environment. The finished cast was then sent to the machine shop for further processing.
- Different Furnaces are:- 1) Electrical Induction 2) Oil fired furnace 3) Gas-fired furnace
- For heat insulation uses sand bricks And the continuous flow of water

NON-FERROUS FOUNDRY

At HAL F&F division magnesium casted products are made and these come under non-ferrous foundry. such dissolved gases. Air or nitrogen is used for purging the dissolved gases. Once the melMAGNESIUM FOUNDRY

INTRODUCTION

Magnesium foundry is unique and the only largest magnesium foundry in the country. It has developed and manufactured complicated casting for aeronautical and aerospace applications. Its internal customers are the helicopter division, engine division, aircraft division, Lucknow division, Kanpur division, etc. of HAL. The shop has a melting capacity to melt and cast 115-Tonnes of Magnesium alloy per annum. Products made here are used in casings and gearboxes of flights.

Magnesium is very reactive so sand moulds are used. Zirconium oxide and Alcohol mixtures are used in the sand as binders, these binders are proportionately mixed. Sand used here is imported from Saudi Arabia. The cast is poured into mould at temperature 750-770 degree Celcius. Three types of casts are used

1. Magnesium -96%, Zinc-4%
2. Magnesium-95%, Aluminium-5%
3. Magnesium-98%, Silver-2%

Some common defects found are shrinkage, blowholes, segregation, cracks, cold shots and inclusions. To avoid inclusions chill moulds and metal castings are used. During pouring of metal sulphur dust is added to avoid burning. Sand powder as fire extinguisher

PRECISION FOUNDRY (INVESTMENT CASTING*)*

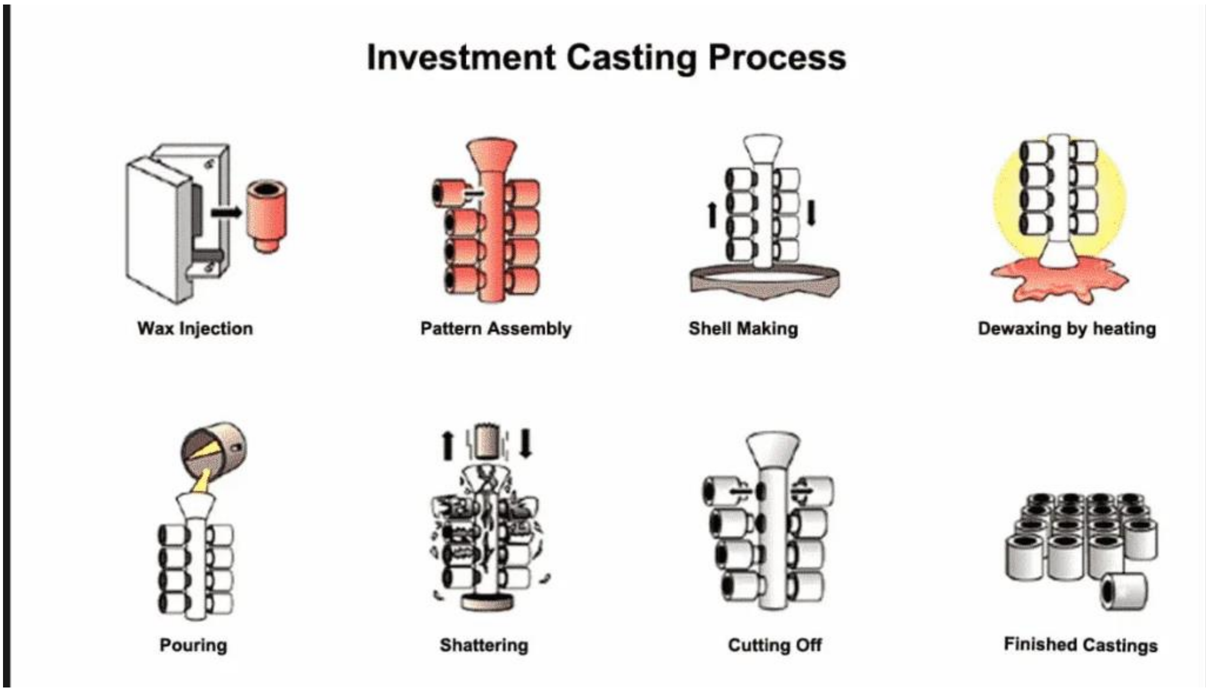
INTRODUCTION

Precision foundry is engaged in the development and manufacture of precision investment casting for aeronautical applications. It caters mainly to other divisions of HAL, particularly the Aero-engine division. Helicopter division, aircraft division, Kanpur & Lucknow division.

PROCESS

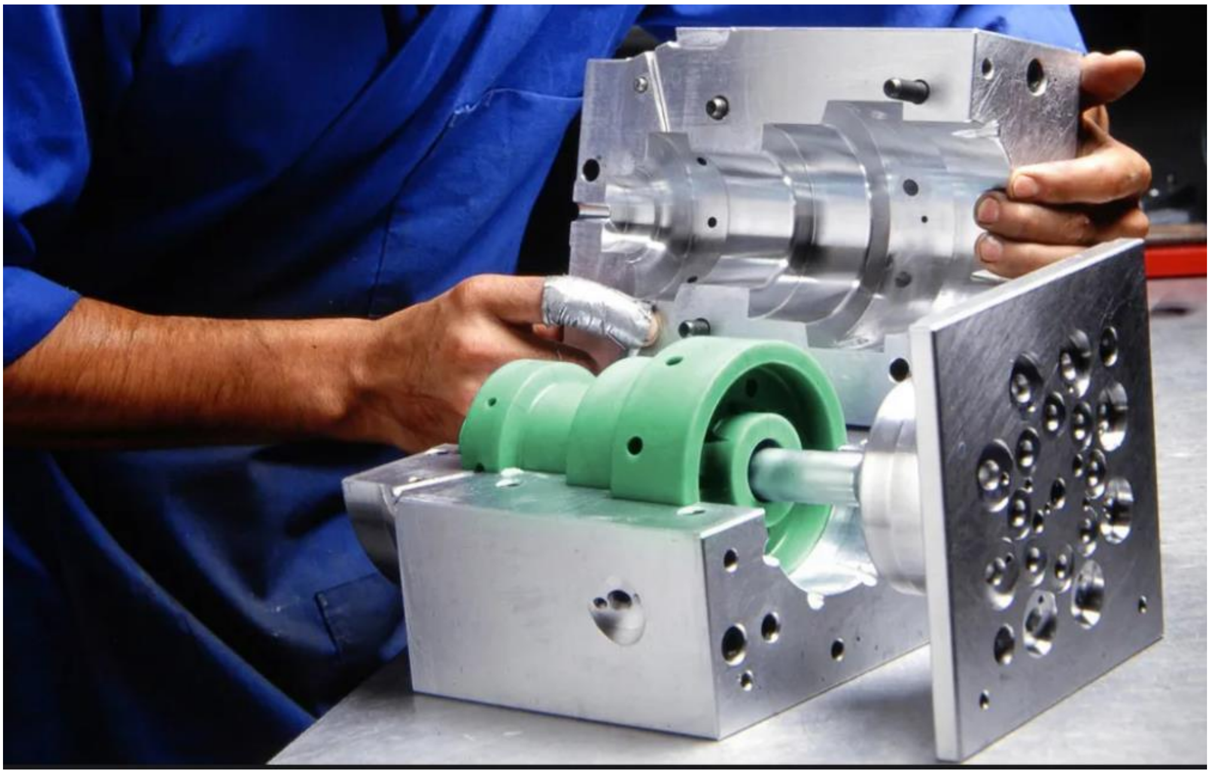
- The wax is injection molded into a master die, made of Aluminium. It is injected in such a manner as to cover the inner surface of the mold uniformly.
- Multiple wax patterns are created and joined together by a wax gating system, consisting of a runner and sprue, to form a ‘wax tree’. The wax patterns are then dressed to make the wax look like the finished piece.
- The wax tree is dipped into a slurry of fine refractory material (primary slurry), like zircon sand. Any excess is drained off, to produce a uniform coating. The fine material gives a smooth surface finish and reproduces the fine details. Then it is kept to dry for 4 to 5 hours.
- After that, it is stuccoed with coarser sand. The coating is allowed to harden for 4 to 5 hours.
- The above steps are repeated to give the required thickness of the coating. For Aluminium alloys, 8 such coatings are required. For steels, 6 coatings are applied. Binders, like colloidal silica, are used to hold the refractory material together.
- The investment is then dried, which takes about 16 to 48 hours. It is then put into an autoclave to melt and remove all the wax.
- Secondary firing is done to remove any remaining wax and moisture. The investment is then preheated. This is done to increase the dimensional accuracy of the final casting.
- The molten metal is produced by melting metal in vacuum heating furnaces or resistance heating furnaces. The liquid metal is sent for spectral analysis, to check the composition.
- It is then poured into the investment, which has been placed cup-upwards in a tub filled with sand.
- After the solidification of metal, the shell is knocked out using vibrations.
- The sprue is removed, and the final casting is subjected to sandblasting.

