Research and Development Intern

LG Electronics

Internship Report

Submitted in partial fulfillment of the requirements for the award of degree of

Bachelor of Technology

(Mechatronics)

Submitted to

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA, PUNJAB

From 08/01/24 to 06/31/25

Submitted by

Aditi Verma

12102910

Submitted to

Jitendra Ramje

Team Leader

LG

LG Electronics India Pvt. Ltd.
(16th to 20th Floor) C 001 ,Tower D , KK Project ,Sector – 16 B.
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Date : 26/07/2024

Aditi Verma
LOVELY PROFESSIONAL UNIVERSITY

SUB: Summer Internship Letter

Dear Ms. Aditi Verma

This is with reference to your letter for Training / Industrial Project in our organization.

We are pleased to inform you that you have been permitted to proceed with your training.

Location	:-	NOIDA
Department	:-	Development Planning
Reporting To	:-	MOHIT JAIN (9899302094)
Duration of Training	:-	12 Months (01/08/2024 to 31/07/2025)
Contact Person	:-	PUNEET DUA (9899302972)
Address	:-	Plot No. 51, Udyog Vihar, Surajpur Kasna Road, Greater Noida

Project details will be given by the respective department.

BINAY DUBEY
SENIOR G.M. - Noida HR

List of Contents

To whom so ever it may concern

I, **Aditi Verma**, **12102910**, hereby declare that the work done by me as a “Research and Development” from **August**, **2024** to **July, 2025**, under the supervision of **Mr. Jitendra Ramje**, **Team Leader, and Mr. Saurabh Puranik, Part Leader, LG Electronics, Greater Noida, UP** and **Mr. Guravtar Singh**, **Training and Placement Coordinator, Lovely professional University, Phagwara, Punjab**, is a record of original work for the partial fulfillment of the requirements for the award of the degree, **Bachelors of Technology**.

Aditi Verma (12102910)

Dated: 30 May, 2025

To whom so ever it may concern

This is to certify that **Aditi Verma**, **12102910** from **Lovely Professional University, Phagwara, Punjab,** has worked in **LG Electronics** as "**Research and Development Intern**" under my supervision from **August**, **2024** to **July**, **2025**. It is further stated that the work carried out by the student is a record of original work to the best of my knowledge for the partial fulfillment of the requirements for the award of the degree, **Bachelor of Technology.**

Jitendra Ramje	**Guravtar Sigh**
Team Leader	**Training and Placement Coordinator**
Dated: 30 May, 2025	**Dated: 30 May, 2025**

Acknowledgement

I would like to express my sincere gratitude to everyone who has supported me during my one-year internship at LG Electronics. This report would not have been possible without their guidance, encouragement, and assistance.

First and foremost, I would like to sincerely thank my mentor, **Ms. Mamta Bhandari**, for their constant guidance, valuable insights, and unwavering support. Their mentorship has been instrumental in shaping my learning experience and enhancing my professional skills. I am deeply appreciative of the time and effort they invested in helping me grow both personally and professionally.

I would also like to extend my gratitude to **Mr. Jitendra Ramje**, the Team Leader, and **Mr. Saurabh Puranik**, Part Leader for providing me with the opportunity to contribute to the team and for their exceptional leadership. Their encouragement, constructive feedback, and trust in my abilities motivated me to perform at my best and provided me with a deeper understanding of the work in this field.

Special thanks to **Mr. Guravtar Singh** and **Mr. Sanjeev Kumar**, for their continuous academic support and for recommending this internship as part of my academic program. Their guidance throughout my academic journey has been invaluable, and this experience has enriched my knowledge and broadened my perspective in ways that will benefit me throughout my career.

Finally, I am thankful to **Lovely Professional University** for providing me with the opportunity to pursue this internship as part of my academic program. The combination of practical experience and theoretical knowledge gained will undoubtedly play a pivotal role in my future career.

Once again, thank you to everyone who contributed to making my internship experience truly valuable and memorable.

Aditi Verma

List of Tables

List of Figures

Chapter 1

INTRODUCTION OF THE COMPANY

1.1 About the Company

LG Electronics Inc. is a South Korean multinational major appliance and consumer electronics corporation headquartered in Yeouido-dong, Seoul, South Korea. It is a subsidiary of the LG Corporation, which was originally known as Lak-Hui, a name that was changed to LG in 1995. LG stands for "Lucky Goldstar," which refers to the company's founding roots in 1947. It comprises four business units: home entertainment, mobility, home appliances & air solutions, and business solutions. LG Electronics acquired Zenith in 1995 and is the largest shareholder of LG Display, the world's largest display company by revenue in 2020. LG Electronics is also the world's second largest television manufacturer behind Samsung Electronics. The company has 128 operations worldwide, employing 83,000 people.

Fig 1.1: LG Electronics

1.2 Origin and Growth of Company

In 1958, LG Electronics was founded as GoldStar. It was established in the aftermath of the Korean War to provide the rebuilding nation with domestically produced consumer electronics and home appliances. The start of the country's national broadcasting that created a booming electronics market and a close relationship it quickly forged with Hitachi helped GoldStar to produce South Korea's first radios, televisions, refrigerators, washing machines, and air conditioners. Goldstar first went public in 1970; by 1976, it was producing one million televisions annually. In 1982, Goldstar opened its first overseas factory, which was based in Huntsville, Alabama. In 1994, GoldStar officially adopted the LG Electronics brand and a new corporate logo. In 1995, LG Electronics acquired the US-based TV manufacturer Zenith and absorbed it four years later. Also in that year, LG Electronics made the world's first CDMA digital mobile handsets and supplied Ameritech and GTE in the US, the LGC-330W digital cellular phone. The company was also awarded UL certification in the US. In 1998, LG developed the world's first 60-inch plasma TV and established a joint venture in 1999 with Philips – LG.Philips LCD – which now goes by the name LG Display. In 1999, LG Semiconductor merged with Hynix. LG Electronics plays a large role in the global consumer electronics industry; it was the second-largest LCD TV manufacturer worldwide as of 2013. By 2005, LG was a Top 100 global brand and recorded a brand growth of 14% in 2006. As of 2009, its display manufacturing affiliate, LG Display, was the world's largest LCD panel manufacturer. In 2010, LG Electronics entered the smartphone industry. LG Electronics has since continued to develop various electronic products, such as releasing the world's first 84-inch ultra-HD TV for retail sale. At the end of 2016, LG Electronics merged its German branch (situated in Ratingen) and European headquarter (situated in London) together in Eschborn, a suburb of Frankfurt am Main. On 5 April 2021, LG announced its withdrawal from the phone manufacturing industry after continuous loss in the market. In 2020, LG faced a loss of 5 trillion won (US$4.4 billion). On 25 December 2021, LG Electronics launched a video campaign showing some of the initiatives the company has taken during the COVID-19 pandemic to support India. The video shows how the company has handled the pandemic from the beginning and includes urgings of good hygiene practices to include social distancing, hand-washing, mask wearing, and using hand sanitizers.

Product Range:

LG Electronics is involved in a wide variety of electronic and home appliance sectors, including:

- Consumer Electronics: This includes products like televisions, home audio systems, sound bars, and smartphones.
- Home Appliances: LG is well-known for making refrigerators, washing machines, air conditioners, vacuum cleaners, and kitchen appliances.
- Mobile Devices: LG used to be a major smartphone manufacturer, but in 2021, the company announced it would exit the smartphone market.
- IT Products: LG produces monitors, laptops, and other IT equipment.
- B2B Solutions: It also provides business solutions, such as signage systems and healthcare-related technology.

Technological Innovation:

LG is well-regarded for its technological advancements, particularly in areas such as:

- OLED and QLED Displays: LG is a leader in the production of OLED (Organic Light Emitting Diode) displays, which are known for their superior picture quality, particularly in high-end televisions.

- Smart Home Technology: LG has developed various smart home appliances and integrates AI into its products through its platform, LG ThinQ, to enable connectivity and automation.
- Green Initiatives: The Company is also focused on sustainability and environmental protection, implementing energy-saving technologies and environmentally friendly manufacturing processes.

Challenges and Developments:

- Smartphone Market Exit: As mentioned, LG exited the smartphone business in 2021, a decision attributed to stiff competition and declining market share.
- Business Transformation: The Company has increasingly focused on high-growth areas such as AI, robotics, and electric vehicle components (particularly through its LG Energy Solution subsidiary).

Key Subsidiaries and Divisions:

- LG Display: A key subsidiary of LG that focuses on the production of display panels, especially OLED panels used in TVs, smartphones, and other electronics.
- LG Chem: Another major subsidiary, LG Chem is a leader in the chemical and battery industries, especially for electric vehicles and energy storage.

1.3 The Significance of Logo

Fig. 1.2: LG Logo

The letters "L" and "G" in a circle symbolize the World, Future, Youth, Humanity, and Technology. Our philosophy is based on Humanity. Also, it represents LG's efforts to keep close relationships with our customers around the world. The symbol consists of two elements: the LG logo in LG Grey and the stylized image of a human face in the unique LG Red color. Red, the main color, represents our friendliness, and gives a strong impression of LG's commitment to deliver the best. Therefore, the shape or the color of this symbol must never be changed. The circle symbolizes the globe. The stylized image of a smiling face in the symbol conveys friendliness and approachability. Overall, LG’s symbol represents the world, future, youth, human, and technology.

1.4 Company’s Vision and Mission

Vision of LG Electronics: LG's vision focuses on achieving leadership in the electronics industry through innovation, customer satisfaction, and responsibility to society.

Vision Statement: "To become the market-leading company with innovation for a better life, providing superior value to customers through smart, sustainable solutions and global excellence."

This vision statement underlines LG’s dedication to technological innovation, customer-centric solutions, and long-term sustainability as core principles in driving their growth and success.

In summary, LG Electronics aims to innovate and provide value through its products, while focusing on sustainability and customer satisfaction to lead in the global electronics market.

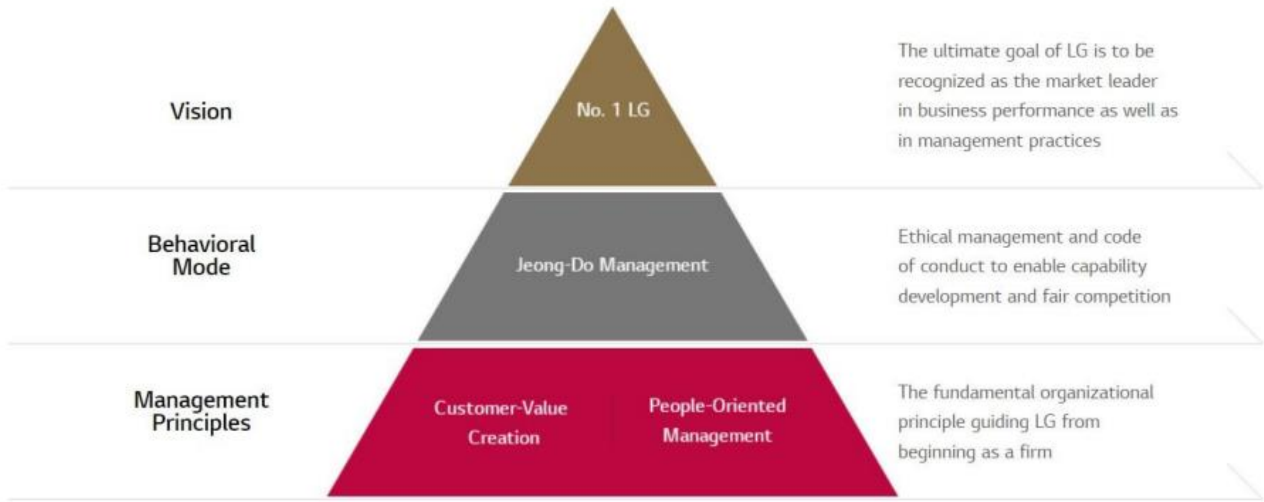


Fig 1.3: LG Vision

Mission of LG Electronics: LG Electronics' mission is to create innovation for a better life, delivering high-quality products and services that improve everyday living, enhance customer satisfaction, and promote sustainable practices.

Mission Statement: "LG Electronics is committed to delivering innovative products and services that make life better and contribute to a sustainable future for customers and communities."

This mission underscores LG’s dedication to creating value for customers, advancing technology responsibly, and ensuring environmental and social sustainability as integral to its operations. In summary, LG aims to innovate, inspire, and make a positive impact globally.

