Process Analysis Report: Assembly of a Small Electric Motor

Quality and Innovation Engineering
Luca Rigoni 247451

July 12, 2025

1. Introduction

The purpose of this report is to analyze the assembly process of a small electric motor by applying quality and innovation engineering principles. Electric motors are fundamental components in a wide range of modern applications, including electric mobility, automation systems, drones, and household devices. Given the increasing demand for high performance, low noise, and long durability, the quality of the assembly process plays a crucial role in ensuring product reliability and customer satisfaction.

The analysis is developed in the context of a recurring issue reported by several clients: excessive noise and premature failures in a specific batch of motors. Preliminary investigations attribute the anomalies to rotor imbalance and improper alignment during the final assembly stage. In parallel, the engineering department is required to adapt the production line to accommodate a new motor variant with tighter performance specifications and higher rotational speed.

In response to these challenges, this report aims to:

- Translate customer and regulatory requirements into internal quality and process standards,
- Analyze the complete assembly workflow, highlighting critical steps and influencing variables,
- Identify risks and quality gaps through structured tools (risk matrix, fishbone diagram),
- Define corrective and preventive actions to improve process capability and reduce defect rates.

The ultimate objective is to redesign the motor assembly process to ensure consistent product quality, operational efficiency, and compliance with applicable standards such as ISO 9001 and ISO 1940-1 for rotor balancing.

2. Requirements Analysis

This section identifies and classifies the requirements that shape the assembly process of the electric motor. These include customer expectations related to performance and durability, internal operational needs such as process control and workforce capability, and compliance with mandatory technical and regulatory standards. Each requirement is analyzed in terms of risks, opportunities, and the methods adopted to satisfy it.

2.1 Customer Requirements

The following table summarizes the primary requirements expressed by customers and their implications on quality and process execution.

Requirement	**Why it is important**	**Risks**	**Opportunities**	**How to satisfy**
Silent operation	Minimizes noise and vibrations, especially for applications in drones or consumer goods	Rotor imbalance, bearing misalignment, resonance	Market differentiation, premium perception	Rotor balancing (ISO 1940), precision bearing fit, vibration testing
Thermal stability	Ensures safe operation and prevents overheating or burnout	Coil insulation failure, excessive current, blocked airflow	Improve lifecycle, enable compact designs	Quality copper windings, thermal paste, airflow design, heat dissipation validation
Output torque consistency	Required to meet application specs (e.g., load handling, control feedback)	Misaligned magnets, winding asymmetry, torque ripple	Enables high-end servo/control applications	Precision magnet positioning, controlled winding process
Compact dimensions	Important for integration in tight spaces (e.g., handheld devices, drones)	Packaging constraints, risk of overheating in dense designs	Entry into mobile and embedded markets	Miniaturization, modular component sourcing
Long service life	Reduces maintenance, improves brand image	Premature bearing wear, magnet demagnetization, coil fatigue	Reduced warranty claims, improved customer retention	Endurance testing, supplier qualification, cleanliness during assembly

2.2 Internal Requirements

Internal requirements reflect the organizational needs to ensure repeatability, efficiency, safety, and traceability throughout the assembly process.

Requirement	**Why it is important**	**Risks**	**Opportunities**	**How to satisfy**
Standardized assembly process	Ensures repeatability and traceability of critical operations	Bureaucracy, loss of flexibility, dependency on documentation rather than process understanding	Improve first-pass yield, easier training	Define a standardized document for all process steps; update it continuously based on feedback
Skilled workforce	Allows to perform tasks with precision, accuracy, and efficiency; enables process innovation	High training cost and time investment; possible gaps in knowledge or improper task execution	Enhanced quality, productivity, and employee empowerment	Invest in structured training programs; promote knowledge sharing and update skills through periodic refreshers
In-line quality control	Early detection of defects to reduce downstream costs	Defects passed to testing stage, increased scrap	Reduction in late-stage rejects	Integrate resistance, polarity, and rotation tests at key points
Component traceability	Critical in case of failure analysis and warranty	Unable to isolate faulty batch	Faster root cause analysis, better supplier accountability	Implement serial/batch tracking per component group
Tool calibration and upkeep	Maintains accuracy in torque, alignment, and resistance measurement	Out-of-spec assemblies, safety hazards	Preventative maintenance, better compliance	Define calibration intervals, maintain instrument logs

2.3 Mandatory Standards and Regulations

The table below lists the applicable standards and regulations that must be met to ensure product compliance and marketability.