The casting is near the net which means that it is very close to the final shape required of the product, reducing the need for machining. The schematic diagram of the process is shown below:



Investment Casting Whole Process

Robots to do coatings (Shell Maker)



Making Wax Patterns

INFRASTRUCTURE

- Wax pattern injection machine
- Wax pattern assembly facility
- Ceramic shell preparation
- Dewaxing autoclave
- Vacuum induction melting for superalloys
- Aluminium oxide grit blasting
- Induction air melting

- Heat treatment including vacuum heat treatment
- Radiography using x-rays and other non-destructive tests
- Robotic shell maker

WHY DO WE NEED INVESTMENT CASTING?

- Intricate shape
- Close tolerances
- Small size
- High-strength alloys
- Surface finish

Patterns used for investment casting are injection molded of either wax or plastic. Paraffin and microcrystalline waxes are the most common base material for patterns.

RUBBER SHOP

INTRODUCTION

The rubber shop creates shock mounts, O-rings, gaskets, seals, supporting covers, bushes, etc. that are made to exacting aeronautical specifications. Several high-performance, composite elastomeric materials, include EPDM, silicone, neoprene, silicone rubber, fluorocarbons, and fluorosilicone.

These rubber products are used for operational requirements of aircraft or helicopters in the areas of gear boxes, fuel systems, engines, electrical circuits, vibration damping, and structures to avoid friction between break pads, as well as in between aircraft doors and other openings and oil tank lids to contour air leaks and oil leakages (maintain the required atmospheric pressure difference between the aircraft and the outside).

The physical and resistance properties of rubber components depend upon factors like type of base material, the constituent composite ingredients added and the process of manufacturing the compound.

Various parameters are to be considered when selecting a suitable elastomer for a specific design and application of the object, such as temperature stability of the elastomer, resistance to chemicals at operating temperature, maximum pressure it can withstand, vibration damping ability, etc.

Here at HAL these elastomers are mainly prepared by process of casting or compression molding. These elastomers are also applied to avoid friction, improve air tightness (gaskets) and ensure torque (shock mounts).

PROCESS

O-rings are manufactured as mentioned below:

- The die of the extruder is heated to 140 degrees before extruding.
- Rubber is introduced and pressed with a pressure of 1500-2000 psi for 15 min at 170-200 degrees.
- After extruding we take the wired rubber to make ‘O’ rings.
- This extruded rubber is placed in different dies to produce different types of ‘O’ rings.
- This extruded rubber is pressed at a pressure of 2000psi.

- The ‘O’ rings are obtained in the cavity provided and the excess rubber which is called flash is removed.
- POST CURING: Post curing is done to obtain required hardness.
  The obtained ‘O’ rings are heated to their respective curing temperatures for a given time. This is called post curing. Two rolling mills at high temperature are used to produce sheets of thickness of about 8mm. Pressure applied is about 2100 psi and temperature is 180℃.

  Different rubbers are used based on the application conditions i.e. silicone rubber is used for low temperature application and Viton is used for high temperature applications.

EQUIPMENT

1. Hydraulic presses up to 150 ton capacity with automatic temperature and time control
2. Hot air ovens
3. Extruder
4. Roll mixing mills

UNIQUE CAPABILITIES

1. Moulded products with close tolerance limits of ± 0.02 to + 0.1 mm up to a size of 200 * 200 * 200 mm.
2. Development of rubber compounds to any specifications and pre-determined requirements.

PATTERN SHOP

In the case of casting machine parts, pattern is necessary. Pattern shop is more useful in the foundry process. Pattern is the main factor for the foundry process. Wood is the most useful material as a pattern.

Because its process is easy and cost is limited in few amount. It is also available and get easily as demand.

TYPES OF PATTERN

- Single piece pattern: - It is simply the replica of the desired casting. It is slightly larger than the casting. This pattern may be of wood, metal or plastic (hard plastic).
- Match plate pattern, Cope & drag pattern, lagged-up pattern, Built up pattern, Multi-piece pattern, Gated pattern, Sweep pattern, Skeleton pattern, Shell pattern and loose piece pattern, Left and right hand pattern, Follow board pattern, Segmental patterns are some of the types of patterns.

To compensate for any dimensional and structural changes which will happen during the casting or patterning process, allowances are usually made in the pattern.

ALLOWANCES

- **Contraction allowances / Shrinkage allowance:**

  The metal which undergoes shrinkage during solidification and contracts further on cooling to room temperature. To compensate for this, the pattern is made larger than the required casting. This extra size given on the pattern for metal shrinkage is called shrinkage allowances.

- **Draft allowance:**

  When the pattern is to be removed from the sand mould, there is a possibility that any leading edges may break off or get damaged in the process. To avoid this, a taper is provided on the pattern so as to facilitate easy removal of the pattern from the mould, and hence reduce damage to edges. The taper angle provided is called the Draft angle.

- **Finishing or Machining allowance:**

  The surface finish obtained in sand castings is generally poor (dimensionally inaccurate), and hence in many cases, the cast product is subjected to machining processes like turning or grinding in order to improve the surface finish. During machining processes some metal is removed from the piece. To compensate for this, a machining allowance (additional material) should be given in the casting. The amount of finish allowance depends on the material of the casting, size of casting, volume of production, method of moulding etc.

STEPS IN PATTERN MAKING

- Prepare layout to full scale on AI sheets based on casting drawing
- Develop templates in AI sheets
- Cut wood, plane router and laminate for pattern and core box
- Rough mill the blocks
- Mill/turn the shapes
- Assemble the pieces in case pattern /core box are to be made in a number of details
- Finish the shapes by bench work
- Prepare the match plate
- Fix the match plate with pins
- Mark the match plate with pins
- Mark the match plates for pattern locations. Fix patterns
- Layout the gating system on a plywood
- Cut wood, plane router and laminate for gating and risering
- Develop gating and rinsing as per layout
- Fix gating and risering system on match plate
- Mark identifications such as project and part number on match plate /follow board
- Arrange for mould and core and sort out mould /core assembly problem

- Release the pattern for proving trial
- Inspect the TP casing for dimension and report
- Rework the pattern as per report
- Inspect the pattern for rework carried out
- Release the pattern DAR bath
- Rework the pattern for DAR snag
- Inspect the pattern /casting for DAR snag ● Release the pattern for production.

Wooden pattern *(generally used when the number of castings to be made is low).*

Metal pattern *(more no. of castings)*

RING ROLLING SHOP

INTRODUCTION

The ring rolling facility is equipped with a state-of-the-art ring rolling mill that incorporates the latest technologies such as computerized operation control and laser gauges.

State-of-the-art ring rolling mills can manufacture profile rolling rings from a variety of ferrous and non-ferrous alloys. The advantage of roll-forming rings is the low input material. Desirable particle flow and improved metallurgical properties along with the rolling profile.