1.5 Various Departments and their Functions

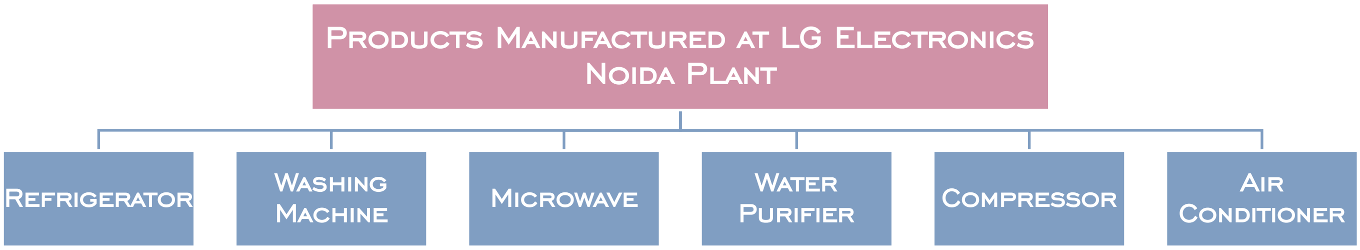


Fig 1.4: Range of Products at Noida Plant

The seamless functioning of any organization relies on its core departments working collaboratively, with each playing a vital role—from Research & Development innovating products to Quality Assurance ensuring their excellence, and from efficient material management to fostering a productive and supportive workplace through Human Resources.

1. **Research & Development (R&D):**
   - Develops new models to meet market needs and trends.
   - Focuses on cost and design optimization to balance performance, aesthetics, and affordability.
   - Implements Engineering Change Orders (ECO) to update designs or resolve issues in existing products.
   - Prepares and manages the Bill of Materials (BOM), listing all components and materials needed for production.
2. **Procurement:**
   - Sources and develops new parts for projects and products.
   - Identifies alternate suppliers to ensure continuous supply and cost-effectiveness.
   - Manages 4M changes (Man, Machine, Material, Method) to accommodate updates in production.
   - Localizes part sourcing to reduce costs and enhance supply chain efficiency.
3. **Material Management:**
   - Purchases raw materials required for manufacturing, ensuring availability and timely delivery.
   - Maintains inventory levels to avoid production delays or overstocking.
4. **Production:**
   - Oversees mass production to meet demand while adhering to planned timelines and budgets.
   - Ensures production lines run efficiently and meet quality standards.
5. **Quality Assurance (QA):**
   - Conducts quality checks on raw materials (input), production processes (line quality), and finished goods (output).
   - Develops and enforces quality standards to meet customer and regulatory requirements.

1.6 Concepts Being Followed at LG

1. **5S:** 5S is a five-step organization technique to create and maintain an intuitive workspace, which are:
   - Sort (Seiri): Focuses on identifying and removing unnecessary items, retaining only what is essential to reduce clutter and enhance organization.
   - Set in order (Seiton): Involves arranging tools and materials logically, labeling them for easy access, and adhering to the principle of "a place for everything, and everything in its place.
   - Shine (Seiso): Emphasizes thorough cleaning to maintain tidiness, ensure equipment is in good condition, and create a safe and prideful work environment.
   - Standardize (Seiketsu): Establishes clear procedures and checklists to maintain consistency in the first three steps, along with training employees to uphold these standards.
   - Sustain (Shitsuke): Encourages a disciplined culture where regular audits and personal responsibility ensure the system's longevity and success.

Fig 1.5: 5S Chart

2. **7 Waste:** For an organization, any activity that doesn't add value to a product is waste. A lean organization is the one which identifies waste activities and eliminate them through continues improvements. 7 types of waste are:
   - Overproduction: Producing items sooner, faster, or in greater quantities than customer demand, leading to excess inventory.
   - Inventory: Accumulation of raw materials, work-in-progress, or finished goods without immediate value addition.
   - Transportation: Unnecessary movement of materials, parts, or people between processes, causing inefficiencies.
   - Motion: Unproductive movements of workers, machines, or parts, often due to poor layout or workflow design.
   - Waiting: Idle time when people or parts are waiting for the next step in the process.
   - Defects: Errors or nonconforming products requiring rework, repair, or replacement, wasting time and resources.
   - Over processing: Performing more work or adding features beyond what the customer requires, resulting in wasted effort and cost.

Fig 1.6: 7 Waste

3. **3R - 3 Rightness**: The 3R - 3 Rightness framework in lean management emphasizes minimizing waste through proper handling of materials and resources:
    - Right Position: Ensure materials and parts are stored and used in the correct locations to minimize time and effort spent in searching or handling.
    - Right Container: Use standard containers for storing and transporting materials to reduce losses during supply or movement.
    - Right Quantity: Purchase, store, and produce only the necessary amount to avoid overstocking, waste, or shortages.

Chapter 2
COMPRESSOR

2.1 What is Compressor?

A compressor is a mechanical device designed to increase the pressure of a gas by reducing its volume, making it a key component in various systems and industries. In refrigeration and air conditioning systems, compressors circulate refrigerants, enabling heat exchange and cooling. They work by drawing in gas, compressing it through mechanical means like pistons, rotors, or diaphragms, and discharging it at higher pressure for specific applications. Compressors are similar to pumps: both increase the pressure on a fluid (such as a gas) and both can transport the fluid through a pipe. The main distinction is that the focus of a compressor is to change the density or volume of the fluid, which is mostly only achievable on gases. Gases are compressible, while liquids are relatively incompressible, so compressors are rarely used for liquids. The main action of a pump is to pressurize and transport liquids. Compressors come in various types, including reciprocating, rotary, and centrifugal, each suited to different needs and capacities.

2.2 Types of Compressor

Compressors are classified based on their working principle and enclosure type. By operation, they are divided into positive displacement (e.g., reciprocating, rotary) and dynamic types (e.g., centrifugal, axial). Based on enclosure, they include hermetic (sealed), semi-hermetic (partially sealed, serviceable), and open (exposed motor) designs, each suited to specific applications and maintenance needs.

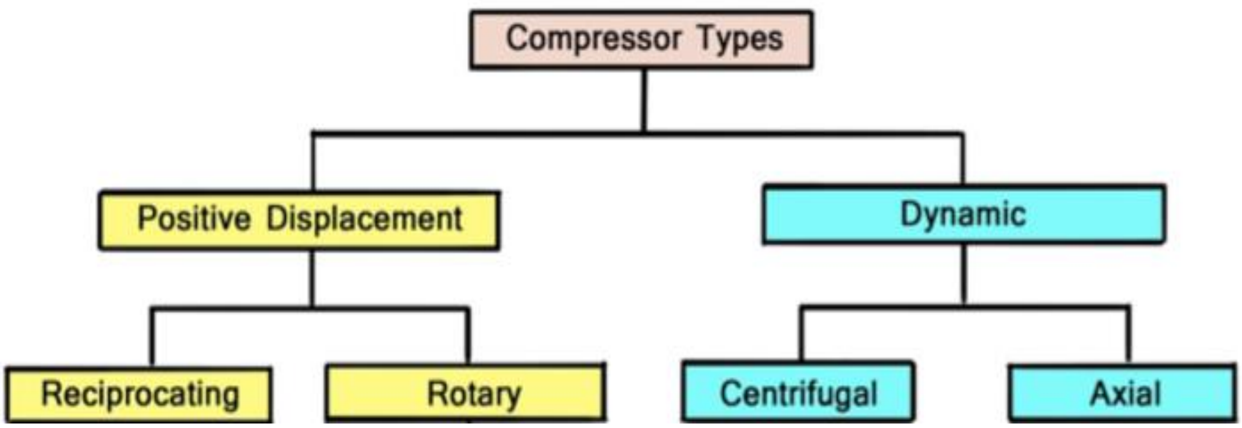


Fig 2.1(a): Types of Compressors Based on Working Principles

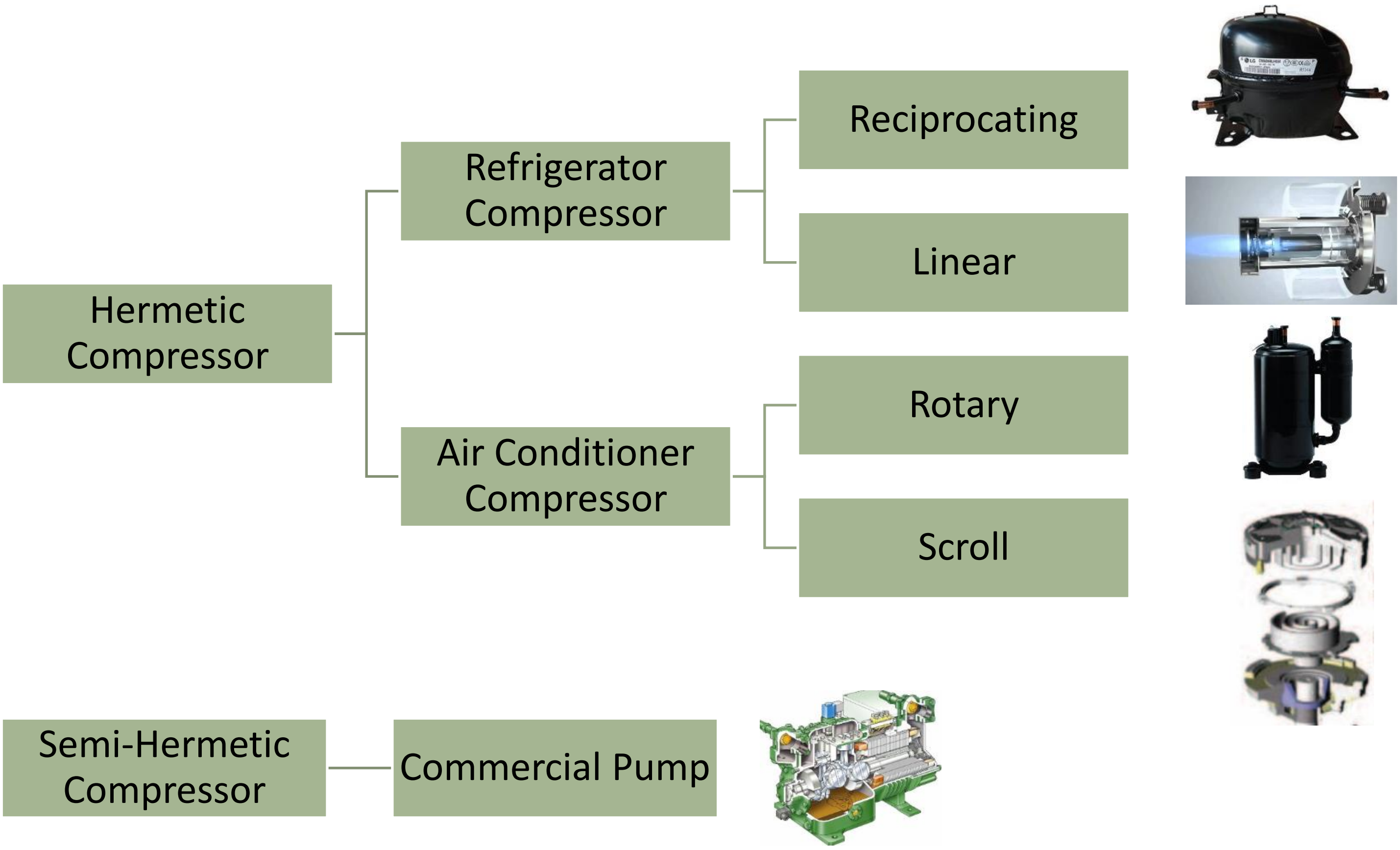


Fig 2.1(b): Types of Compressors Based on Working Principles

Type of Compressor	Description	Common Applications
Positive Displacement	Compresses air or gas by reducing its volume, typically using pistons or rotating elements.	Refrigeration, air conditioning, pneumatic tools
Reciprocating	Uses pistons moving up and down in cylinders to compress air or gas.	Small-scale industrial, automotive, HVAC
Rotary	Compresses air or gas using rotating elements like screws or vanes.	Industrial air systems, manufacturing
Dynamic Compressors	Increases air velocity and then converts it into pressure, typically using high-speed rotating blades.	High-volume applications like gas turbines
Centrifugal	A type of dynamic compressor that uses an impeller to increase the velocity of air, then converts it to pressure.	Large-scale industrial, HVAC systems
Axial	Uses rotating blades to compress air along the axis of rotation, typically in multiple stages.	Jet engines, large industrial systems

Table 2.1: Types of Compressors Based on Working Principles

Compressors can be categorized by enclosure type into hermetic and semi-hermetic. Hermetic compressors are fully sealed, preventing leaks but are non-repairable. Semi-hermetic compressors have bolted casings, allowing for maintenance and repair, making them suitable for commercial and industrial applications.

Semi-Hermetic Compressor: A semi-hermetic compressor has a bolted casing that allows easy access to internal components for maintenance and repair. This design combines durability with serviceability, making it suitable for commercial and industrial refrigeration systems. Unlike hermetic compressors, which are sealed and non-repairable, semi-hermetic compressors can be disassembled and fixed, reducing replacement costs over time. Their construction minimizes gas leaks while offering better performance and longevity, especially in applications requiring heavy-duty and continuous operation.