Standard / Regulation	Why it is important	Risks if not respected	Opportunities	How to satisfy
ISO 9001	Establishes framework for quality management and continual improvement	Process inconsistency, poor documentation	Structured continuous improvement, international recognition	Implement QMS, document control, internal audits
ISO 1940-1	Governs rotor balancing for rotating machinery	Vibration, noise, bearing wear	Assured performance and reduced maintenance needs	Perform balancing tests, define tolerance class per motor type
RoHS 2011/65/EU	Restricts hazardous substances in electronic components	Legal penalties, environmental harm	Market access in EU and eco-certifications	Source compliant components, maintain material declarations
IEC 60034	IEC standard for rotating electrical machines (safety, performance, temperature)	Safety violations, performance failures	Enhanced interoperability, lower testing effort for customers	Align product specs and testing procedures with IEC guidelines
CE Marking Directive	Declares conformity with EU safety, health, and environmental protection directives	Market exclusion in Europe, regulatory blockage	Confidence for distributors and end users	Complete technical file, ensure compliance of all components, apply CE label

3. Process Analysis

The assembly of a small electric motor consists of a sequence of tightly controlled operations, each of which influences the performance, reliability, and durability of the final product. The quality management team has identified the following key steps, highlighting for each the most critical influencing factors that impact process stability and output quality.

Step	**Description**	**Factor 1**	**Factor 2**	**Factor 3**
Stator winding	Copper wire is wound around the stator laminations to create the electromagnetic field	Wire tension	Turn count accuracy	Insulation integrity
Magnet placement	Permanent magnets are positioned and fixed on the rotor with adhesive, ensuring correct polarity and spacing	Polarity orientation	Positioning accuracy	Adhesive curing process
Rotor–stator assembly	Rotor is inserted into the stator, maintaining the designed air gap and axis alignment	Shaft centering	Air gap uniformity	Clean assembly environment
Bearing installation	Bearings are press-fitted into housings to support rotor rotation with minimal friction	Press-fit tolerance	Lubrication quality	Bearing seating alignment
Wiring and soldering	Coil leads and sensors are soldered to terminals and connected to control wiring	Solder joint integrity	Strain relief application	Lead orientation
Final assembly & sealing	End caps, casing, and protective elements are mounted, sealing the motor enclosure	Fastening torque accuracy	Casing alignment	Ingress Protection sealing effectiveness
Functional testing	The motor undergoes functional testing for rotation, current, noise, and temperature behavior	Test protocol accuracy	Load conditions	Instrument calibration

4. Risk Analysis

Understanding and managing process-related risks is essential to ensure the reliability and safety of the assembled electric motor. The quality team conducted a structured risk analysis using a scoring method based on likelihood and severity, in order to prioritize the most critical threats to process stability and product quality.

4.1 Risk Matrix

Risk Description	Likelihood	Severity	Score	Notes
Rotor imbalance due to magnet misplacement	2	3	6	Leads to vibration, noise, reduced bearing life
Coil short circuit from insulation failure	1	3	3	Risk of overheating, reduced lifespan
Excessive friction from misaligned bearing seat	2	2	4	Causes wear, noise, reduced efficiency
Solder joint defect at wiring terminals	1	2	2	Potential loss of electrical connection
Adhesive failure during magnet curing	1	3	3	Magnet detachment, malfunction at high RPM
Water/dust ingress due to poor sealing	2	2	4	Risk of corrosion, short circuit, product failure
Use of uncalibrated measuring tools	2	3	6	Leads to incorrect tolerances, undetected defects