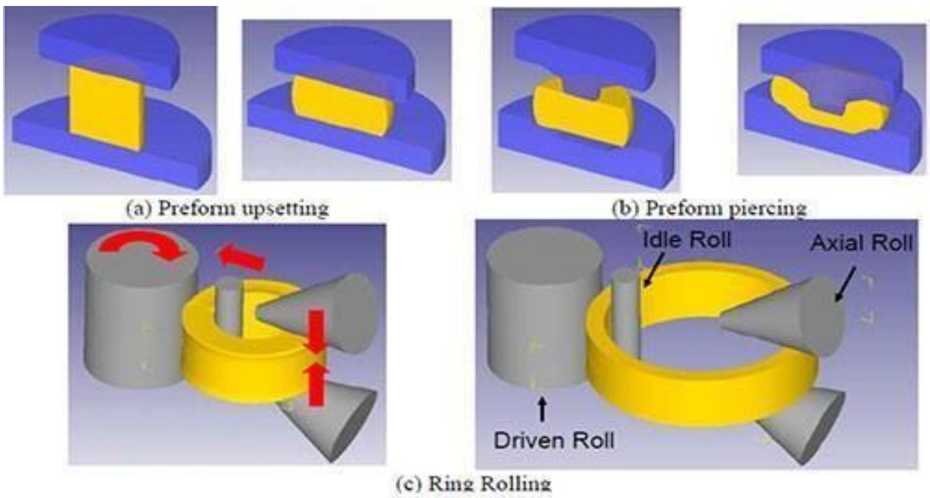
This unit has the expertise and skills to manufacture rings from edge steel, a strategic material for defense and aerospace applications, and tightly controls the parameters of hot stamping and heat treatment processes.

- ❖ Ti6Al4 alloy is mostly used in aerospace. This can easily be forged.

- ❖ Ti6Zr3 alloys are difficult to forge.

PROCESS

- ❖ Rod is heated in the high temperature furnace (900℃ – 1180℃). Those are electrically heated furnaces (It raises the temperature slowly, which is a limitation, hence LPG suits the situation better).
- ❖ Pressing is done by hydraulic press (1500 tonne).



(a) Preform upsetting (b) Preform piercing

(c) Ring Rolling

- ❖ A hollow circular preform is prepared by upsetting and piercing (See figures below). Tool steel is used for punching holes in materials whose wear resistance is high.
- ❖ These are again heated in the furnace for a decent soaking time determined by the material properties, leading to uniform distribution of the heat. Over soaking leads to grain growth.
- ❖ After heating, they are hot rolled in the ring rolling mill.
- ❖ Ring rolling mill consists of mandrel, main ring, centering roll, two axial rods. Centering rod has sensors which give feedback. Axial rods control the thickness of the rod. The rod is compressed between the mandrel and main ring. The rod will expand more in radial direction.
- ❖ When heated, some bending may occur, hence they are pressed under hydraulic press.
- ❖ After rolling, they are heat treated to improve the properties and then machined.
- ❖ After this they are cooled, and then subjected to testing.

1. X ray testing (radiography): X rays are passed through the rod. These can detect internal defects (cannot detect the surface cracks and also cracks at the joining).
2. Ultrasonic test: ultrasonic waves are passed through the rod which can detect subsurface cracks.
3. Nondestructive test: this can give information about the surface cracks.
4. Fluorescent penetration test: this can detect the presence of non-magnetic impurities (Al etc.).

PRODUCT RANGE

- ❖ Small rings used in aircraft engines.
- ❖ Larger rings which are used as bearings in helicopters and in transmission parts, battle tanks, and satellite launch vehicles.
- ❖ Titanium, Nickel and Steel rings which are used in helicopters.

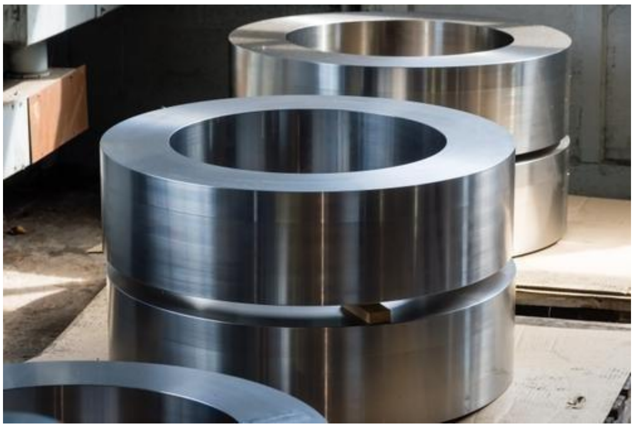
Alloy	Mill 1(100/63T)			Mill 2(200/250T)		
	OD (mm)	HT (mm)	I/P Wt (Kgs)	OD (mm)	HT (mm)	I/P Wt (Kgs)
Aluminium	3000	300	225	3000	500	1000
Steels	2000	300	1200	3000	500	2000
Titanium	1500	300	200	2000	500	500
Nicket	500	85	50	2000	500	250

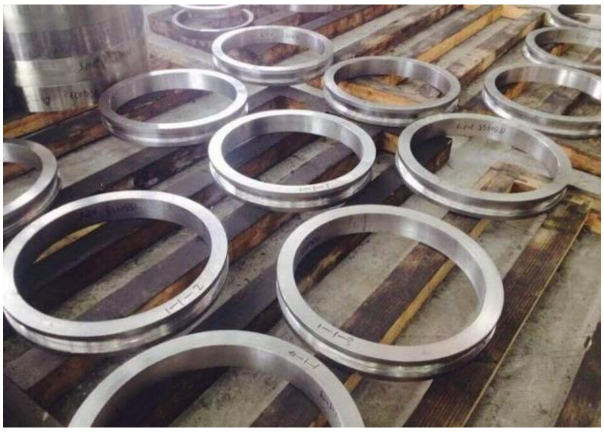
INFRASTRUCTURE

- Computer controlled ring rolling mill with 100-tonne radial force and 63 tonne axial force
- Battery of electrically heated low and high temperature (up to 2.2m length) with temperature controllers & recorders.
- Quenching operation after rolling wherever applicable.
- An 800-tonne capacity ring expander.
- A 3000 tonne and 1500 tonne upsetting press.
- Handling aids such as manipulators and EOT cranes for heavy products.

❖ Raw materials cutting facility (up to 400 mm square section) in all alloys.

❖ Bottom drop quench furnace for heat treatment of Al alloy rings (up to 3.5m diameter).