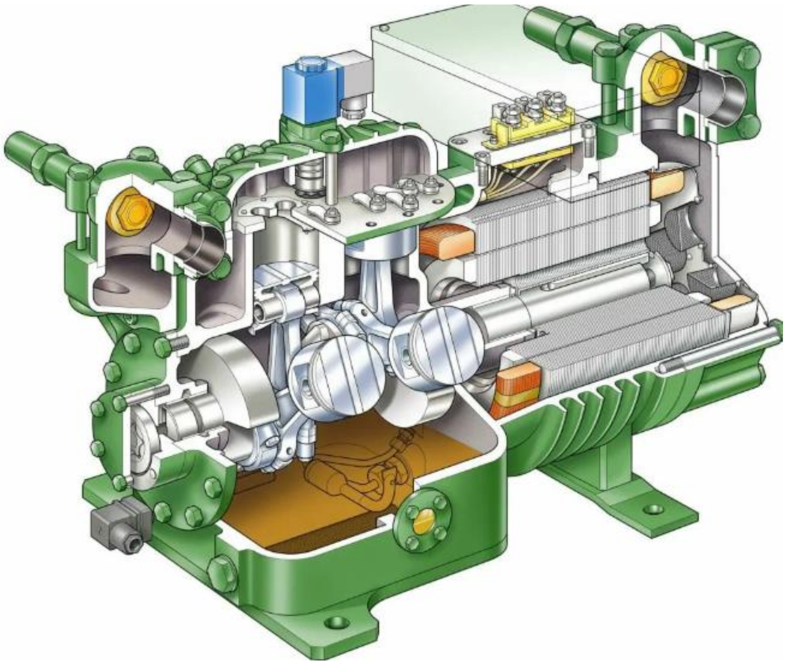


Fig 2.2: Semi-Hermetic Compressor

Hermetic Compressor: A hermetic compressor is a fully sealed system where the motor and compressor are enclosed within a welded steel casing, preventing gas leaks and ensuring reliable operation. This design is highly efficient and commonly used in household appliances like refrigerators, air conditioners, and small cooling systems. However, its sealed nature makes it non-repairable, so if a fault occurs, the entire unit must be replaced. Hermetic compressors are ideal for applications requiring compact and maintenance-free operation.

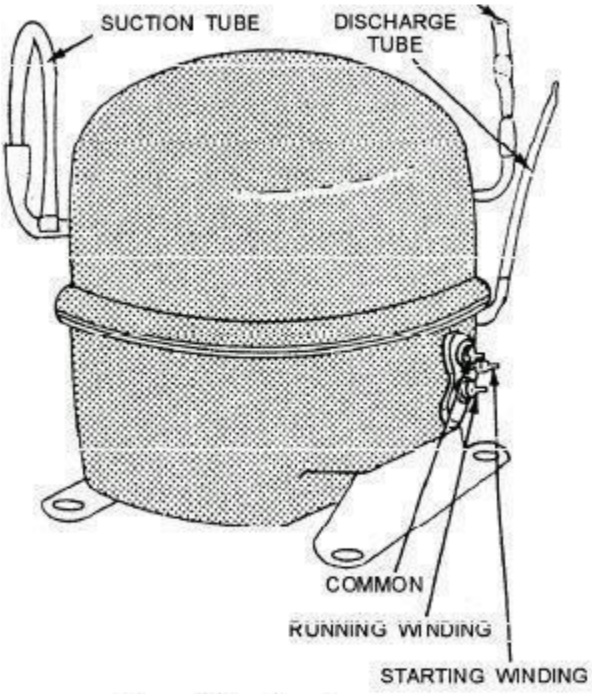


Fig 2.3: Hermetic Compressor

2.3 Required Characteristics of a Compressor

Compressors are vital for refrigeration and air conditioning, requiring key characteristics to perform effectively. These include adequate cooling capacity for varying loads, high efficiency to minimize energy use, reliable operation over time, and low noise levels to ensure comfort in residential, commercial, and industrial applications. The required characteristics of a compressor include:

1. **Cooling Capacity:** The cooling capacity refers to the compressor's ability to circulate refrigerant through the system, ensuring effective heat transfer and achieving the desired temperature control. A well-designed compressor must handle varying load conditions, such as changes in ambient temperature or heat loads in the space being cooled, without performance degradation. This ensures the system maintains consistent cooling performance across diverse operating scenarios.

   <u>*Compressor capacity (cc) calculation*</u>:

   CC $(cm^3) = \pi r^2 * L/1000$

   $* \, r: \ \frac{\text{piston OD}}{2}$

   ** L: Crankshaft Q*2*

2. **Efficiency:** Efficiency is a crucial characteristic as it directly impacts the energy consumption and operational cost of the refrigeration system. Compressors must convert mechanical energy into pressure energy with minimal losses. Advanced technologies like variable speed drives and optimized motor designs improve efficiency by adjusting the compressor's output to match cooling demand. High-efficiency compressors contribute to lower energy bills and reduced environmental impact.

Efficiency (COP):

$$COP\ (W/W) = \frac{\text{the amount of heat absorbed by the refrigerant in the evaporator (Eva)}}{heat\ equivalent\ of\ work\ supplied\ by\ the\ compressor}$$

$$= \frac{cooling\ effect\ (freezing\ capacity)}{compresion\ work}$$

3. **Reliability:** Reliability ensures that the compressor performs consistently over its intended lifespan with minimal downtime. This depends on robust design, high-quality materials, and resistance to wear and tear. Compressors must withstand challenges such as temperature extremes, fluctuating pressures, and continuous operation in demanding environments. Features like thermal protection, oil management systems, and overload safeguards enhance reliability.
4. **Noise Levels:** Low noise levels are vital for user comfort, particularly in applications like residential air conditioners, refrigerators, and commercial cooling systems. Excessive noise can be disruptive and indicate inefficiencies or mechanical issues. Manufacturers achieve quieter operation through design improvements like balanced components, soundproof enclosures, and vibration dampers. Modern compressors often include noise-reduction technologies to meet stringent sound-level standards.

2.2 Working Principle of Refrigerator Compressor (Reciprocating Compressor)

A reciprocating refrigerator compressor functions as the heart of the refrigeration system, compressing the refrigerant gas to facilitate heat transfer. A reciprocating refrigerator compressor works by converting mechanical energy into pressure energy to compress refrigerant gas. It operates through these steps:

1. **Suction Stroke:** During the suction stroke, the piston moves downward within the cylinder, increasing the cylinder's volume and reducing the pressure inside. This pressure drop causes the suction valve to open, allowing low-pressure, and low-temperature refrigerant gas from the evaporator to flow into the cylinder. Once the cylinder is filled with the refrigerant, the suction valve closes, sealing the gas inside and preparing it for compression.
2. **Compression Stroke**: During the compression stroke, the piston moves upward within the cylinder, reducing the cylinder's volume. This reduction compresses the refrigerant gas, causing a significant increase in its pressure and temperature. Although the gas is now high-pressure and high-temperature, the discharge valve remains closed at this stage, ensuring the gas is fully compressed before being released from the cylinder.
3. **Discharge Stroke**: During the discharge stroke, as the piston reaches the top of the cylinder (top dead center), the pressure of the compressed refrigerant gas surpasses the pressure in the discharge line. This pressure difference causes the discharge valve to open, allowing the high-pressure, and high-temperature refrigerant gas to exit the cylinder and flow into the condenser. Once the discharge is complete, the piston reverses its direction, starting a new cycle.

2.3 Compressor Assembly

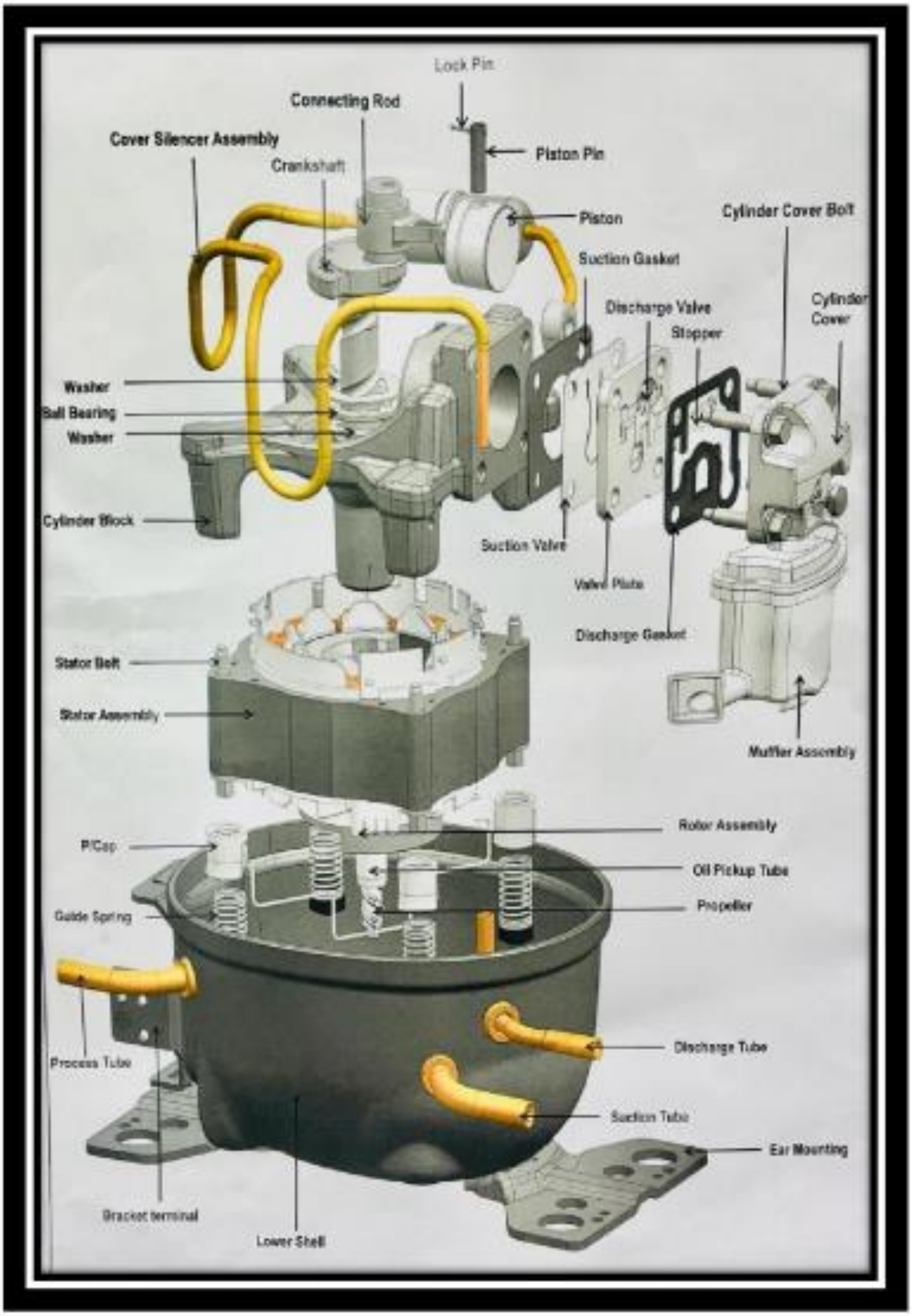


Fig 2.4: Compressor Assembly

2.4 Modules of Reciprocating Compressor

A reciprocating compressor has five modules: compression mechanism, motor, suction/valve system, discharge system, and appearance/supporting module, ensuring efficient gas compression, flow, and structural integrity.

Compression Mechanism Module	
Motor Module	
Suction and Valve System Module	
Discharge Module	
Appearance Supporting Module	

Table 2.2: Modules of Compressor

2.5 Functions of Key Components in a Compressor

A compressor comprises various components, each playing a crucial role in its operation. From the compression chamber to the valves and cooling systems, these parts work together to regulate pressure, ensure efficiency, and maintain durability. Understanding their functions helps in optimizing performance and diagnosing issues effectively.

1. **Cylinder Frame:**

- Forming a Compression Space (Compression Chamber): The cylinder frame houses the compression chamber, where the gas or fluid is compressed. This space is designed to withstand high pressures and maintain durability during continuous operation.
- Role of Shaft: The shaft, supported by the cylinder frame, transfers mechanical energy from the motor to the piston. This movement enables the piston to compress the gas effectively.

- Head Cover Assembly Support: The cylinder frame provides a sturdy base for mounting the head cover assembly, which seals the compression chamber and houses valves for intake and exhaust.
- Stator and Piston Support: The cylinder frame also serves as a support structure for the stator (in electric-driven compressors) and the piston assembly, ensuring alignment and stability during operation.

2. Piston & Con-rod:

- Suction, Compression, and Discharge of Refrigerant: The piston, driven by the connecting rod, moves within the cylinder to create the suction, compression, and discharge cycles. During suction, the piston draws refrigerant into the cylinder; it compresses the refrigerant during its upward stroke, and finally, discharges it into the system under high pressure.
- Inducing the Opening and Closing of Valves: The piston's movement generates pressure differences within the cylinder, triggering the automatic opening and closing of intake and exhaust valves. This ensures the refrigerant flows efficiently through the system.
- Reciprocating Motion inside the Cylinder: The connecting rod converts the rotary motion of the crankshaft into the piston's linear reciprocating motion. This precise movement ensures the refrigerant undergoes the compression cycle accurately and effectively.

