REPORT ON INTERNSHIP

BOSCH

Submitted on completion of Internship by

Vishal K

Reg no: 2310324, Electronics and Communication Engineering,

National Institute of Technology, Surathkal

Guided by

Sureshkumar TM,

Department of TEF,

BOSCH Automotive Electronics India Private Limited,

Oragadam - Wallajabad Road, Sriperumbudur Taluk,

Kanchipuram, Tamil Nadu - 631604

Acknowledgment

We would begin by expressing our heartfelt thanks and gratitude to Mr. Sureshkumar TM, TEF, Bosch Automotive Electronics India Private Limited, for giving us this opportunity. We extend our gratefulness to Mr. Ratheesh, TEF, Bosch Automotive Electronics India Private Limited, for guiding the Traceability Project. Also, we thank them for their constant support, encouragement, and valuable guidance throughout the project. Their continuous motivation, technical expertise, and constructive feedback have been crucial in overcoming challenges and achieving our objectives. Their words of wisdom and dedication have inspired us at every stage of this project.

We would also like to convey our sincere thanks to the faculty and staff members of the TEF and MSE departments for their cooperation and assistance throughout the course of our work. Their unwavering support, resources, and technical input have helped us progress and accomplish our goals.

Finally, we express our gratitude to everyone who contributed directly or indirectly to the successful completion of this project. Their support and encouragement have been a constant source of strength throughout this journey.

Sureshkumar TM,

Internship Guide,

Department of TEF,

BOSCH Automotive Electronics India Private Limited

(Signature)

Table of Contents

S.No	**Topic**	**Pg.No**
1	Introduction	4
2	Stator Manufacturing Process	5
3	Rotor Manufacturing Process	7
4	Motor Assembly Process	8
5	Hall Effect and Hall Sensor	9
6	Project T	10
7	Enhancement	12
8	Conclusion	13

Introduction

Electric motors are at the heart of modern automation systems, providing reliable, efficient, and controlled motion essential for various applications, including door automation, industrial machinery, and high-precision devices. The quality and performance of a motor depend heavily on the accuracy and reliability of its components — primarily the stator and rotor — as well as the rigorous testing and assembly processes followed during production.

This report presents a comprehensive overview of the manufacturing processes for stators and rotors, detailing each critical step from shaft pressing, wiring, and Hall sensor integration in the stator to magnetization, magnet assembly, and curing in the rotor. It also covers the motor assembly process, focusing on precision tasks like bearing pressing, oil seal fitting, and comprehensive quality inspections. Additionally, this report explains essential quality testing methodologies such as the Direct Current Resistance (DCR) test and Surge test, which ensure electrical integrity and detect hidden faults in motor windings. Advanced diagnostic tools like Electromagnetic Performance (EP) testing are discussed to emphasize their role in ensuring motor safety and performance. The principles behind Hall Effect sensors and their application in motor control are explored to illustrate how these devices enable precise position feedback and efficient motor operation. Moreover, the integration of Variable Frequency Drives (VFD) and Space Vector Modulation (SVM) is explained, showcasing how modern electronics contribute to improved energy efficiency, smoother operation, and superior motor control.

Stator Manufacturing Process

The stator manufacturing process begins with shaft pressing, where the shaft is inserted using a pressure of 3.92 Bar. Following this, cable and insulation tube assembly is performed to ensure electrical insulation and structural integrity. The next step is crimping, where cable leads are twisted together with the phase wires to establish secure electrical connections. After crimping, soldering is carried out, followed by cooling to stabilize the joints.

Subsequently, the Printed Circuit Board Assembly (PCBA) is integrated into the stator, which includes the gluing of the Hall sensor onto the assembly. The next step involves the insertion of six wires into the PCBA with designated color codes as follows: A - Blue, N - Red, G - Black, B - Yellow, C - Green, and T - White. Once wiring is complete, shaft hole gluing is applied to provide additional mechanical strength, and the thermal sensor is glued in place.

An essential step is the Electromagnetic Performance Testing (EP Testing), which ensures the electrical performance and reliability of the stator assembly. Finally, a thorough inspection is conducted to verify that the stator meets all quality standards and specifications.

EP Test

In EP testing, the stator winding is subjected to a controlled electrical pulse generated by a high-frequency surge tester. This pulse induces an electromagnetic field within the winding, creating an oscillating waveform that is recorded and analyzed. The waveform characteristics, such as frequency, damping factor, and amplitude, are compared with those of a known good stator.