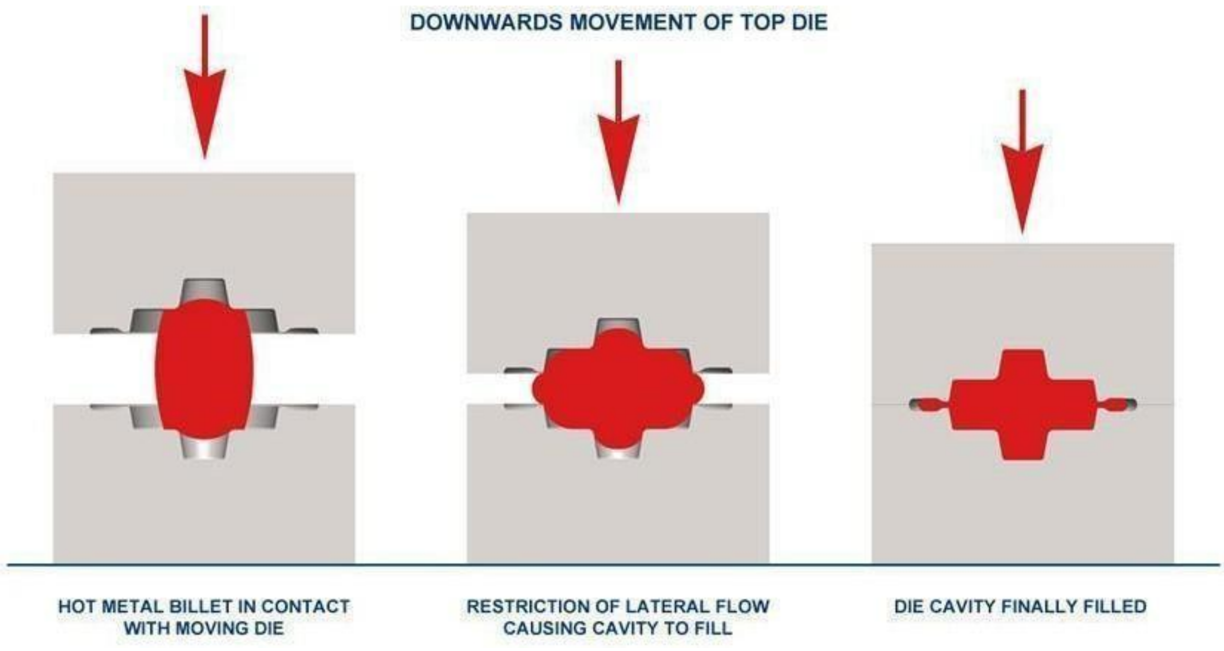


GENERAL FORGE

INTRODUCTION

The general forge shop has the unique capability and experience to cater to a large range of customer specifications of shapes, sizes, weights and numbers. The forging process is designed with the help of Deform simulation software which enables design of performance and optimization of the process the shop has manufactured forging in a variety of alloys in many complex configurations.Forging is done to obtain good mechanical properties. The raw material is heated above recrystallization temperature which is about half of the melting point of the metal.

PROCESS



1. Metal is heated in a furnace.

2. The metal is then put under compressive forces by a process known as banning.

(Pneumatic hammers of 1500, 1000,500 and 10 kg are available. These are Open

Die Power Forging hammers and use pneumatics to drive the hammer. These are used for closed and open die forging wherein the hammer strikes a workpiece which is placed on a die of required shape and rain blows on it create an impression of the die. For example, the BANNING 1000 kg hammer gives 100 blows per minute and the BANNING 1500 kg hammer gives 85 blows per minute to the work piece).

3. It is then put in a high temperature furnace.

4. Soaking time is given for proper heat transfer across the entire material.

5. In case of die forging, hot metal is put between male die and female die, then the die puts pressure and metal takes the shape of the die as shown in figure.

INFRASTRUCTURE

- ➢ 3000-tonne Hydraulic press with standalone die heating furnace.
- ➢ 10-Tonne counter blow hammer with four 500-tonne clipping press, a one tonne drop gravity hammer and pneumatic hammer of 1500kg, 1000kg, 500kg,150kg capacity.
- ➢ Cutting machine such as vertical and horizontal band saw, cold circular saw, electric discharge saw, abrasive cutting unit.
- ➢ Battery of electrical resistance pre-heating furnaces.
- ➢ Heat treatment section with furnaces for hardening, tempering, solutioning, aging, normalizing and annealing.
- ➢ Shot blasting machine.
- ➢ Full fledged process and fettling shops.

HEAT TREATMENT FACILITIES

Various furnaces are available for use in the heat treatment section. Most of these are NADCAP approved and assigned various classes, based on the temperature tolerance range. The temperature tolerance range is the temperature above or below the operating temperature of the furnace, which can be tolerated by the furnace.Some of the furnaces:

➢ GH-10 Furnace is a Class 4 and Class 5 furnace with an operating temperature of 650-1180°C.It is used for the process of annealing.

➢ GH-4 Furnace is a Class 1 and Class 2 furnace, with lower operating temperature than GH-10 furnace. It is an air circulation type furnace, where a fan is used to circulate air and uniformly distribute heat within the furnace. This furnace is used for tempering.

➢ GH-5 Furnace is a Class 2 furnace with operating temperature of 150-680°C .It is a type D instrument, which means that it consists of 1 Main Controller and 1 Recorder for the furnace. This furnace is also used for tempering.

➢ GH-7 Furnace is a Class 3 and Class 4 furnace and can be used for normalising, tempering and hardening.

➢ GH-3 Furnace is a Class 1 and Class 2 furnace with a rather low operating temperature of 100-350°

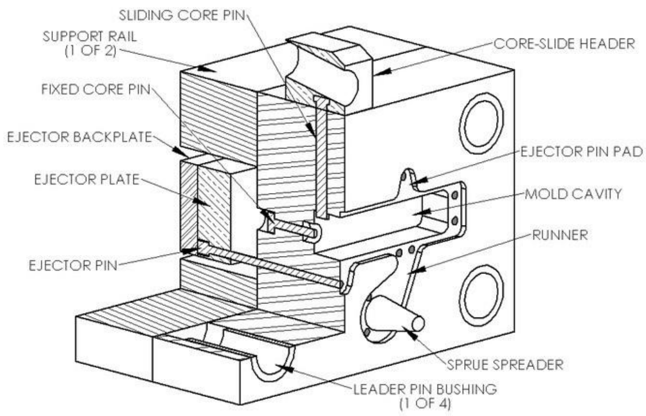
DIE SHOP

Die casting is a metal casting process that involves feeding molten nonferrous alloys into dies under high pressure and at high speed to rapidly create molded products. The main materials used in die casting are alloys of aluminum, magnesium, and zinc. HAL's Foundry and Forge division majorly focuses on manufacturing dies required for the forging shop of aluminum and magnesium. After the shape of the die required is obtained from the Development Department, the dies are manufactured by manually controlled cutting machines or by CNC. The two categories of die shapes performed are i. Simple Shape and ii. Complex Shape.

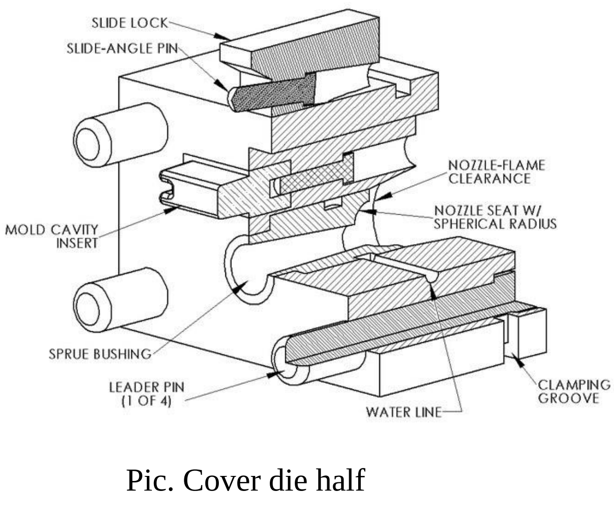
1. Simple shapes are performed by conventional machining. Electrical discharge machining (EDM) is majorly used for simple shapes.
2. Complex shapes are performed through CNC machines.

This shop has a vertical machining center. VMC is a machining center in which the spindle axis and the rectangular worktable are set vertically, which is suitable for processing workpieces with high accuracy and precision, even with multiple procedures and complex shapes. It has a simple structure, and small floor area, and can be equipped with multiple adjustments. It is versatile, adaptable, and low cost. The major difference between the precision forge and general forge is the tolerance of the product and the die required. In precision forge, we use a die with a wedge angled around 5°. Two dies are used in die casting, one is called the "cover die half" and the other "ejector die half". The cover die contains the sprue (hot-chamber machines) or shot hole (for cold-chamber machines), which allows the molten metal to flow into the dies; this feature matches up with the injector nozzle on the hot-chamber machines or the shot chamber in the cold-chamber machines. The ejector die contains the ejector pins and usually the runner, which is the path from the sprue or shot hole to the mold cavity. Other die components include cores and slides. Cores are components that usually produce holes or openings, but they can be used to create other details as well. The coolant used is a mixture of oil and water as it acts as a lubricant and helps in dissipating heat generated due to friction

The following are the four steps in traditional die casting, also known as high-pressure die casting, these are also the basis for any of the die casting variations: die preparation, filling, ejection, and shakeout. The dies are prepared by spraying the mould cavity with lubricant. The lubricant both helps control the temperature of the die and it also assists in the removal of the casting. The dies are then closed and molten metal is injected into the dies under high pressure. Once the mold cavity is filled, the pressure is maintained until the casting solidifies. The dies are then opened and the shot is ejected by the ejector pins. Finally, the shakeout involves separating the scrap, which includes the gate, runners, sprues, and flash, from the shot. This is often done using a special trim die in a power press or hydraulic press. Other methods of shaking out include sawing and grinding. A less labor-intensive method is to tumble shots if gates are thin and easily broken; separation of gates from finished parts must follow. This scrap is recycled by remelting it. The yield is approximately 67%. The dies are checked by using Plaster of Paris as the molten metal and checked for cavity formation.