3. Crankshaft:

- Transmitting Rotational Force to the Connecting Rod: The crankshaft converts the motor's rotational force into reciprocating motion by transferring energy to the connecting rod, enabling the piston to compress the refrigerant.
- Maintaining Piston Stroke Distance: The crankshaft ensures the piston's stroke distance remains consistent, allowing precise compression cycles for efficient operation.
- Pumping Oil for Lubrication: The crankshaft often includes built-in oil passages or mechanisms to pump lubricating oil, ensuring smooth operation and reducing wear on moving parts like the piston, connecting rod, and bearings.
- Supporting the Rotor: The crankshaft provides mechanical stability and alignment to the rotor in motor-driven compressors, enabling seamless energy transfer and operation.

4. Rotor:

- Induced Current Flow: The rotor generates mechanical energy through electromagnetic induction when current flows in the stator coils. This process creates the necessary torque to drive the compressor.
- Rotation: The rotor rotates at high speed, driven by the electromagnetic field produced in the stator, forming the foundation for the compressor's motion.
- Transmitting Torque to the Crankshaft: The rotor transfers rotational energy to the crankshaft, which converts it into the reciprocating motion needed to drive the piston and complete the compression cycle.

5. **Stator:**

- Generating Magnetic Flux and Current: The stator is the stationary part of the motor that houses the windings. When supplied with electrical power, it generates a rotating magnetic field, inducing current in the rotor to produce mechanical energy.
- Providing Electromagnetic Drive: The stator's magnetic field ensures a consistent and efficient rotational force for the rotor, which powers the crankshaft and drives the compression process.

6. **Suction Valve:**

- Adjusting Suction Amount of Refrigerant: The suction valve regulates the quantity of refrigerant entering the compression chamber, ensuring optimal flow for efficient operation based on system requirements.
- Preventing Reverse Flow of Refrigerant: During compression and discharge, the suction valve closes to prevent the refrigerant from flowing backward into the suction line, maintaining the compressor's efficiency and pressure balance.

7. **Discharge Valve:**

- Adjusting Discharge Amount of Refrigerant: The discharge valve controls the volume of refrigerant being expelled from the compression chamber into the system, ensuring proper flow and pressure levels for efficient operation.
- Preventing Backflow While Inhaling Refrigerant: The discharge valve closes tightly during the suction and compression phases to prevent refrigerant from flowing back into the compressor, maintaining proper refrigerant flow and system pressure.

8. **Cover Silencer:**

- Reducing Noise and Vibration: The cover silencer helps reduce noise and vibration by absorbing vibrations from the compressor body, leading to quieter operation and less mechanical stress.
- Leading High-Pressure Refrigerant Gas: The cover silencer directs high-pressure refrigerant gas from the compressor's discharge side, ensuring smooth and controlled flow into the system.
- Enhancing Compressor Efficiency: By reducing noise and managing gas flow, the cover silencer contributes to the overall efficiency and performance of the compressor, supporting stable operation.

9. **Upper and Lower Shell:**

- Protecting the Electric Compressor: The upper and lower shells provide a protective casing around the compressor's internal components, shielding the electrical and mechanical parts from external damage and contaminants.
- Blocking Internal Noise from Radiating Outside: These shells help contain the noise generated within the compressor, preventing excessive sound from radiating outward and ensuring quieter operation.
- Storing Freezer Oil: The shells house and contain the compressor oil, keeping it securely stored for lubrication and cooling of moving parts, which is essential for the compressor's longevity and performance.

- Preventing Refrigerant Leakage: The upper and lower shells ensure that the compressor remains sealed tightly, preventing refrigerant from leaking out and maintaining system efficiency and pressure integrity.

10. Hermetic Terminal:

- Connecting External Power to Stator: The hermetic terminal provides a sealed connection for external power supply to the stator windings, allowing the compressor motor to function properly.
- Supporting PTC and OLP: It supports the installation of a PTC (Positive Temperature Coefficient) and OLP (Overload Protector), which protects the compressor from overheating by monitoring the temperature and disconnecting the power supply if the temperature exceeds safe levels.

11. Spring:

- Supporting the Body: The spring helps support and stabilize the compressor body by providing a flexible connection between the compressor components and the mounting base.
- Absorbing Body Vibration: The spring absorbs vibrations produced during compressor operation, reducing mechanical stress on the components and minimizing noise while enhancing operational stability.

12. Positive Temperature Coefficient:

- Protect from Overheating: The PTC thermistor protects the compressor by increasing its resistance when the motor's temperature exceeds safe limits, reducing current flow and preventing further overheating.
- Overload Protection Mechanism: When overheating occurs, the PTC limits current flow. As the motor cools, the PTC's resistance decreases, restoring normal operation and preventing damage.

13. Overload Protector:

- Shut off Power in Overcurrent: The OLP disconnects the power supply if the current exceeds a safe threshold, preventing damage to the motor and compressor by stopping operation during electrical overloads.

14. PCB:

- Controlling Motor Operation: The PCB regulates the compressor motor's start, stop, and speed, ensuring efficient operation through proper timing and power management.
- Monitoring Protection Mechanisms: It interacts with protection components like the PTC (Positive Temperature Coefficient) and OLP (Overload Protector), ensuring the motor does not overheat or suffer from electrical issues.

Chapter 3
Motor

3.1 Motor and its Types

An electric motor is a machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft. Electric motors can be powered by direct current (DC) sources, such as from batteries or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators. Electric motors produce linear or rotary force (torque) intended to propel some external mechanism. This makes them a type of actuator. They are generally designed for continuous rotation, or for linear movement over a significant distance compared to its size.

Electric motors may be classified by considerations such as power source type, construction, application and type of motion output. They can be brushed or brushless, single-phase, two-phase, or three-phase, axial or radial flux, and may be air-cooled or liquid-cooled.

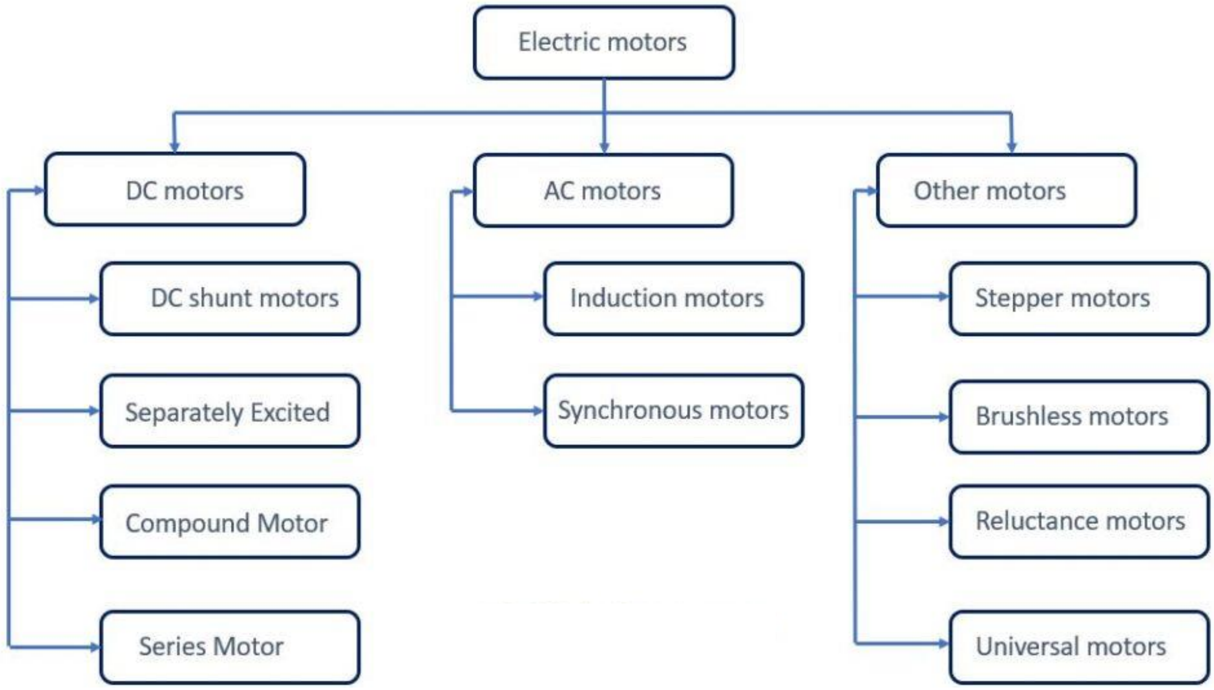


Fig 3.1 Types of Motors

3.2 Fundamental Rules Followed by Motors

Motors are an essential component of modern technology, powering everything from household appliances to industrial machinery and electric vehicles. Various types of motors, including DC, AC, and specialized variants like stepper and servo motors, are designed to meet diverse application needs. The operation of these motors is governed by fundamental laws of physics, such as Faraday's Law of

Electromagnetic Induction and Fleming's Left-Hand Rule, which explain the interaction of electric current and magnetic fields to produce motion. Understanding motor types, rules, and governing laws is crucial for their efficient design, application, and maintenance. Several fundamental laws of physics and engineering followed by motors are:

1 Faraday's Law of Electromagnetic Induction: Faraday's Law states that a voltage (or electromotive force, EMF) is induced in a conductor when it experiences a change in magnetic flux. The law is mathematically expressed as:

$$e = -\frac{d\phi}{dt}$$

Where:

- e is the induced voltage.
- ϕ is the magnetic flux.
- $\frac{d\phi}{dt}$ is the rate of change of magnetic flux.
- The negative sign indicates the direction of the induced EMF opposes the change in flux (Lenz's Law).

2 Fleming's Left Hand Rule: This rule states that if we arrange our thumb, forefinger and middle finger of the left-hand perpendicular to each other, then the thumb points towards the direction of the force experienced by the conductor, the forefinger points towards the direction of the magnetic field and the middle finger points towards the direction of the electric current.

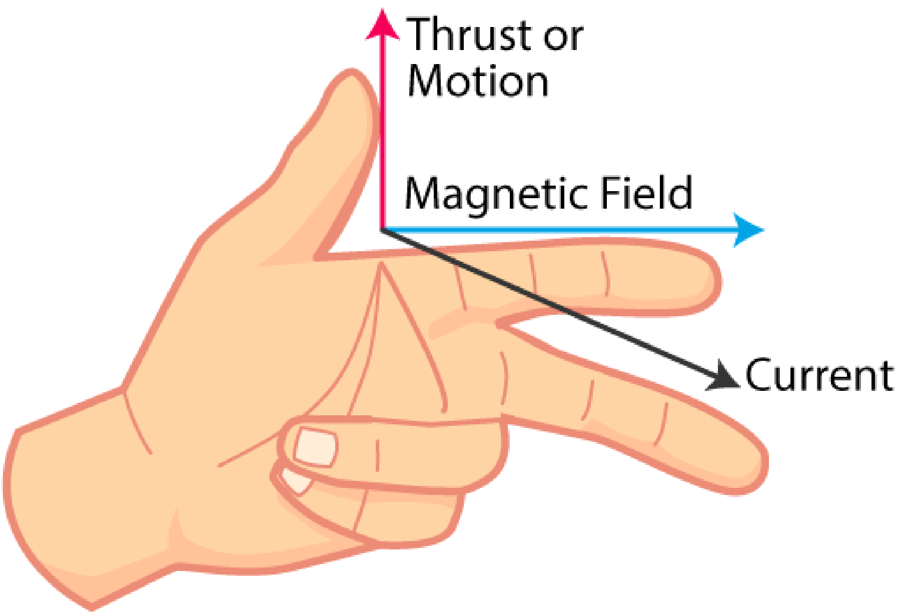


Fig 3.1: Fleming's Left Hand Rule

3 Lenz's Law: Lenz's Law states that the direction of the induced current (or electromotive force, EMF) in a conductor opposes the change in the magnetic flux that caused it.

4 Lorentz Force Law: The Lorentz Force Law describes the force experienced by a charged particle or a current-carrying conductor when it interacts with electric and magnetic fields.