DCR Test

The DCR (Direct Current Resistance) test measures the electrical resistance of stator windings. A DC current is passed through the winding, and the resistance is measured using a DCR meter. A significantly higher than expected resistance indicates faults such as broken lines or loose connections.

Surge Test

In the surge test, a capacitor is charged and rapidly discharged into the winding, creating a high-frequency voltage pulse. This sequentially tests each winding turn and coil, helping detect turn-to-turn shorts, coil-to-coil shorts, and phase-to-phase shorts in the stator.

The pulse generates an oscillating waveform, with its frequency and damping factor (Q-factor) affected by motor impedance. Healthy windings produce a smooth, decaying waveform, while defective windings show irregular patterns or frequency shifts.

The difference between healthy and faulty waveforms is quantified as %WD (Wave Difference) or %EAR (Error Area Ratio). EP testing compares the measured waveform to a master waveform across a specified frequency range, ensuring the motor passes with acceptable %WD and %EAR values.

Rotor Manufacturing Process

The rotor manufacturing process starts with the magnetization of the rotor magnets, aimed at increasing their magnetic strength. Once magnetization is complete, the magnets are separated and prepared for pre-assembly onto the rotor structure. The next step involves pressing the magnets firmly into place to guarantee stability.

Following magnet pressing, magnet gluing is performed, and the assembly undergoes a curing period of approximately one hour to ensure the magnets are securely bonded. It is important to note that magnet gluing is performed on both sides of the rotor, with a gap of around 10 minutes between each side to achieve proper alignment and adhesion.

The rotor manufacturing process concludes with a comprehensive inspection to confirm that the assembly is completed accurately and meets all required quality standards.

Motor Assembly Process

The motor assembly process begins with the application of lubricant and the pressing of ball bearings for both brake covers. After this, gluing is performed on the end cover line, followed by the screwing of the brake cover over the rim. Oil seal pressing is done for the top brake cover, which is then placed over the stator. After 24 hours of curing, the assembly is checked through a safe launch station.

Next, the stator and rotor are assembled, and the structure is secured with screws. A thorough inspection is conducted after 24 hours of curing. The motor then undergoes a leakage test at 20.4 Bar pressure, a functional test, and a noise test, where an average of 52.3 dB at 950 rpm is expected.

Final testing at the safe launch station includes an End of Line (EOL) test, which involves subjective noise evaluation and tie-up assembly. Additional testing at the safe launch station includes a noise test at 1260 rpm, run-out checks ensuring readings are below 100, and a Hall sensor check.

Hall Effect and Hall Sensor

The Hall effect occurs when a current-carrying conductor is placed in a magnetic field, causing charge-carrying electrons or holes to deflect and accumulate on one side of the conductor. This accumulation creates a potential difference known as the Hall voltage, which is directly proportional to the current and magnetic field strength.

Mathematically, Hall voltage **(V_h)** is given by:

$$V_h = (B * I) / (n * e * d)$$

Where:

- n is the number of charge carriers per unit volume (in $1/m^3$)

- e is the electron charge (1.6 x 10^-19 C)

- d is the thickness of the conductor (m)

- B is the magnetic field strength

- I is the current

A Hall sensor consists of a thin strip of conductive material that detects the Hall effect when exposed to a magnetic field. In motors, Hall sensors measure the strength and direction of the magnetic field generated by the rotor's permanent magnets. As the rotor rotates, the magnetic field changes, and the sensor detects these changes, providing position feedback.

The information from Hall sensors is used to control the commutation process, which switches currents in the stator windings to generate a rotating magnetic field that aligns with the rotor. This eliminates the need for brushes and energizes the stator windings in specific sequences for smooth operation. Hall sensors also enable precise speed control by providing continuous feedback on the rotor's position.

Project T

Manual data recording is prone to errors, time-consuming, and often lacks the real-time visibility required for effective process control and quality management. This project addresses these challenges by providing an automated, precise, and user-friendly method for tracking components throughout their assembly journey.

This project titled as ‘Project T’ which is ‘Project of Traceability’ is worked on specifically for the ‘Stator and Rotor Assembly’ sub station of the ‘Motor Assembly Line’ of the ‘In-Hub’ motor. The project is aimed to enhance the accuracy, efficiency, and reliability of data collection for critical assembly processes. By leveraging Human Interface Device (HID) compatible QR and barcode scanners, the system automates the capture of unique identifiers, directly channeling this information into a structured Excel format for comprehensive traceability.