Pic. Ejector die half



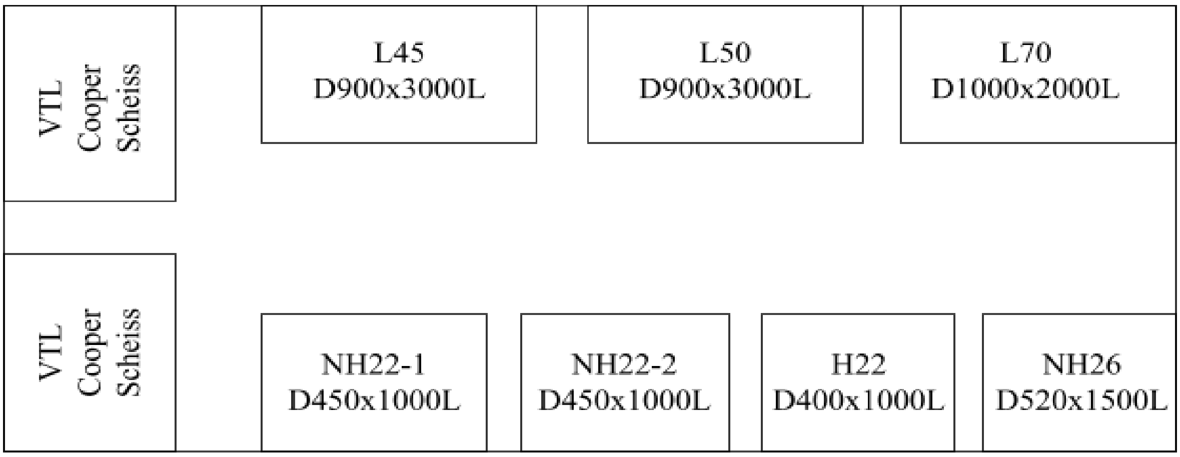
Pic. Cover die half

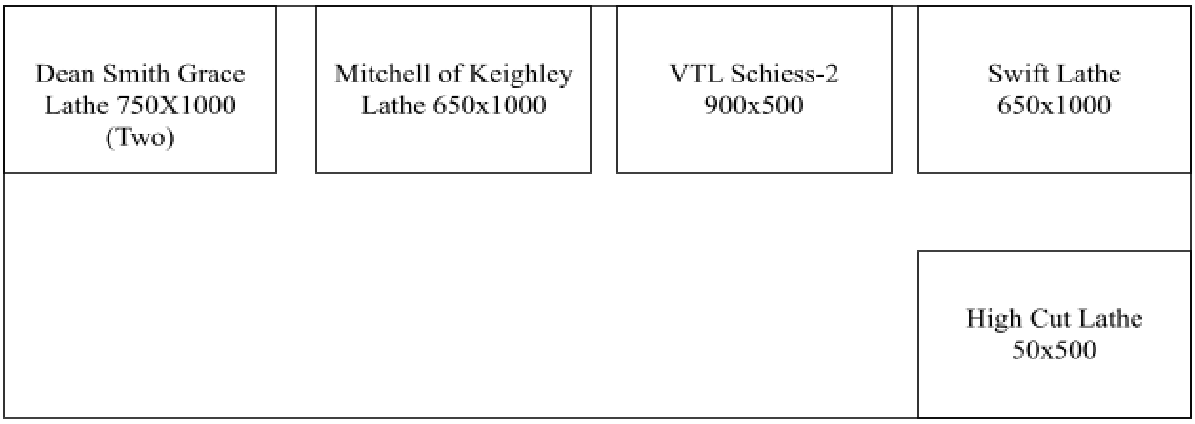
MACHINE SHOP

Many components that have been manufactured have to be finished and brought to appropriate dimensions after casting, forging, and heat treatment operations, as specified in the route card given by the development department. This is accomplished by machining the components on lathe or milling centers. **HAL F&F division** has its very own machine shop for such operations. Castings produced are generally rough and must be finished on lathe or milling centers. The machine shop consists of various lathe and milling centers ranging from vertical lathe to horizontal lathe and vertical milling machines are also prevalent in the machine shop.

The difference between vertical and horizontal lathes is that vertical lathes have better productivity, higher depth of cut, and reduced cycle times than their horizontal counterparts, also the chances of slippage are very low in vertical lathe machining as compared to horizontal lathe machining.

Vertical lathes also help by not occupying large spaces, due to them not requiring a tail stock. The presence of a vertical lathe helps the division to machine Ni alloys, TI alloys, a variety of steels, etc. at a reduced cycle time. The machining blade here used is a composite coated with other material at the top, as a result, its cost is near the y same as that of the uncoated blade but the wear resistance has drastically increased. Vertical lathes are also used for bigger rings. The nomenclature of the lathe machines follows a certain rule. For example, L70 indicates that a 1400 mm (1.4 m, which is 70 x 2 = 140 cm) job can be held. The 2000L signifies the stroke length equals 2000 mm. VTL, which stands for Vertical Turning Lathe, flips a traditional lathe design on its end, employing gravity to help hold the workpiece in place.





Two types of tolerances will be mentioned in the process sheet- Unilateral and Bilateral. Unilateral tolerance exists when a target dimension is given along with a tolerance that allows variation to occur in only one direction. Bilateral tolerance exists if the variation from a target dimension is shown occurring in both the positive and negative directions.

Some specifics from the shop are as follows:

- Turning, milling and surface finishing are the operations carried out in the shop.
- Irregular shapes do not undergo turning.
- Carbide inserts (~60-65 HRC) are used. Slow rate of turning is employed (~30-45 HRC) for Nickel materials, whereas a higher turning rate is employed for Aluminium materials.
- Minimum rpm of the lathes is usually ~40. But Ni requires lower rpms. In order to achieve this, lubricating oil will be used to add pressure and lower the rpm.
- The carbide inserts employed have a certain shelf life. Materials like Ni with high HRC wear out the inserts at a faster rate than other materials. Hence, 45^{o} parting tool is used for Ni.
- Longitudinal feeds (mm/rev) can be controlled using levers.
- Measurements are carried out manually using vernier and micrometre scales.

During turning, the thickness that can be cut, depends on the material. For example, steel can be cut to a depth of 5 mm, while Ni can only be cut to a depth of 2.5-3 mm.

PRECISION FORGE

INTRODUCTION

As the name suggests, precision forge is done in order to minimise the machining after the forging operation. Engine blades like Rotor and Stator blades are mostly manufactured by this process. Complicated shape parts are available in precision forging. Since conventional closed die forging process is limited to produce parts with simple shape. However, in precision forging process, more complex shape are allowed, which is the same as casting.

These are critical components hence the process involves a lot of tests for defects etc. A combination of state-of-the-art facilities and traditional hand skills has enabled the Precision Forgings Section to engineer quality into its high technology products. The process and inspection support has been designed around production of precision forgings to close tolerance.

PROCESS

- Aluminium alloys (400-500 °C) are made by the following procedure:
- The raw materials for this are either small billets or pre-forged materials which are forged at high temperatures.
- The aluminium alloy is first soaked in order to maintain equilibrium heating of the grain pillets.
- The sample is glass coated to prevent H_2 interaction
- The forging is done along the grain flow direction. The parts are then sent to the fettling section where the excess or the unwanted parts are removed, and surface finishing is done. Hot blast is done to remove scales formed.
- Then the products are sent to the final inspection unit to check whether surface and internal defects are present and then they are passed for the service.
- Different processes to detect defects are done.
- The products are degreased i.e. vapour degreasing or alkaline degreasing and then etching and electro polishing is done.