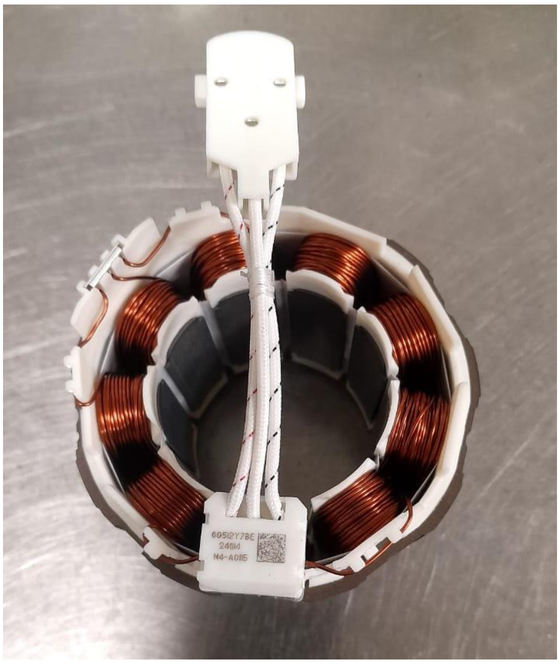
3.3 BLDC Motor

A conventional DC motors suffers from the following two major problems:

(i) They require more maintenance and need to replace brushes periodically

(ii) Their operating voltage and speed is limited because of commutation difficulties

To over-come these difficulties, we have to eliminate commutator and brushes. Thus, a motor that retains the characteristics of a DC motor but eliminates the commutator and brushes is called a brushless DC motor. The brushless DC motors are equipped with electronic circuits and devices which perform the same function as that of a mechanical commutator A brushless DC electric motor (BLDC), also known as an electronically commutated motor, is a synchronous motor using a direct current (DC) electric power supply. It uses an electronic controller to switch DC currents to the motor windings producing magnetic fields that effectively rotate in space and which the permanent magnet rotor follows. The controller adjusts the phase and amplitude of the current pulses that control the speed and torque of the motor. It is an improvement on the mechanical commutator (brushes) used in many conventional electric motors. The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor. They may also use neodymium magnets and be outrunners (the stator is surrounded by the rotor), inrunners (the rotor is surrounded by the stator), or axial (the rotor and stator are flat and parallel).



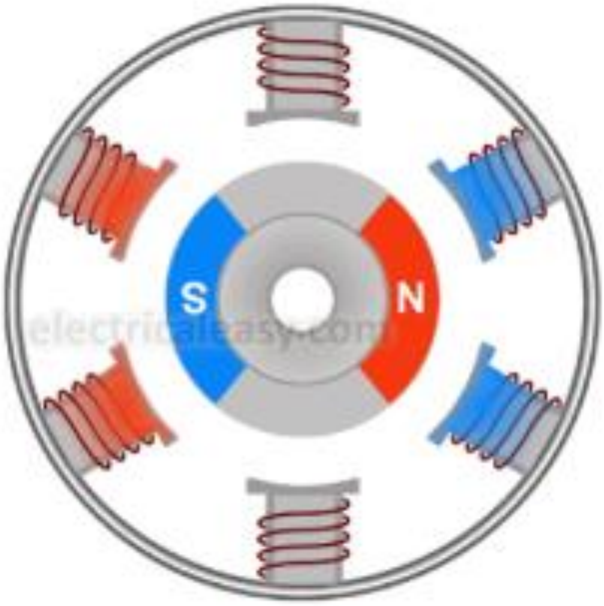


Fig. 3.2: BLDC Motor

3.4 Operating Principle

The schematic diagram of a brushless DC motor is shown in Fig. 3.3. It consists of a multi-phase winding wound on a non-salient stator and a permanent magnet (PM) rotor. The required voltage is applied to the individual phase winding through a sequential switching operation such that the necessary commutation is achieved to impart rotation to the motor. The necessary switching operation is achieved by using electronic circuit and devices such as transistors.

Switching Operation:

When switch S1 is closed, winding-1 is energized, the PM rotor is aligned with its magnetic field. When switch S1 is opened and S2 is closed, winding-2 is energized, the PM rotor is aligned with its magnetic field and turn through a particular angle. When a number of such phase windings are energized sequentially, the rotor rotates. In such motors, the windings can be designed for required voltage and very high speeds, as high as 40000 rpm.

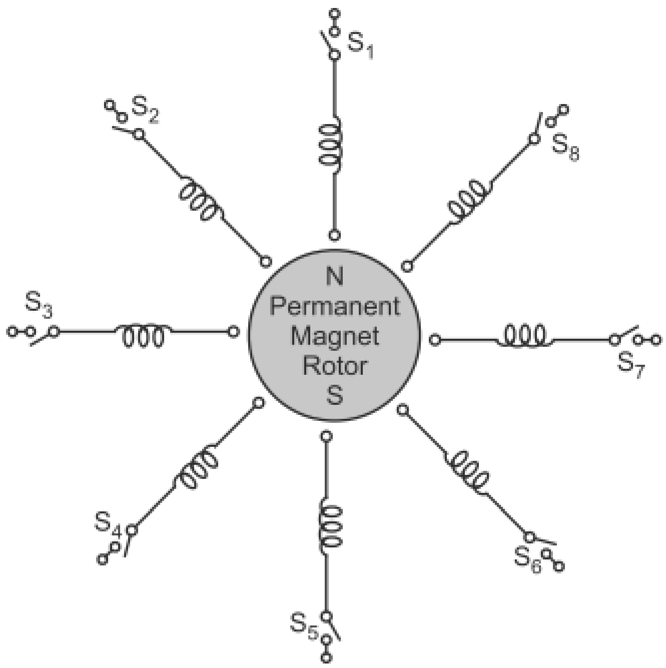


Fig 3.3: Conventional diagram of a brush-less DC motor

Advantages:

- Require little or no maintenance
- Have longer operating life
- Less losses, more operating efficiency
- No sparking, hence can be used in the vicinity of combustible fluids and gases.
- These are very reliable and efficient (efficiency is more than 75%).
- They are capable to run at very high speeds (more than 40000 rpm)

Disadvantages

- More expressive then conventional DC motors
- Additional electronic circuit and devises are required that increases the overall size of the machine

3.5 Types of Windings

There are two primary motor windings: distributed windings, where coils span multiple slots, ensuring smooth operation with low noise, and concentrated windings, where coils surround individual teeth, offering compact size and high torque density.

Concentrated Windings: Concentrated windings are characterized by coils wound around individual teeth of the stator core, with no overlap between adjacent phases.

Features:

- Compact Design: Winding is localized around a single stator tooth, reducing the length of end windings.
- High Torque Density: Due to the strong localized magnetic field around the teeth, these windings offer better torque per unit volume.
- Simple Manufacturing: Easier to wind as there is no interconnection between teeth or slots.
- Higher Harmonics: The concentrated nature leads to increased harmonic content in the back-EMF, causing torque ripple.
- Noise and Vibrations: Due to higher harmonics, noise, and mechanical vibrations can be more pronounced.
- Applications: Common in small motors, drones, and applications requiring high torque and compact designs.

Fig 3.4: Concentrated Winding

Distributed Windings

Distributed windings span multiple stator slots, with coils of each phase spread out and overlapping in the stator core.

Features:

- Smooth Torque Production: The distributed nature reduces torque ripple, leading to smoother operation.
- Low Harmonic Content: Minimizes harmonics in back-EMF and current, improving efficiency.
- Reduced Noise and Vibrations: Lower harmonic content results in quieter operation.
- Complex Manufacturing: Winding is more intricate due to overlap, requiring precise placement and connections.
- Larger Size: Increased winding overlap increases the motor's overall size.
- Applications: Widely used in industrial motors, EVs, and appliances where efficiency and smooth operation are critical.

Fig 3.4: Distributed Winding

3.6 Parts of Stator Assembly

The stator assembly serves as the heart of the BLDC motor, playing a pivotal role in the generation of the magnetic field that drives the motor's operation. It is an intricately designed structure that combines precision engineering with advanced materials to achieve optimal performance. Every component within the stator assembly works in perfect harmony to create the electromagnetic forces necessary for smooth, efficient, and reliable motor functionality. The stator is not merely a passive structure; it is the powerhouse that sets the entire motor into action. From the robust silicon steel core, which channels the magnetic flux with exceptional efficiency, to the meticulously arranged insulation layers that ensure electrical safety and durability, every detail of the stator assembly is engineered for excellence. The magnet wire, carefully wound to form the motor windings, transforms electrical energy into a powerful electromagnetic field. This field interacts dynamically with the rotor's magnets, creating the motion essential for the motor's operation.

Beyond its functional importance, the stator assembly is a masterpiece of modern manufacturing. Advanced insulation materials- such as upper and lower insulation sheets and high-quality insulation paper- provide critical protection against electrical breakdown, ensuring long-term reliability even under extreme operating conditions. The harness and mag-mate connectors simplify integration, ensuring secure and efficient electrical connections that withstand thermal and mechanical stresses.

In a BLDC motor, the stator assembly is more than just a component; it is the foundation of performance, efficiency, and durability. Without its precise design and flawless execution, the motor could not achieve the high levels of torque, speed control, and energy efficiency demanded in today's cutting-edge applications. Its significance cannot be overstated- it is the engine within the engine, the unseen force driving innovation forward.

Core:

The stator core is one of the most critical components of a BLDC motor, designed to channel the magnetic flux efficiently and serve as the structural foundation for the motor's operation. It becomes a path for magnetic flux and uses thin silicon steel sheets with insulation on both sides to reduce iron loss by reducing eddy current and hysteresis losses.

- The core also provides mechanical support for the windings, securely holding them in place within the motor housing. It ensures that the windings remain properly aligned for consistent magnetic interactions.
- As the windings generate heat during operation, the core helps dissipate this heat, ensuring the motor operates within a safe temperature range.
- The core features slots where the windings are placed. These slots are carefully designed to optimize the winding placement, minimize air gaps, and reduce magnetic flux leakage.
- Slot shape and size significantly influence the motor's performance, including torque production, efficiency, and heat dissipation.
- The laminated structure also minimizes hysteresis losses, which occur due to repeated magnetization and demagnetization of the core material during motor operation.

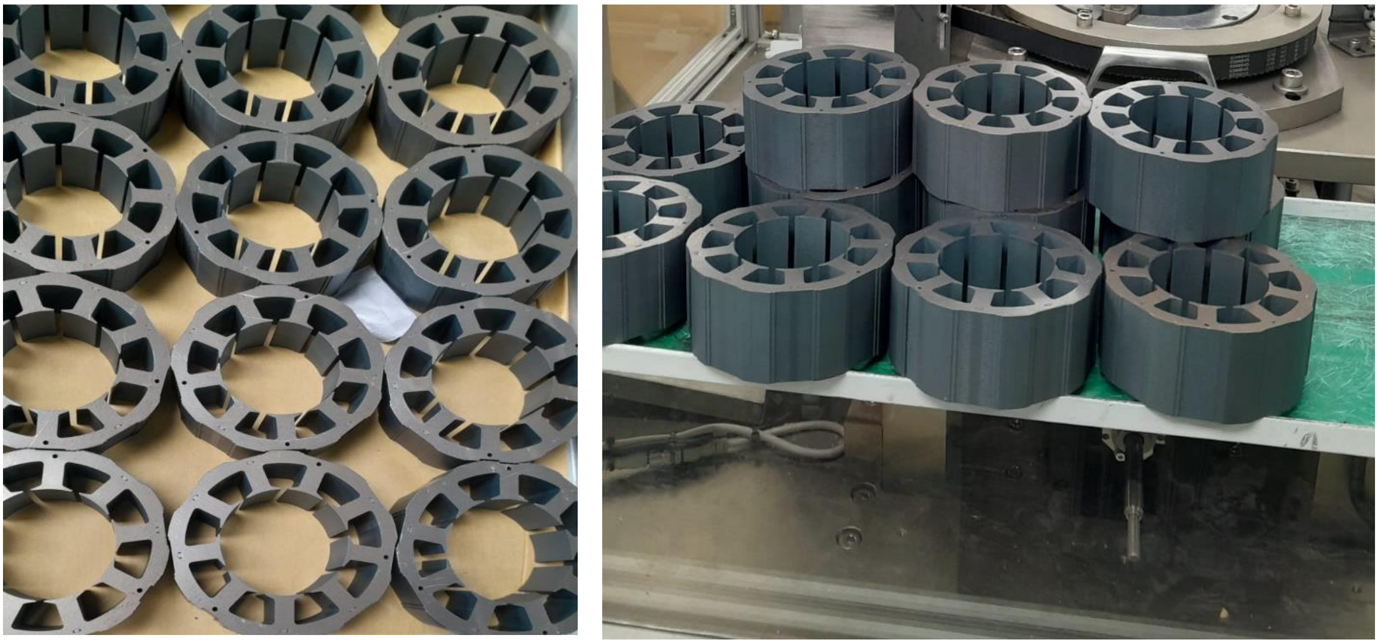


Fig 3.5: Stator Core

Material: **Laminated Silicon Steel (Si Steel)**

The stator core is made from silicon steel, a soft magnetic material that exhibits excellent magnetic permeability and low core losses. The addition of silicon improves electrical resistivity, significantly reducing eddy current losses, which are parasitic currents induced by the alternating magnetic field. The laminations are typically coated with a thin insulating layer to further inhibit eddy currents and reduce heat generation. Instead of a single solid piece of steel, the core is built from thin sheets (laminations), often 0.35–0.5 mm thick. These laminations are stacked together and insulated from each other to minimize the flow of eddy currents, ensuring higher efficiency.