Scoring Interpretation Tables

Likelihood

Frequency	Score
Low frequency	1
Medium frequency	2
High frequency	3

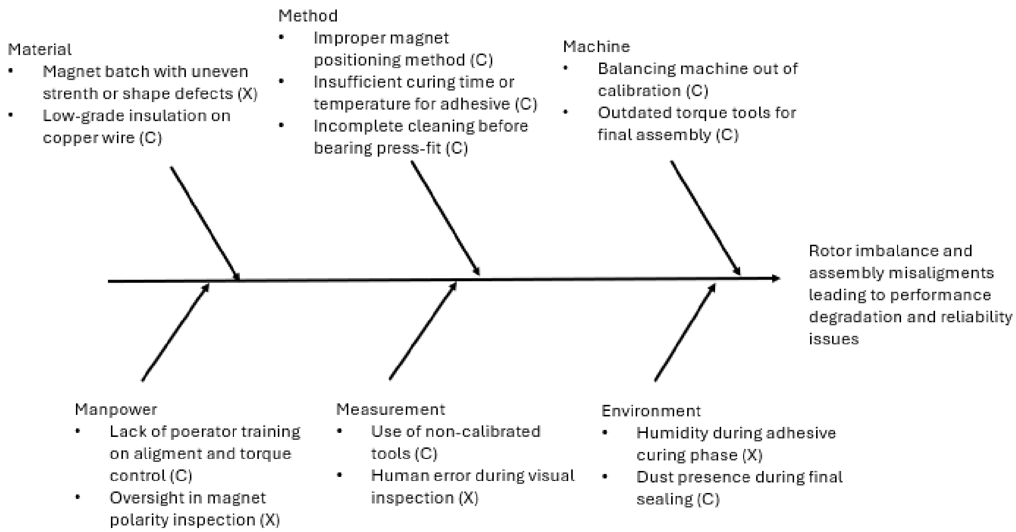
Severity

Impact	Score
Low impact on performance/client	1
Potential impact on performance	2
Major impact on safety/performance	3

4.2 Cause Identification – Fishbone

Legend:

- C = controllable and preventable
- X = controllable and preventable only with further researh
- N = non controllable or preventable



5. Action Plan

The quality team has developed the following set of corrective and preventive actions to reduce the occurrence and impact of the most significant risks identified. Each action includes method of implementation, responsible party, required resources, and means of verification.

Cause	**Action**	**Responsibility**	**Resources**	**How to Verify Effectiveness**
Rotor imbalance due to magnet misplacement	Introduce positioning jig and polarity checker during magnet insertion	Production engineer, operator	Alignment fixture, polarity sensor module	First-pass yield rate, torque ripple test results, in-line QA records
Coil short circuit from insulation failure	Implement resistance and insulation test before stator integration	Quality assurance (QA) team	Multimeter, insulation tester, updated SOP	Electrical compliance report, sampling records
Bearing misalignment or friction	Use calibrated press and visual control template for bearing insertion	Assembly technician, QA	Precision press, 3D printed gauge	Noise measurement under free rotation, verification checklist
Adhesive curing failures	Standardize curing time/temp per adhesive datasheet and install timer	Process engineer	Controlled oven or curing station, timers, datasheets	Curing log, magnet detachment rework rate
Uncalibrated measurement tools	Establish routine calibration plan for gauges and test equipment	QA manager	Calibration logbook, external calibration service	Tool calibration certificates, audit compliance
Dust during final sealing	Introduce final assembly in controlled/cleaner workstation	Maintenance + Production lead	HEPA filtered workstation, anti-static matting	Cleanliness inspection logs, failure traceability reports
Operator training gaps	Conduct role-specific training with focus on critical assembly steps	HR + QA + experienced staff	Training program, SOPs, mentor assignment	Training completion records, on-line observation, assembly error trends

6. Conclusion

The analysis conducted on the assembly process of a small electric motor highlights the central role of process control, material integrity, and skilled labor in ensuring consistent product performance. Particular attention was paid to critical phases such as magnet placement, bearing alignment, and insulation integrity–operations that directly influence motor balance, durability, and operational noise.

The structured risk analysis revealed that unbalanced or misaligned assemblies represent the most significant threat to product quality, with potential effects including vibration, accelerated wear, and customer dissatisfaction. Root causes were traced back to factors such as insufficient process standardization, tool miscalibration, inadequate operator training, and environmental conditions during curing or sealing.

The proposed action plan provides a framework to mitigate these risks through a combination of:

- Targeted training initiatives,
- Technical controls (e.g., jig fixtures, resistance testing),
- Systematic calibration routines,
- Environmental safeguards in the final assembly stage.

Beyond corrective measures, the company is encouraged to adopt a culture of **continuous improvement** based on feedback loops and data-driven monitoring. This includes empowering operators with decision-making authority (e.g., stop-and-fix procedures), and progressively integrating **Industry 4.0/5.0 technologies** such as:

- Digital twins for simulating motor behavior and optimizing tolerances,
- IoT sensors to monitor assembly parameters in real time,
- Predictive maintenance applied to key production equipment,
- Augmented Reality to guide operators during high-precision steps.

By addressing both immediate risks and long-term strategic enablers, the company can improve product quality, reduce rework, and enhance customer trust while maintaining operational efficiency and regulatory compliance.