INFRASTRUCTURE

- It contains Friction screw presses of 2000-tonne, 500-tonne, and 300-tonne capacity.
- 3200 and 1000-todirect-driverive presse250-tonnetonne horizontal up-setter.
- Double-ended polishing lathes.
- 1.5 meters rotary hearth furnace.
- Low and high-temperature box type furnace.
- 45-tonne and 70-tonne trimming presses.
- Abrasive blasting equipment.
- Vibratory finishing mills.
- Process shop for degreasing, etching, electro polishing and size-etching operations.
- Fluorescent penetrant inspection unit.
- Dedicated inspection facility including CMM for precision-forged blades.

UNIQUE CAPABILITIES

- Complex precision forged products including aerofoil shapes in all wrought alloys and precision blades from component drawing using CAD/CAM/CMM route of manufacture
- Custom built equipment for forging, processing and inspection of precision forgings especially compressor and turbine blades
- Abrasive blasting and vibratory finishing equipment
- Optical projectors and multi-gauging equipment backed by checking fixtures, gauges and other inspection aids
- Range of screw presses to undertake manufacture of a wide range of precision forged
- products

CHEMICAL SECTION

This section handles the cleaning and coating of components. There are many processes which are carried out in this section. Some include:

1.Anodizing: Anodizing is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts. All aluminium alloys undergo anodizing The process is called anodizing because the part to be treated forms the anode electrode of an electrolytic cell. It increases compressive strength on the surface which increases the fatigue strength.

2.Etching: Many types of etchants are used, for example caustic etch etc. Nitric acid is used to remove the black surface.

3.Acid pickling : Surface metal cleaning process which uses strong acids to clean the surface of the metal which has impurities, stains, oxide layers formed on the product.

SHAPE MEMORY ALLOY(SMA)

INTRODUCTION

Nitinol (an alloy of nickel and titanium mixed in almost equal proportion) shows a shape memory effect. Shape memory alloys have the unique property of remembering their shape. Once deformed, they revert to their original shape after crossing a certain transformation temperature. The SMA shop at this division produces ferrule rings which are used to clamp polyether ketone tubes into aluminum tubing which carries fuel. Ferrule rings are made up of
Ni-Ti-based alloy.

INFRASTRUCTURE

Vacuum Induction melting furnace (VIM) - 50kg capacity
Vacuum Arc remelting furnace (VAR) - produces ingots of 150mm dia
Differential Scanning Calorimeter (DSC)

PROCESS

1. Ni-Ti of equal proportion are melted in a vacuum induction furnace.
2. These are then refined in vacuum arc remelting to get pure SMA.
3. The vacuum arc remelting is also carried out to weld any shrinkage defects that have been formed in the ingot.
4. It is then tested in a differential scanning calorimeter to monitor and identify its transformation temperature.
5. This pure material is subjected to hot rolling, forging followed by heat treatment and machining.
6. It finally undergoes a process known as thermal cycling where the ring is subjected to expansion at temperatures lower than its transformation temperature in a liquid nitrogen bath.
7. Ferrules used for LCA have a transformation temperature of -55°C**.**

CAPABILITY

1. Production of SMA ingots.
2. Refining using vacuum arc remelting.
3. Forging of ingots.

CMPL (CENTRAL MATERIAL PROCESSING LAB)

INTRODUCTION

The Central Materials and Processes Laboratory and NDT Center in the Foundry & Forge Division of the Bangalore Complex is one of the leading materials testing and R & D laboratories in the country.

This laboratory is recognized as a research and development center by the Science and Industry Research Division. Access to production facilities available in the foundry and forging departments. Induction, resistance and oil-fired melting furnaces, various hammers, hydraulic and friction presses with related furnaces, heat treatment equipment including vacuum heat treatment, powder compression and sintering equipment, surface blasting and processing equipment, and sophisticated tool rooms facility.

CMPL is divided into the following sections:

- **Chemical inorganic section**
- **Chemical organic section**
- **Calibration section**
- **NDT section**
- **Metallurgy section**
- **Mechanical testing section and workshop**
- **Learning centre and documentation unit**

NON DESTRUCTIVE TESTING

A. Facilities:

- X ray equipment -225kV constant potential

➢ Ultrasonic flow detector (microprocessor based)

➢ Eddy current flow detector

➢ Eddy current equipment for conductivity checking with NIST traceable standards

➢ Photo flourimeter for checking the brightness of fluorescent penetrant ➢ Magnetic yoke for magnetic particle inspection. **B. Services:**

➢ Radiographic inspection of casting, welding’s, assembled components

➢ Electrical conductivity check by eddy current method

➢ Ultrasonic and eddy current inspection

➢ Magnetic particle inspection

➢ Penetrant test.

Radiography is used to check for defects in metal parts to endure safety in the products in a non-destructive manner. Open field radiography involves testing on gas or oil pipelines in the field. X-rays or gamma rays are used in industrial radiography in a fixed location.

Industrial radiography devices make use of radioactive source which is sealed to emit gamma rays. They are portable. In-built shielding is provided to protect the operator from the radiation.

Lab X-ray technique (LXT): If the sample has a single thickness, one reading is taken. A sample having multiple thicknesses requires multiple readings. Casted products are checked for defects before application. The designated zones which are used to take the reading are named alphabetically. The defects that can be detected by radiography are shrinkages, cracks, porosity, cold shut etc.

There are two types of radiography analyzers namely film radiography which utilizes films and computer radiography which utilizes a PAP plate (phosphorous imaging plate)

QUALITY CONTROL DEPARTMENT

HAL Foundry and Forge Division manufacture castings, forgings such as Aero-engine blades, seamless rolled rings, rubber parts, Metallo-ceramic and organic brake pads, brake pad segments, bimetallic sectors, rubber components and shape memory alloy parts for aeronautical, space, and defence applications.

Light Combat utilizes manufactured goods. Cheetah/Chetak Helicopter, Advanced Light Helicopter, Light Combat Helicopter, Light Utility Helicopter, Jaguar Aircraft, SU-30 MKI, Hawk MKI32. A quality control unit and staff are present in every department. At the shop level, the QCD engages with these divisions to discuss quality management systems, approvals, and customer complaints. These clients can be internal or external. HAL provides services to PSUs like the Indian Space Research Organization (ISRO), Bharat Heavy Electronics Ltd (BHEL), and ammunition factories. Rolls Royce, Jaguar, and Honeywell are some of the external customers.

In order to continuously deliver goods and services that satisfy clients and/or pertinent legal and regulatory criteria, HAL Foundry and Forge Division created and put into practice a quality management system. When a standard's requirements conflict with those of a client or a regulatory body, the latter prevails. The Foundry and Forge division's Quality Control Department operates on two levels. Engineering control is used at the shop level, and quality control is tailored for the finished product.

Quality Management System (QMS) addresses customer requirements, and applicable statutory and regulatory requirements. The process approach and efficient application of the process throughout the business form the foundation of the QMS. The documentation for the QMS specifies the standards and procedures required to guarantee the control and functioning of these processes. These procedures are supported by the resources required to support their operation and supervision. A system is in place to track measures and examine these procedures. Actions necessary to achieve planned results and continual improvement of these processes are planned. Wherever processes are outsourced the necessary controls are determined and applied.

The Quality Control Department abides by 3 Quality objectives:

1. To understand and meet customer needs.

2. To monitor process effectiveness continuously.

3. To reduce process and product non-conformances through a system of continuous review and improvement.

The QCD conducts internal audits once in every 3 months to suggest changes and corrections so that the manufacturing standards correspond to customer requirements. These audits involve periodic analysis and calibration of furnaces, thermocouples and other important equipment following the standard Quality Analysis Procedure. The audits ensure that the manufacturing process proceeds as per the customer requirement and the AS 9100 ISO standards. These standards include:

- ISO 9000: 2005 – Quality management system-Fundamentals and vocabulary
- ISO 9001: 2008 – Quality management system-Requirement
- AS 9102 – First article inspection
- AS 10007 – Guidance on configuration management
- AS 9100 Revision C – Aerospace standards

These standards are required for special processes in the Foundry and Forge division such as Non-destructive testing (NDT-004,006,015), Heat treatment (HPS-905,407) and Laboratory testing (chemical, mechanical, and metallurgical).