Fig 3.6: Si Steel Lamination

Insulation:

Insulation is a vital component of the stator assembly in a BLDC motor. It ensures electrical isolation between the stator windings and the core, preventing short circuits and maintaining the motor's reliability and performance. A BLDC Motor consists of upper insulator, lower insulator and insulator paper. Deterioration of insulating material may be caused by mechanical causes such as abrasion and repeated stress, or by physical or chemical changes such as crystallization, dissolution, and corrosion or contamination loss. However, among these, the most notable is deterioration due to heat.

Electrical insulation materials are classified into various thermal classes based on their maximum operating temperature. These classifications ensure that motors operate safely under specific conditions. Below is a detailed explanation of the insulation classes commonly used in motors, including their temperature ratings and materials.

Class of Insulation	Description	Allowable Maximum Temperature
Class Y	Made of materials such as cotton, silk, paper, etc. and not impregnated with varnishes or oil	90°C
Class A	Consisting of the same material as class Y, impregnated with varnishes or oil	105°C
Class E	Polyurethane resin, epoxy resin, cotton laminate, and paper laminate for enamel wire	120°C
Class B	Constructed using adhesive materials such as mica, asbestos, glass fiber, etc.	130°C
Class F	Consisting of bonding materials such as silicon alkyd resin or a material as Class B	155°C
Class H	Using same material as Class B and Class F as a silicon resin or a material with equivalent properties	180°C
Class C	Those that consists solely of raw mica, asbestos, porcelain, etc. or used with adhesive materials	Higher than 180°C

Table 3.1: Class of Insulation

Purpose and Importance:

- Electrical Isolation: Prevents the flow of unintended electrical currents between the stator windings and the core, avoiding short circuits and damage to the motor.
- Thermal Protection: Insulation materials are designed to withstand high temperatures generated during motor operation, ensuring the windings do not degrade under thermal stress.
- Mechanical Protection: Shields the windings from mechanical damage due to vibrations, thermal expansion, or the sharp edges of the stator core.
- Enhanced Reliability: By preventing electrical faults and protecting against environmental factors, insulation extends the operational life of the motor and reduces maintenance requirements.

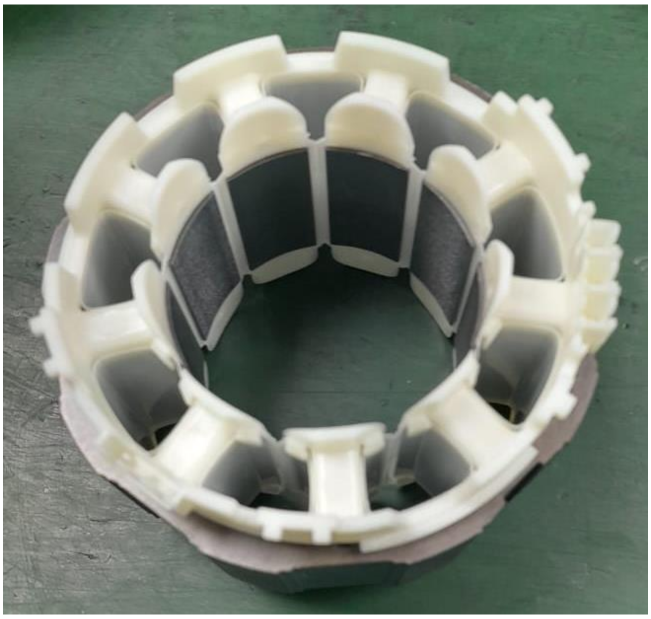


Fig. 3.7: Stator Core with Insulation

Upper insulation, placed at the top of the stator core slots, prevents electrical contact between winding ends and motor components, provides mechanical stability, and protects against environmental factors like dust, moisture, and vibrations. Lower insulation, located at the bottom of the slots, acts as a barrier to prevent electrical leakage or short circuits between the windings and the core. Insulation paper, lining the slot walls, offers additional protection against mechanical wear, absorbs vibrations, and ensures electrical isolation and durability under high temperatures, safeguarding the windings during operation.

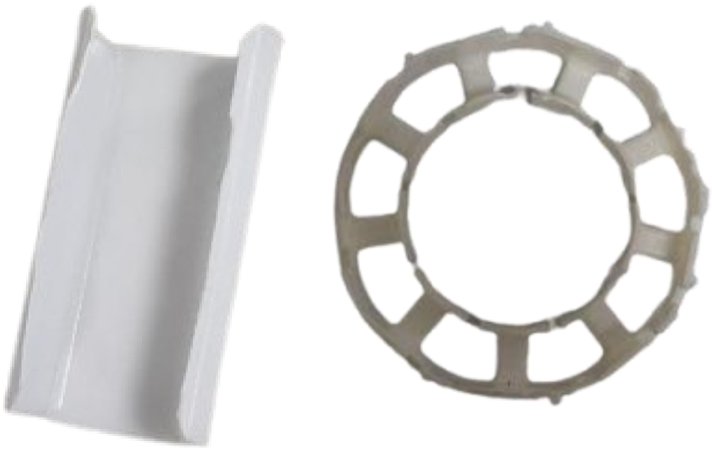


Fig. 3.8: Insulation Paper and Upper Insulation

Magnet Wire:

Magnet wire, also known as enameled wire, is a vital component of the stator assembly in a BLDC motor. It is specifically designed to carry electrical current while generating the electromagnetic field necessary for motor operation. It is a medium that forms a magnetic field, has a great influence on the reliability and material cost of the motor.

Material:

- Copper: It is the most commonly used material due to its excellent electrical conductivity, allowing efficient current flow with minimal resistance. It also offers high mechanical strength and flexibility, making it suitable for intricate winding patterns.
- Aluminum: It is a lighter and more cost-effective alternative, often used in applications where weight reduction is critical. However, aluminum has lower electrical conductivity compared to copper and requires a larger wire diameter to compensate for resistance.

Enamel Coating:

Both copper and aluminum wires are coated with a thin layer of insulating enamel to prevent short circuits between adjacent wire turns. The enamel is made of materials like polyurethane, polyimide, or polyester, chosen for their heat resistance and dielectric strength. The coating is uniform and durable, ensuring insulation integrity even under high thermal and mechanical stress.

Magnet wire in the stator windings generates an electromagnetic field when current flows, interacting with the rotor's magnets to produce torque and rotation. Its high conductivity enables efficient energy conversion from electrical to mechanical energy, minimizing losses and enhancing motor performance.

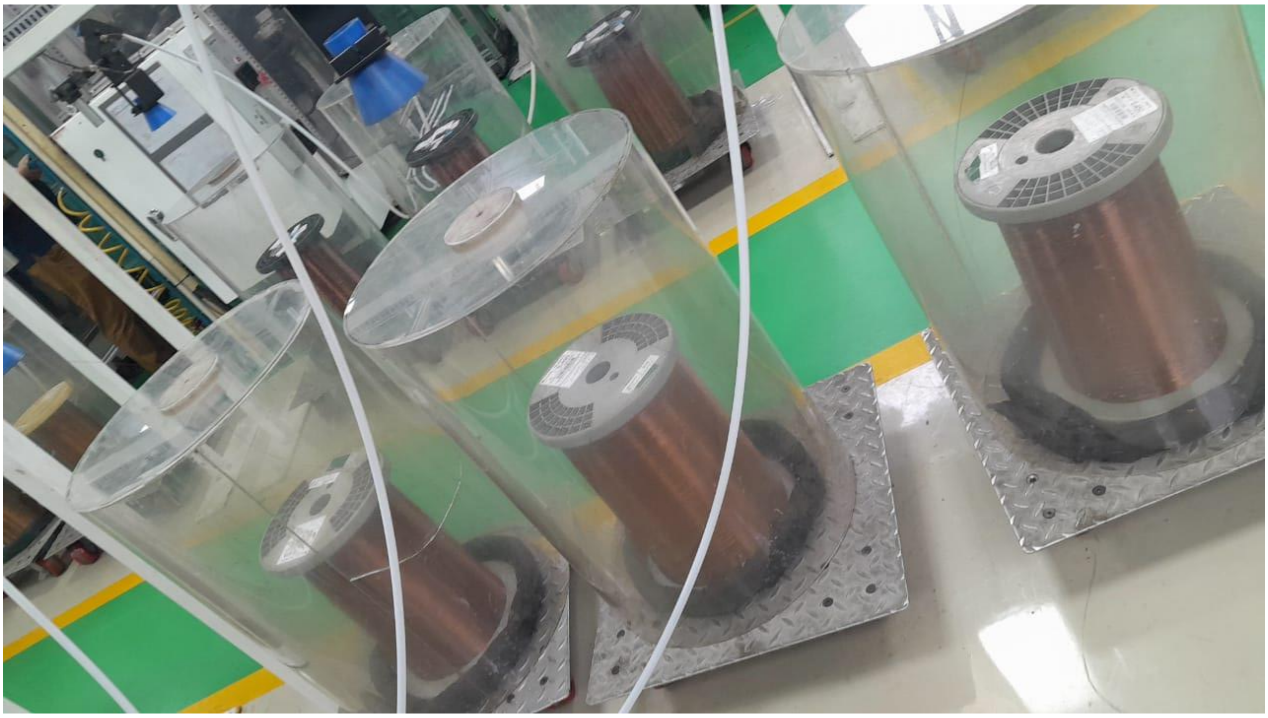


Fig. 3.9: Magnet Wire Spool

Harness and Mag-mate:

The harness ensures efficient and secure electrical connections between the stator windings and external systems, while the Mag Mate simplifies the termination process, providing durable and reliable connections for winding ends. Together, these components enhance the motor's performance, ease of assembly, and operational longevity.

- Harness: The harness is a vital component of the BLDC motor's stator assembly, facilitating the seamless transfer of electrical power to the motor windings. It connects the stator windings to the external power supply or motor controller, ensuring stable and efficient current flow for optimal motor operation. In addition to power, the harness may transmit control signals between the motor and controller, enabling precise speed and torque regulation. It also provides insulation and shielding to protect against electrical faults, environmental factors, and interference. Designed to withstand mechanical stresses, vibrations, and harsh environments, the harness ensures long-term reliability and performance.

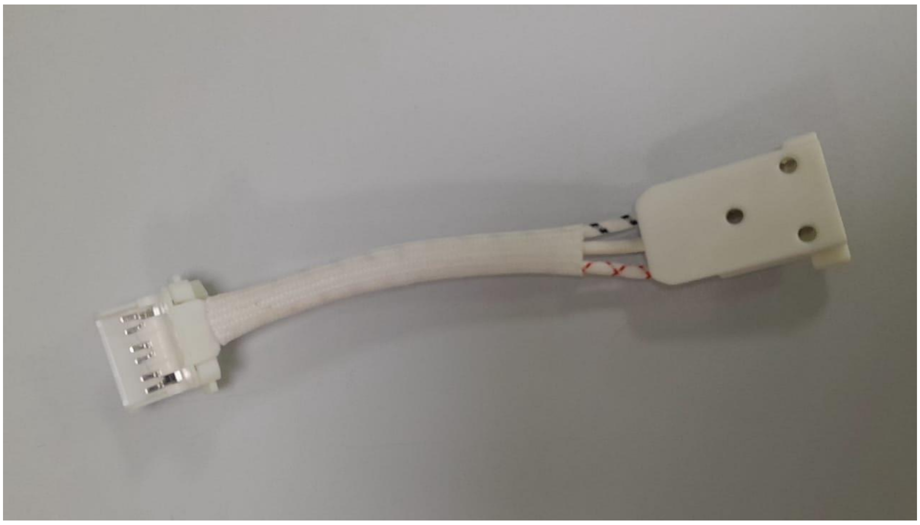


Fig. 3.10: Harness

- Mag-mate: Mag Mates are specialized connectors designed to simplify the termination and securement of stator winding ends, ensuring quick, reliable assembly without the need for soldering. Mag-mates can be 1 pin (1P mag-mate) type or 3 pin (3P mag-mate) type. These connectors provide a fast and efficient means to link winding ends to the harness or external circuitry, reducing assembly time and labor. They ensure low-resistance, stable connections, maintaining performance under high currents and vibrations. Made of heat-resistant and conductive materials like copper alloys with protective coatings, Mag Mates are designed for durability in high-temperature environments, preventing degradation over time. Featuring easy insertion mechanisms such as spring-loaded or snap-fit designs, they integrate seamlessly with insulation systems to ensure proper electrical isolation and mechanical strength. Tested for robustness, they maintain connection integrity under mechanical stress, elevated temperatures, and operational demands.