This project is implemented using the ‘Python’ language and HID (Human Interface Device) scanner. The idea of the project revolves around logging in the necessary part details of every motor being assembled, on an infinite loop and without allowing duplication.

Solution Implemented:

The implemented solution is a streamlined, cost-effective system that integrates HID-compliant QR and barcode scanners directly into the assembly workflow. The core functionality revolves around the scanner acting as a keyboard input device, feeding scanned data directly into an Excel spreadsheet.

Key Components:

1) QR/Barcode Scanners (HID Mode): Standard industrial-grade QR and barcode scanners configured to operate in HID (Human Interface Device) emulation mode were deployed at key assembly stations. In this mode, the scanner behaves like a standard keyboard, transmitting the decoded data as if it were typed.
2) Microsoft Excel Spreadsheet: A pre-configured Excel workbook serves as the central data repository. This workbook is designed with specific columns for various data points, such as:
3) Stator QR Code
4) Motor Barcode

Workflow:

- ➔ Timestamping: Date and Time of Scan.
- ➔ Data Entry Automation: When an operator scans a QR code or barcode on a Stator or Motor, respectively, the scanner instantly decodes the information (e.g., unique serial number). This decoded string is then "typed" by the scanner directly into the active cell of the Excel sheet.
- ➔ Sequential Data Capture: The Excel sheet is structured to guide the operator through the data capture process. For instance, after scanning the Stator serial number into one cell, the cursor automatically moves to the next cell, prompting the scan of the Motor serial number. This ensures a logical and consistent data entry sequence.
- ➔ Data Validation (Optional/Future Enhancement): While the initial setup focused on capture, the Excel sheet can be enhanced with data validation rules to ensure correct data formats or cross-reference with master data (e.g., checking if a scanned serial number exists in a pre-approved list).
- ➔ This straightforward architecture minimizes complex software development, leveraging existing, widely available tools (scanners, Excel) to deliver a robust and immediate solution for traceability.

Enhancement:

The project also helps in enhancement of the whole process of traceability. The python code is updated with a sequence detection method and to indicate the user if this sequence is violated.

Invalid Scan Feedback: When the program run starts, scanning of QR takes place as the first step. Only after the QR is scanned, barcode scan requirement is indicated. If in case a barcode is scanned in place for a QR scan, then the software automatically beeps and does not take the barcode input. Therefore, cycle starts with QR and then barcode. Cycle ends with the barcode scanned. The software emits beep even if a QR is scanned in place of a barcode, alerting the operator instantly to the error. (The beep frequency is of 850Hz.)

Duplicate Scan Feedback: If the scanned QR/barcode is detected as a duplicate (i.e., already present in the main Excel sheet for the current batch or within a specified timeframe), a different "beep" sound is triggered, indicating that the item has already been processed. This prevents redundant entries and alerts operators to potential process errors. The part details are still stored in the excel but with a 'Duplicate' status besides it in the same row. (The beep frequency is of 600Hz.)

(Note: Values of the beep frequency and beep duration can be changed by the user and based on the device setup for the process.)

Recheck Excel: The 'Recheck Excel' is a separate excel sheet which can be used for part details recheck, if any, to avoid the value changes in the original excel sheet used for everyday production run. The part scanned is compared with the original excel sheet and if the part details exist in original then the rechecked part details are stored in recheck excel sheet with a 'Duplicate QR' or 'Duplicate Barcode' status.

FR (Found from Recheck): During the rechecking process the software checks for new part details which do not exists in the original excel sheet. If found any, then that part details are sent to original excel sheet and are stored with a 'FR' remark besides in the same row as stored.

Conclusion

Project T (Project of Traceability) successfully enhances the stator and rotor assembly process by automating data capture and improving traceability within the In-Hub motor assembly line. By integrating HID-compatible QR and barcode scanners with a Python-based system and Excel logging, the project eliminates manual errors, ensures real-time tracking, and simplifies the operator's workflow.

The system guides users through a structured scanning sequence, reinforced by beep alerts for invalid or duplicate inputs—helping maintain data integrity. Additional features like the 'Recheck Excel' utility and duplicate detection ensure thorough verification and prevent redundancy.

Overall, this solution delivers a cost-effective, efficient, and scalable approach to traceability, significantly improving quality control and laying the groundwork for future digital advancements in the production environment.