Each section of the Foundry and Forge division has its own non-destructive testing personnel who perform a routine battery of tests on the finished parts:

1. Dye penetrant test
2. Magnetic particle testing
3. Ultrasound testing
4. Eddy current testing
5. Radiography

Some additional points:

- ➢ Dye penetrant test can only be used to detect surface cracks.
- ➢ Magnetic particle testing can only be used to detect surface and subsurface cracks.
- ➢ Ultrasound testing and radiography can be used to detect internal defects.

QUALITY WORK INSTRUCTION SHEETS

Quality Work Instruction Sheets include a step by step procedure for the various processes carried out at the foundry and forge division. Some sheets are shown below:

1. **Raw Materials Stores Inspection:**

Bar Stock:

a. Receive P.O (Purchase Order) copies from IMM Department

b. Receive reports from Receiving Stores along with all the relevant documents such as Test Certificates, Release Notes etc.

c. Keep the raw materials protected.

d. Locate the item in the receiving process area and check material for cost number, melt number, batch number, specification and size punched on the bars.

e. Check for visual defects, dimension compliance and geometrical distortions.

f. The test results are verified with the help of CMPL (Central Materials Processing Laboratory).

g. Periodic validations of the raw material (chemical and ultrasonic)

h. Assign F&F division batch and consignment numbers.

i. Any non-conformances are reported to the IMM.

j. If found satisfactory, release the material for size, specification, batch number and colour coding of the bars.

k. Test certificates are filled with relevant batch record files.

2. Colour code system for Materials:

a. The goal here is to establish an identification system.

b. Visual aids must be provided to:

i. Identify the material
ii. Avoid mix-ups
iii. Better control of melting and castings
iv. Systematic storing

c. Colour coding procedure:

i. Cast ingots: Done on one side of each ingot, A distinctly available spacing is ensured.

ii. Risers and Gates: A rounded dot, with approximately 10 mm spacing iii. Bars/Billets: If l>1m, colour coding is done on both sides of the bar. If l<1m, colour coding is done on only one side of the bar. If diameter is less than or equal to 100 mm, the colour code covers 100 mm diameter completely on both the sides. If diameter > 100 mm, colour code extends on both sides also.1

3. Visual Inspection:

a. Inspect the surface of the component for surface finish

b. Done in a designated area, equipped with proper lighting, visual aids, necessary jigs and fixtures etc.

c. Inspection procedure:

i. Qualified personnel are required to carry out this operation
ii. Oblique dominant illumination is provided along with subdued lighting. The white light intensity shall not drop below 1000 lux.
iii. Surface must be free from foreign matter iv. The different light source types used are as follows: Tungsten, Halogen, Fluorescent, DayLight etc.

d. Sensitivity Check: Fine pencil line of 25 mm is drawn on the test piece using 0.5 mm diameter HB lead. This must be visible when viewed in the inspection area under normal inspection conditions.

4. Radiography:

a. Exposure:

i. Follow the exposure chart for the selection of exposure factors.

ii. Penetrameter is used on the thickest section of the part to measure the depth of penetration of the X-rays.

iii. Exposed films are not left behind and not mixed with unexposed ones.

iv. Necessary safety precautions are followed.

iv. Various types of filters are used.

v. Always, the defect prone areas must be exposed first.

b. After Exposure:

i. Keep X-ray completed castings at proper place for interpretation.

Switch off the X-ray machine and mains.

DEVELOPMENT DEPARTMENT

A company's research and development department plays an integral role in the life cycle of a product. While the department usually is separate from sales, production and other divisions, the functions of these areas are related and often require collaboration.
This shop is the brain of the division which gives the route card or process card which tells the way in which a given product is produced. i.e. the different process through different shops it needs to go.

To develop and produce dies and components, particularly for precision net form items like aviation engine blade forgings, they use cutting-edge software and CAD/CAM procedures. They use 2D drafting, 3D modelling, and CNC machining to create the tools and components they use. They employ simulation software to create patterns and choose gating, riser, and feeding systems for casting components.

CAPABILITIES

- CAD/CAM for design of dies and engine blade forgings.
- 2dimensional draft, 3dimensional modelling and CNC machine tools program design.
- Computer simulation route used for designing gating, riser and feeding system for castings.

NEW PRODUCT RESEARCH

Before a new product is developed, the development department conducts a thorough study to support the project. The research phase includes determining product specifications, production costs and a production timeline. The research also is likely to include an evaluation of the need for the product before the design begins to ensure it is a functional product that customers want to use.

NEW PRODUCT DEVELOPMENT

The research paves the way for the development phase. This is the time when the new product is developed based on the requirements and ideas created during the research phase. The developed product must meet the product guidelines and any regulatory specifications.

EXISTING PRODUCT UPDATES

Existing products of the company also fall under the scope of development. The department regularly evaluates the products offered by the company to ensure they are still functional. Potential changes or upgrades are considered. In some cases, the development department is asked to resolve a problem with an existing product that malfunctions or to find a new solution if the manufacturing process must change.

INNOVATION

The research and development team aids the company in staying competitive with others in the industry. The department can research and analyse the products other businesses are creating, as well as the new trends within the industry. This research aids the department in developing and updating the products created by the company. The team helps direct the future of the company based on the information it provides and products it creates.

OBJECTIVES

1. Design and develop components manufactured in Foundry and Forge.

2. Starting fundamental operations.

RESPONSIBILITIES

1. Feasibility study.
2. Cost estimation.
3. Constructive review. Develop a product drawing.
4. Test Schedule – Testing requirements approved by the customer.
5. CAD/CAM, 3D modelling, simulation packages for gating systems in casting and die design.
6. Conducting trials.

STORES

This comes under integrated material management (IMM).

As soon as material comes to store the material is tested if the received materials are of proper specifications and if the material fails to qualify the test the material is immediately returned and the dealer is blacklisted.

There are 4 stores are present in **HAL Foundry and Forge division**:

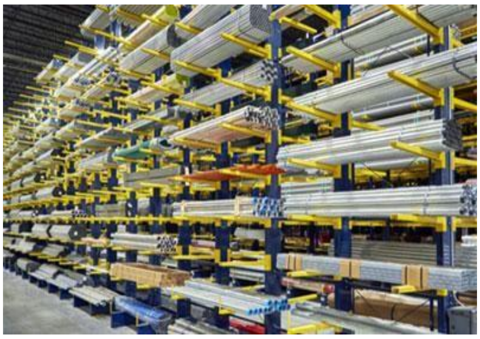
- ❖ **Receiving store**
- ❖ **Holding store**
- ❖ **Packing store**
- ❖ **Salvage store**

RECEIVING STORE

Purpose: To define a procedure for receipt and issue of material to the holding store.

Activity description:

- ➢ Materials received on receipt and quantities received are verified at the distribution center
- ➢ Waybill is prepared.
- ➢ Revenue Register Number is assigned, and RR is generated.
- ➢ Monitor the colour coding of raw materials.
- ➢ Quantity received is transferred to the warehouse and sent for inspection along with other documents
- ➢ The material is tested and the test certificate is verified
- ➢ Charges approved for the accepted quantity



HOLDING STORES

Purpose: To define a procedure for storage and issue of materials

- ➢ Receipt and storage of incoming materials from Receiving stores

- Receipt of items sent from Receiving stores after charges approval
- Verification of parts numbers, description project class, Rules Codes, Unit Of Measurement of items and segregate the items according to storage condition and location
- Receive of materials and updation of records /stock in IFS (Industrial and Financial Systems) and finalise
- Identify/store the items in respective location such that issue can be made on first in first out basis
- Materials are stored as per the goods storage practises /methods & preservations for various types of materials as mentioned in the stores manual
- Issue of materials
- Receive MR / pick list and check the correctness of the content of MR
- Check the availability of item
- Collect the item from storage location
- Enter the details like quantity issued serial number etc. in the MR.