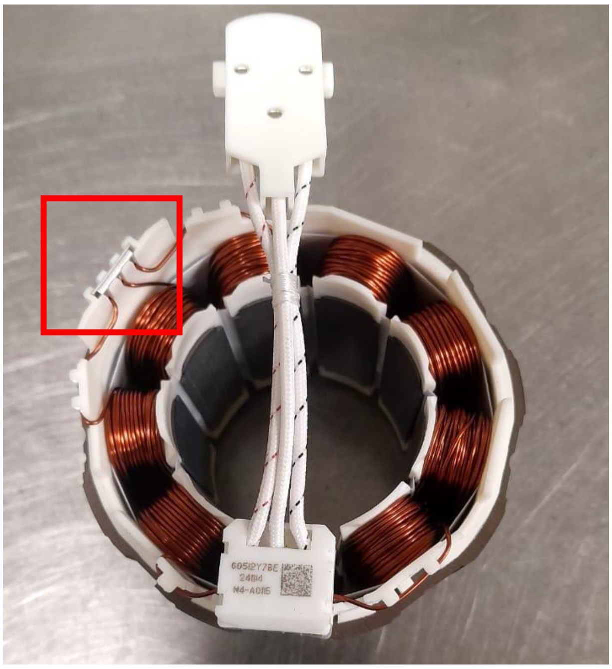


Fig. 3.11: Mag-mate

Chapter 4
PROJECT UNDERTAKEN

4.1 Project and Its Purpose

During my internship at LG Electronics, I had the opportunity to contribute to two major R&D projects: **localization of magnet wire for BLDC motors** and the **implementation of a new SoC-based PCB for compressors**. The goal of the magnet wire localization project was to reduce production costs by replacing imported wire from Korea with high-quality local alternatives. My responsibilities included monitoring motor line trials, measuring stator weights before and after winding to calculate wire usage, and performing quality checks such as pinhole tests, resistance measurements, and ELT testing. These activities were essential to ensure that the locally sourced wire met performance standards without compromising the final product's quality.

In the second project, I was involved in the transition from a traditional PCB design that used separate IPM and microcontroller components to a more efficient System on Chip (SoC) solution. The new PCB was designed in Korea but manufactured through a local supplier. My role involved flashing the firmware onto the PCB, testing the compressor's operation, and conducting reliability tests in collaboration with the Outgoing Quality Check (OQC) department. This ensured that the locally produced PCB met functional and durability requirements before mass production.

4.2.1 Steps Involved in Development of Motor

Following are the steps that are critical in ensuring the motor's reliability, performance, and longevity.

1. Insertion of Insulation Materials:

The process begins with placing insulator paper inside the stator core slots to create a protective barrier between the core and the winding wires. This prevents electrical short circuits and ensures safety during operation. Additionally, upper and lower insulators are installed to safeguard the winding ends and maintain electrical isolation. These insulation materials are carefully positioned to enhance the durability and reliability of the motor.

2. Wire Winding:

Magnet wire is precisely wound around the stator slots to form the stator windings. Depending on the motor design and application, the wire is arranged in either a concentrated or distributed pattern. This winding process is critical as it creates the electromagnetic field required to drive the motor during operation. Proper tension and alignment during winding ensure consistent performance and minimize energy losses.

3. Mag Mate Insertion:

After the winding process, 1P and 3P Mag Mates, specialized connectors, are inserted to terminate and secure the winding ends. These connectors eliminate the need for soldering, streamlining the assembly process and ensuring robust electrical connections. This step enhances manufacturing efficiency while guaranteeing reliable performance under high currents and vibrations.

4. Line Quality Check:

To ensure the motor meets quality standards, a series of rigorous tests are conducted. Resistance testing verifies the electrical integrity of the windings, surge testing checks insulation strength, and rotation testing confirms the motor's operational functionality. These tests help identify and address any defects, ensuring the stator is ready for final assembly.

5. Harness Insertion:

The final step involves attaching the harness, which connects the stator windings to the external power supply or motor controller. This connection enables power and signal transmission, completing the motor's electrical interface. The harness is designed for durability and ensures seamless integration with the motor's control system.

Before the insertion and pressing of harness, the motor has to pass through the line quality check (LQC), where it is checked for resistance for each phase (U, V, W) and also the resistance between two phases (U-V, V-W, W-U). The motor is also tested for surge to check if it can sustain sudden changes in current and voltage. If the motor passes these tests, then only it is allowed for harness insertion after which motor is sent to quality department for further inspection.

Fig. 4.1: Step1- Insulator Insertion

Fig: 4.2 Step 2- Winding Machine

Fig 4.3: Step 3- Mag-mate Insertion and Wire Cutting

Fig 4.4: Step 4- Harness Insertion and Pressing

Fig. 4.5: LQC Testing (Rotation Test)

Fig. 4.6: Laser Marking (QR Code and Label) on Harness and M- Gauge Testing

4.2.2 Challenges Faced During Localization of Wire (Al) for Ref Comp Motor

One of the key challenges encountered during the motor manufacturing process was related to the resistance measurements of the stator windings. After completing all the necessary steps for motor assembly, including winding, pinhole testing, and line quality checks, we observed that the resistance of the windings for some motors was nearing the Upper Specification Limit (USL), and in some cases, it exceeded the USL.

As resistance is directly proportional to the tension of the wire during the winding process, the immediate solution was to reduce the tension applied to the wire in the winding machine. Lowering the tension was expected to decrease the resistance, as it would allow the wire to be wound with less compression, resulting in less resistance. However, this approach was complicated by the fact that there were also strict specifications for the wire tension, which could not be adjusted beyond a certain limit to ensure the winding quality and mechanical strength of the stator.

Despite reducing the tension to the allowable limits, the resistance still remained higher than expected, posing a significant issue. This required us to explore alternative methods and conduct further investigations to identify the root cause of the resistance being out of specification. We had to balance the need to reduce the resistance with maintaining the desired quality and strength of the winding, which added a layer of complexity to the project.

This challenge highlighted the delicate balance between achieving the desired electrical characteristics (such as resistance) and meeting mechanical and process specifications. It also highlighted the need for continuous monitoring and fine-tuning of the manufacturing process to ensure all parameters are within the required tolerances.

4.2.3 Solution to the Problem

To address the challenge of high resistance in the stator windings, we collaborated with our local wire supplier to find a suitable solution. After discussing the issue thoroughly, we concluded that increasing the annealing temperature of the wire could help reduce its resistance. Annealing is a process that alters the physical properties of the wire, including its electrical resistance, by heating it to a specific temperature.

Previously, the annealing temperature was set at 450°C, but after careful consideration and discussions with the supplier, we decided to increase it to 500°C. This adjustment helped in reducing the resistance of the wire, bringing it within the desired range while still maintaining the specified tension limits for the winding process.

By optimizing the annealing temperature, we were able to achieve the necessary electrical properties without compromising the mechanical strength or quality of the winding. This solution not only resolved the resistance issue but also ensured that the motor components met all the required specifications, enabling the motor to pass the final quality checks and move forward in the production process.

4.2.4 Challenges Faced During Localization Of Wire (Cu) for AC Comp Motor

During the localization of copper wire for AC compressor motors, we encountered a significant issue with scratches on the wire after it was wound around the stator. Initially, the locally manufactured motor passed all line quality checks, including resistance, surge, and rotation tests. However, when the motor underwent further testing at the IQC stage, specifically the ELT (Endurance Life Test), inconsistent and unpredictable results were observed.

In the ELT test, the motor is placed in a chamber maintained at 85°C, where a high voltage of 5 kV is applied cyclically—5 seconds on and 1 second off. To pass the test, the motor must withstand a minimum of 2000 cycles without failure. While some motors in the same lot exceeded 2000 cycles with no issues, others failed at a significantly lower number of cycles. This irregular behavior raised concerns about the reliability of the localized wire.

To identify the root cause, the failed motors were subjected to a BDV (Breakdown Voltage) test, where a voltage of 6.3 kV was gradually applied. The results consistently showed that sparks were emanating from the area around the harness. Upon further investigation, all motors that failed in the ELT test exhibited sparks in the same region.

To understand the issue in detail, we decided to cut open the failed motors. Inspection revealed that scratches were present on the magnet wire, specifically in the U, V, or W phases, within the first 1-3 turns of the wire around the stator. These scratches likely compromised the insulation of the wire, leading to localized breakdowns during high-voltage tests. This defect was determined to be the cause of the premature failure of the motors in the ELT test.

The findings pointed to a critical manufacturing issue, emphasizing the need for further process refinement and quality control measures to ensure the integrity of the magnet wire during the winding process.