PACKING STORE

Purpose: To define a procedure for management of dispatching of finished products

- The finished products after all the tests and processes come here
- The products are checked, counted and then kept ready for packing
- It is then packed in plaster,wooden boxes,covers etc
- Some of the finished products which come here are gaskets, metal rings, brake shoe etc.

SALVAGE STORES

Purpose: To define a procedure for management of scrap /surpluses

Functions: Salvage stores is mainly responsible for following functions:

- Receipt of scrap, surpluses etc
- Proper storage and preservation of scrap/surpluses
- Handling of surpluses/salvage store
- Reclamation of items &re issue
- Effort to sell surpluses item before disposal.

Reason for scrap development:

Scrap/surplus normally occurs due to following reasons:

➢ Damage of items beyond economical repair

➢ Expired life items whose life cannot be extended

➢ Items becoming absolute due to technical changes, phasing out new issues, modifying items etc.

➢ Item completing normal operation life.

➢ Corrosion and deterioration beyond economical use.

➢ Rejection of items at receipt.

➢ Small cut items and other scraps produced during manufacturing.

➢ Tool rejection review committee declared tools & gauges.

MARKETING DEPARTMENT

The **marketing department** of a company promotes the company and drives sales of its products or services. It provides the necessary research to identify the company's targeted customers and other audiences. **HAL foundry & forge** division also has a marketing department. Around 50% of the division's income comes from offering services to non-governmental companies, be it national or international. International aerospace companies like Boeing, Volvo, Airbus, Rolls Royce et. While national customers including governmental organisations include BHEL, BMEL, IPL, TATA POWER, INDIAN AIR FORCE(IAF) etc.

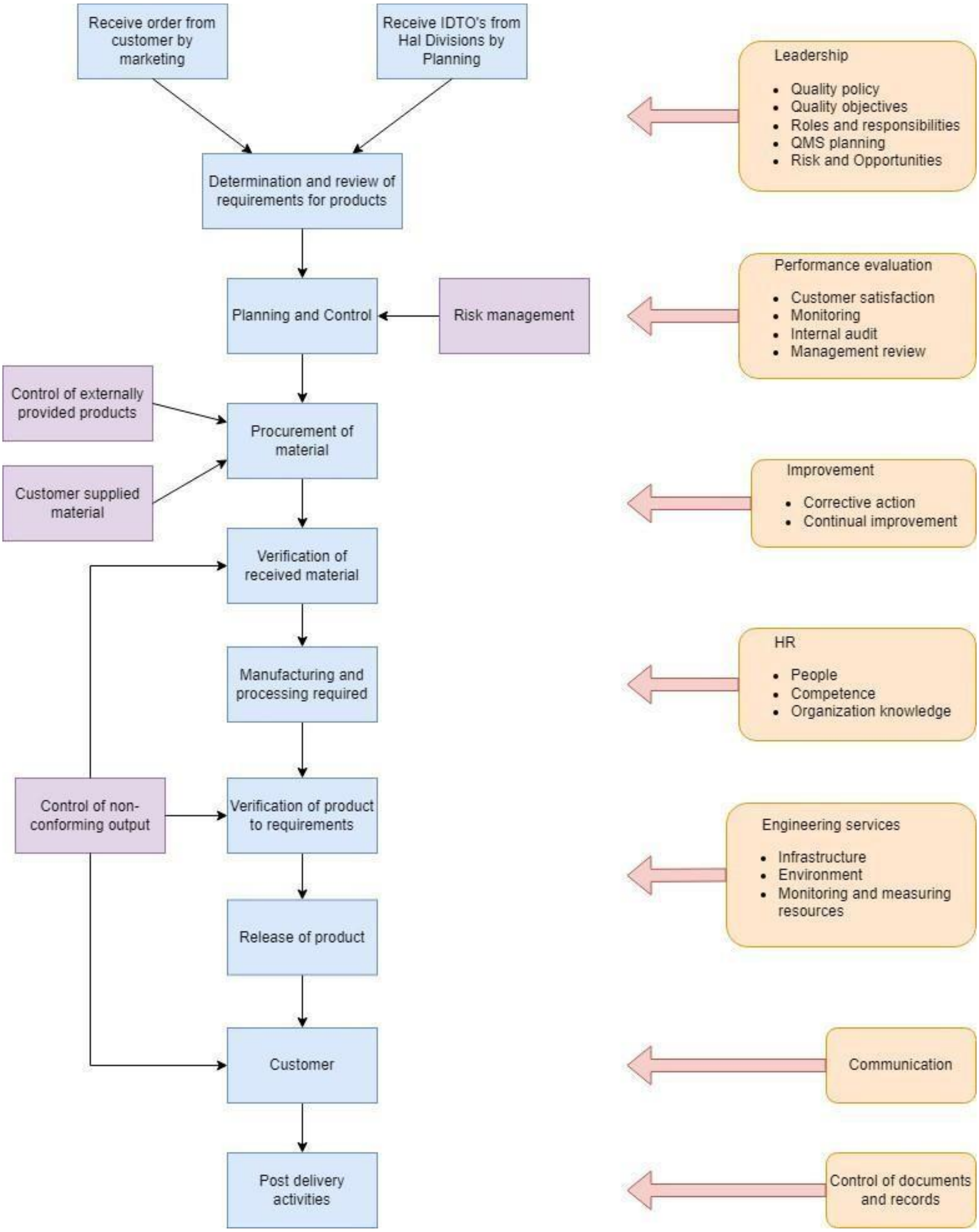
PROCESS

1. Request For proposal (RFP) is filed.
2. Evaluation at the marketing department.
3. Development department & engineering department.
4. Quotation is submitted to the customer.
5. Tender opening (if quality & delivery time are not out of bounds, then supplier selling at lowest price is given the order).
6. Negotiations (commercial or technical) take place.
7. Purchase order is released.
8. Contract review is made.
9. After supplies, payments are collected.

TTI (TECHNICAL TRAINING INSTITUTE)

HAL has its very own training institute where training of various sorts is given to engineering graduates, diploma graduates and SSLC pass-outs. This institute was opened in 1957 by the board of apprenticeship training to increase the employability of graduates. Around 1300 students are admitted into TTI. The above figure is inclusive of trainees from all levels of education. Engineering and diploma graduates from various disciplines like aerospace, mechanical, electrical and metallurgical & materials. This training helps to bridge the gap between the theoretical concepts learnt in college and the industrial requirements. Engineering graduates are trained for a period of one year with some stipend, after this the candidates go through placement sessions where other companies approach HAL to hire industry ready candidates. Stipend is also provided for all other trainees i.e. diploma and ITI trainees. The institute has many training centres equipped with cutting edge technology and modern instruments like CNC milling and lathe machines present in CNC shop, laser tracking machines, electrical shops and mechanical shops.

SEQUENCE AND INTERACTION OF PROCESS



CONCLUSION

The crux of aerospace manufacturing, from what we have learnt at **HAL Bangalore Foundry and forge division** is traceability of components and zero compromise on quality of manufactured products.

Hindustan Aeronautics Limited, Bangalore- **Foundry & Forge Division** manufactures castings, forgings, rolled rings, brake pads, shape memory alloys and rubber products for applications in the aeronautics, defence, locomotive, earth mover and other industries.

This division supplies the products to the various other divisions of HAL manufacturing Aircraft, aero engines besides the space, defence, railways and other heavy engineering industries with an aim to become a significant global player in the aerospace industry.

Having well-equipped facilities, it provides competitive products and services with regular quality checks at each phase of manufacturing without compromising the customer's expectation.

The aim of HAL is to achieve self-reliance in design, development, manufacture, upgrade and maintenance of aerospace equipment diversifying into related areas and managing the business in a climate of growing professional competence to achieve world class performance standards for global competitiveness and growth in exports.

More importance is given to the quality of products as well as meeting the demands with minimal loss of resources.