Fig 4.7: BDV Testing

Fig. 4.8: BDV Tester

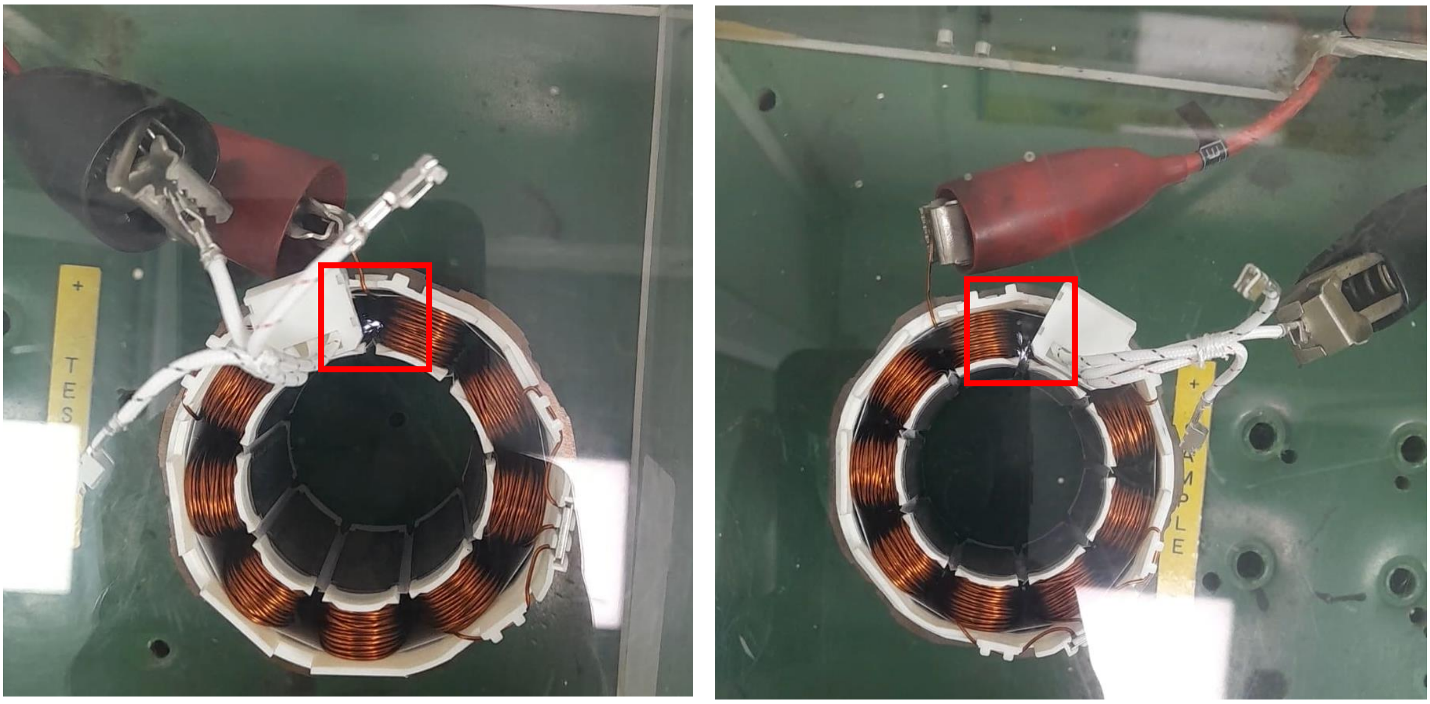


Fig 4.9: Sparks Found During BDV Test

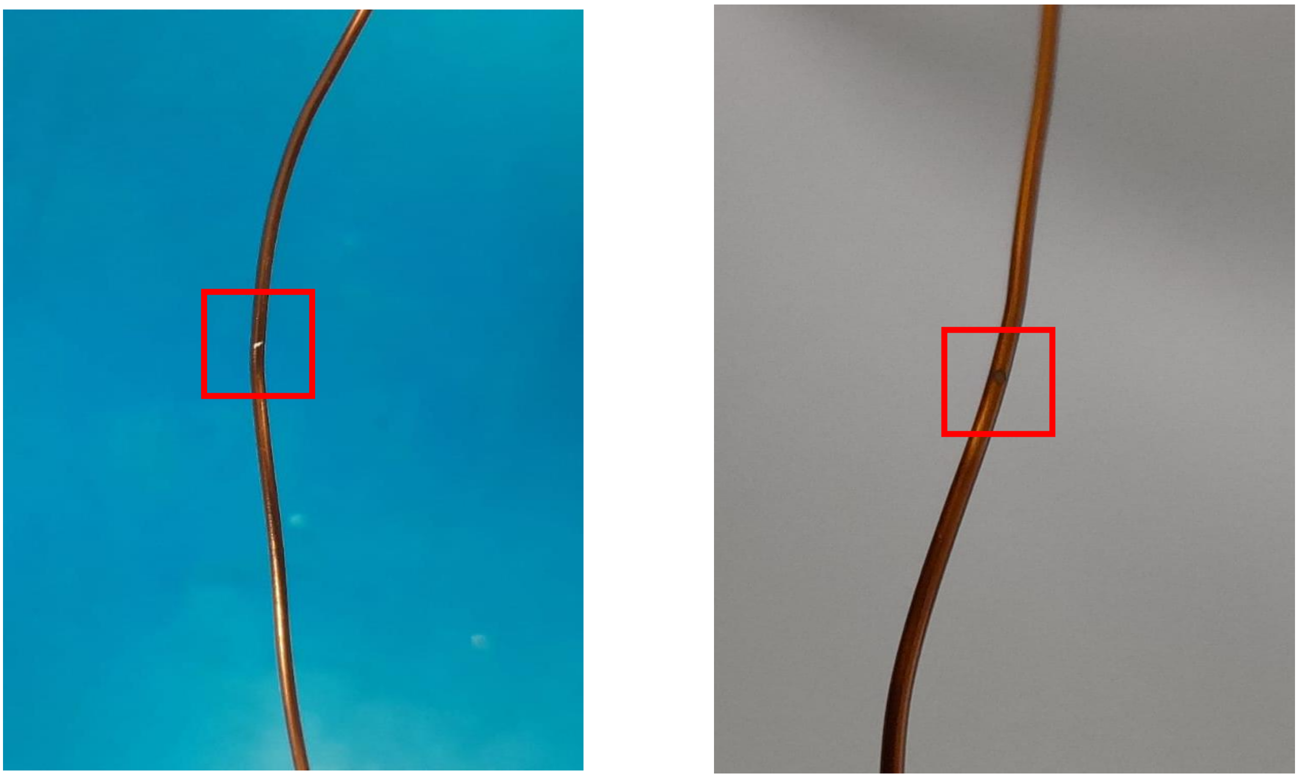


Fig 4.10: Scratches Found on Wire after Cut-Open

4.2.5 Possible Solutions Tried for the Ongoing Project

During the localization project for copper wire used in AC compressor motors, we faced a significant challenge of scratches appearing on the wire after it was wound around the stator. This issue affected the motor's performance and reliability during high-voltage tests. To resolve the problem, the following steps were undertaken:

1. Wire Quality Assessment:

The localized copper wire was subjected to a comprehensive quality evaluation to confirm its suitability for the motor production process. Key parameters, including insulation thickness, wire diameter, tensile strength, surface finish, and electrical conductivity, were rigorously tested. All results indicated that the localized wire met the required standards and closely matched the specifications of the imported wire. However, despite the wire's quality meeting expectations, the issue of scratches persisted, indicating the problem might lie elsewhere in the manufacturing process.

2. Winding Machine Inspection:

The winding machines were carefully examined to identify potential causes for the scratches. Particular attention was given to the nozzle through which the wire is fed during the winding process, as it could create abrasions due to friction or misalignment. Multiple tests were conducted, and adjustments were made to ensure optimal alignment and smooth wire feeding. However, further analysis revealed that motors produced using the same machines for regular mass production did not exhibit similar issues. This ruled out the winding machine as the direct cause of the problem, suggesting that the issue might be specific to the localized wire or unique to the combination of processes used for these motors.

3. Collaboration for Resolution:

Despite extensive testing and analysis, the exact cause of the scratches remained unidentified. Recognizing the complexity of the issue, we decided to seek assistance from specialists at the headquarters. Their advanced expertise and familiarity with the imported wire's manufacturing and handling processes are expected to provide new insights into the problem. These specialists will collaborate with the local team, conducting joint trials and in-depth evaluations to diagnose the root cause of the scratches.

This ongoing collaborative effort is critical to achieving the project's primary goal: successful localization of the copper wire while maintaining the same quality and reliability as the imported counterpart. By addressing this challenge effectively, the project aims to ensure the smooth implementation of localized materials in mass production, resulting in reduced costs without compromising motor performance.

4.2.6 Final Solution to Wire Scratching Issue

1. Increased Nozzle Diameter:

After extensive analysis and multiple unsuccessful attempts to resolve the issue of wire scratching during the winding process, the root cause was identified as the inner diameter of the nozzle in the winding machine. The nozzle, responsible for guiding the wire during winding, had a narrow inner diameter that resulted in excessive contact and friction with the magnet wire. This was especially critical during the first few turns, where the bending radius is tighter, leading to surface abrasions and insulation damage. To address this, the inner diameter of the nozzle was increased, ensuring smoother wire feed with reduced mechanical stress and contact pressure. This modification significantly minimized the occurrence of scratches, improving the insulation integrity of the wire and enabling the motors to pass the ELT (Endurance Life Test) reliably. This solution was both cost-effective and implementable without major changes to the existing winding setup, ensuring continued progress in the localization effort while maintaining product quality.

2. Modified Winding Pattern:

In addition to increasing the nozzle's inner diameter, the winding pattern was modified to reduce insulation damage. As shown in Fig. 4.11, the yellow lines indicate the earlier winding pattern, where the wire entered at a steeper angle, causing sharp bends and higher mechanical stress during the initial turns. This led to increased chances of abrasion and enamel cracking due to tight curvature and contact with slot edges. The new pattern, marked in blue, introduces a gentler curvature and improved alignment during the start of winding. This reduces the stress concentration on the wire's surface, minimizing insulation breakdown and enhancing ELT performance. The adjustment ensured smoother winding and consistent quality without changing the stator design.

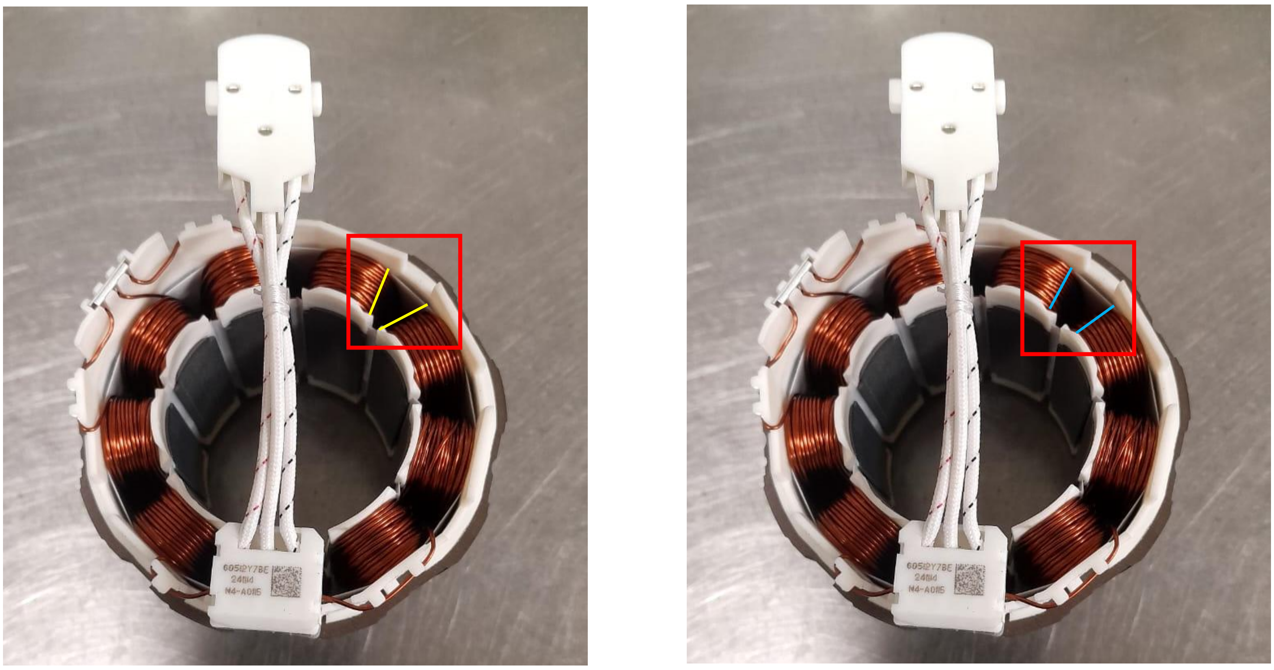


Fig 4.11: Pattern Before and After Modification

4.3.1 SoC PCB Development to Reduce Cost

SoC (System on Chip):

A System on Chip (SoC) is an integrated circuit that combines multiple components of a computing system — such as the processor, memory, power management, communication interfaces, and sometimes motor control logic — into a single chip. It is compact, efficient, and consumes less power compared to using multiple separate components.

Difference from IPM & Microcontroller PCB:

IPM & MCU PCB: In older design, the IPM handled power control and switching, while the MCU managed logic and control tasks. These were separate physical components, which increased PCB size and complexity.

SoC PCB: Combines the functionality of both the IPM and MCU into one compact chip, reducing board space, improving performance, lowering manufacturing cost, and simplifying the circuit design.

4.3.2 Key Responsibilities

1. Firmware Flashing & Testing:

Uploaded the developed firmware into the SoC-based PCB using flashing tools. After flashing, I tested the PCB by connecting it to the compressor and running it under actual conditions. This helped validate motor startup, control algorithms, and sensor feedback to ensure everything worked as expected.

2. Reliability Testing:

Collaborated with the OQC (Outgoing Quality Check) department to carry out reliability tests. These tests included running the PCB continuously for extended periods, checking temperature resistance, and monitoring voltage/current stability to ensure long-term durability and performance before mass production.

3. Manufacturing Support:

Worked with the local PCB manufacturing supplier to ensure the hardware followed the original Korean design. I cross-verified critical components, connector layouts, and soldering quality to confirm that the locally built PCBs were functionally and dimensionally accurate.

4. Documentation Support (NPI):

Helped my mentor prepare and upload New Product Introduction (NPI) documents, which are required for official approval. These documents included part specifications, test reports, failure analysis records, and checklists that summarize the PCB's readiness for production rollout.

4.4 Learning Outcomes

1. Understanding Motor Manufacturing Processes: Gained in-depth knowledge of BLDC motor manufacturing, including key steps such as insulation insertion, wire winding, Mag Mate assembly, line quality checks, and ELT testing. Also observed how motor control PCBs interact with the motor during these stages.
2. Importance of Cost Optimization: Learned the significance of material localization to reduce costs while ensuring consistent quality, especially in critical components like magnet wire for compressor motors and SoC-based PCBs. Understood the economic benefits of sourcing PCBs locally without compromising on design integrity.
3. Quality Assurance Techniques: Acquired practical experience in conducting quality checks such as resistance measurement, pinhole testing, BDV testing, and ELT testing for motors. Additionally, participated in reliability testing of compressor PCBs in collaboration with the OQC department, evaluating their performance under stress and load.
4. Problem-Solving Skills and Teamwork: Developed problem-solving abilities by addressing challenges like high resistance in magnet wire and scratches during winding. On the PCB side, collaborated with the hardware and QA teams to debug performance issues during testing. Understood the need for a collaborative, cross-functional approach, including support from the Korean design team, to resolve both motor and PCB-related challenges.
5. BOM and ECO Processes: Gained exposure to Bill of Materials (BOM) creation and Engineering Change Order (ECO) workflows for both motors and PCB assemblies. Understood how even small design or component changes require careful documentation and approval for smooth production integration.
6. Q Map Creation: Learned how to prepare Q Maps to validate dimensional accuracy of outsourced mechanical parts, and participated in checking the PCB against its design for component placement, solder quality, and connector alignment.
7. Practical Application of Engineering Principles: Applied engineering knowledge to assess wire tension, resistance, and annealing in motor winding. Similarly, understood PCB-related parameters like voltage regulation, signal integrity, and thermal dissipation, which impact compressor performance.
8. Challenges in Localization Projects: Understood the complexities involved in localizing materials such as matching imported quality standards, handling unexpected failures, and adhering to design specifications. This applied equally to magnet wire and to SoC PCBs, where local manufacturing had to be tightly monitored to ensure full compatibility with global design guidelines.
9. New Product Introduction (NPI) Documentation: Assisted in preparing and uploading NPI documents for the new SoC-based PCB, learning how structured documentation—such as part specs, validation records, and testing summaries—is vital for project approval and mass production.

Chapter 5
Conclusion

My internship at LG Electronics has been a comprehensive and enriching experience, offering me the opportunity to engage in both motor manufacturing and PCB development projects. Through the magnet wire localization project, I gained hands-on experience in production trials, quality assurance techniques, and cost optimization strategies—deepening my understanding of how engineering and economic factors are balanced in real-world manufacturing. I was actively involved in identifying and solving practical issues such as wire resistance variations and insulation scratches, which sharpened my analytical and problem-solving skills.

Simultaneously, working on the SoC-based PCB project exposed me to modern embedded system design practices, as I supported firmware flashing, functional and reliability testing, and the preparation of NPI documentation. This dual exposure allowed me to build a strong foundation in both hardware implementation and system validation, while also highlighting the importance of cross-functional collaboration with teams such as quality control, suppliers, and headquarters.

Overall, this internship has not only strengthened my technical and operational capabilities but also enhanced my communication, teamwork, and documentation skills. The experience has prepared me to take on future challenges in research, development, and quality engineering with greater confidence and competence.

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