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# Automatic Core Yoke Staking Machine

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**ABSTRACT:** The rapid evolution of electrical machinery, especially in the fields of electric vehicles, industrial automation, and energy systems, demands precise, efficient, and scalable manufacturing processes for electric motors. One of the critical steps in motor assembly is the staking of the core and yoke — a process that ensures mechanical rigidity, structural alignment, and optimal magnetic performance. Traditionally, this process has been carried out manually or semi-automatically, which often results in inconsistencies, lower throughput, and increased labor dependency. To address these challenges, this project presents the design and development of an Automatic Core Yoke Staking Machine, an advanced solution aimed at automating this crucial step in electric motor manufacturing.

The proposed machine is engineered to precisely align and stake the laminated stator core within the motor yoke using programmable logic control (PLC) and servo-based actuation systems. It features a robust mechanical framework integrated with a rotary indexing table, automated clamping units, and a high-force pneumatic or hydraulic staking system. The staking operation is performed at predefined locations along the yoke periphery, ensuring uniform force distribution and secure core retention. The automation not only reduces cycle time and manual intervention but also enhances consistency, repeatability, and product quality.

This machine is equipped with a user-friendly human-machine interface (HMI) for real-time control and monitoring, as well as safety interlocks to protect operators during operation. Sensors and feedback systems are implemented for position accuracy, pressure control, and error detection, enabling predictive maintenance and reducing downtime. The modular design allows flexibility for accommodating different core sizes and yoke configurations, making it suitable for a wide range of motor assembly lines.

The development of the Automatic Core Yoke Staking Machine contributes significantly to the modernization of motor production by improving assembly precision, increasing production efficiency, and reducing labor costs. It aligns with the current industrial trends of Industry 4.0, promoting smarter and more autonomous manufacturing solutions. This project combines principles of mechanical engineering, automation, and control systems to deliver a high-performance solution tailored to the future of electric motor manufacturing.

**KEYWORDS:** Automatic staking machine, core yoke assembly, electric motor manufacturing, PLC automation, servo control, hydraulic pressing, rotary indexing, stator core alignment, industrial automation, precision assembly, smart manufacturing, mechanical design, staking mechanism, production efficiency, Industry 4.0.

## I. INTRODUCTION

The manufacturing of electric motors has seen a significant surge in demand across multiple industries, including automotive, aerospace, industrial automation, and household appliances. With the growing emphasis on electrification, energy efficiency, and sustainability, electric motors have become more integral than ever before. As a result, the need for more reliable, precise, and efficient motor production processes has gained considerable attention. Among the several stages involved in motor manufacturing, the assembly of the core and yoke—two critical components of the stator—is fundamental to ensuring the motor's structural integrity, alignment, and electromagnetic performance.

The core, typically composed of laminated electrical steel sheets, forms the magnetic path of the motor, while the yoke provides the outer casing or frame, supporting and enclosing the stator assembly. Traditionally, the staking or joining of the core and yoke has been done manually or using semi-automatic systems. These conventional approaches are prone to several limitations, such as inconsistent staking pressure, misalignment, human error, and longer cycle times. As manufacturing trends move toward automation, precision, and scalability, there is a growing need for a system that can perform this process with high repeatability and minimal human intervention.

This project addresses that need through the design and development of an Automatic Core Yoke Staking Machine—a fully automated solution engineered to perform staking operations with enhanced precision and efficiency. The machine is built to automatically position the stator core inside the yoke and perform staking operations at multiple locations around the circumference using servo or hydraulic actuators. Equipped with programmable logic controllers (PLCs), Human-Machine Interfaces (HMIs), sensors, and safety mechanisms, this system enables real-time control, monitoring, and fault detection.

The machine not only reduces dependency on skilled labor but also ensures uniform staking quality across all units, contributing to improved reliability of the final motor product. Additionally, the integration of modern automation techniques aligns with Industry 4.0 goals, promoting smart manufacturing and data-driven decision-making in production environments.

The Automatic Core Yoke Staking Machine represents a step forward in the evolution of motor manufacturing technology. It brings together elements of mechanical engineering, electronics, control systems, and industrial automation to create a robust and intelligent system capable of meeting the high demands of modern production lines. This project outlines the design considerations, working principles, control strategies, and implementation techniques required to develop such a machine, while also discussing the potential impact it can have on productivity, quality control, and cost-efficiency in the motor manufacturing industry.

## **II. LITERATURE SURVEY**

The increasing demand for high-performance and energy-efficient electric motors has driven researchers and industries to innovate in motor assembly technologies. One of the most critical yet often overlooked steps in electric motor manufacturing is the staking process used to join the stator core and the yoke. The staking operation is vital to maintain structural stability and magnetic alignment, directly affecting the motor's reliability and efficiency. This literature survey explores the evolution of staking processes, advancements in automated assembly systems, and relevant technologies like PLC control, servo systems, and smart manufacturing.

### **1. Manual and Semi-Automated Staking Methods**

Historically, core and yoke staking was done using manual presses or semi-automated hydraulic systems, which relied heavily on skilled labor. According to Sharma et al. (2015), manual staking leads to inconsistent force application, misalignment, and lower production throughput. These limitations result in reduced motor lifespan and increased manufacturing costs. Semi-automated systems, although an improvement, still required human intervention and lacked the consistency needed for mass production.

### **2. Precision Assembly in Electric Motor Manufacturing**

Mohanraj and Rajendran (2017) emphasized the importance of precision and repeatability in motor core assembly, especially for high-speed motors used in electric vehicles. Misaligned cores during the staking process can lead to unbalanced magnetic fields, vibration, and overheating. Their research highlighted the growing need for automated solutions that could deliver controlled and repeatable staking forces.

### **3. Automation and Control Technologies**

The integration of Programmable Logic Controllers (PLCs) in manufacturing has revolutionized automation. According to Gupta and Singh (2018), PLCs offer modularity, flexibility, and reliability in industrial automation. In

stating machines, PLCs control the actuation sequence, timing, and feedback monitoring, ensuring precise coordination of mechanical actions. Coupled with Human-Machine Interfaces (HMIs), operators can monitor processes, adjust parameters, and respond to system alerts in real time.

#### 4. Servo and Hydraulic Actuation in Staking Systems

Bose and Kulkarni (2019) explored the role of servo motors and hydraulic actuators in high-precision assembly machines. Servo systems offer high positioning accuracy and programmable motion profiles, making them ideal for controlled staking force application. Hydraulic systems, on the other hand, are known for their power density and have been widely used in heavy-duty staking machines. Modern designs often combine the two technologies to balance precision and power.

#### 5. Intelligent Manufacturing and Industry 4.0

With the advent of Industry 4.0, manufacturing is shifting toward data-driven, interconnected, and autonomous systems. According to Kumar et al. (2020), implementing smart technologies such as sensors, IoT, and real-time data analytics in assembly machines can dramatically improve process control and product quality. An automatic core yoke staking machine integrated with such technologies can self-adjust to variations, detect errors proactively, and reduce downtime.

#### 6. Case Studies and Industrial Applications

Several industrial case studies have demonstrated the effectiveness of automated staking systems. Siemens and ABB, for instance, have developed proprietary automated motor assembly lines incorporating robotic staking arms and closed-loop force feedback systems. These solutions have shown a reduction in assembly time by up to 40% and significant improvements in quality consistency. Furthermore, a study by the International Journal of Advanced Manufacturing Technology (2021) documented a 25% increase in throughput using automated staking solutions in a mid-sized motor production facility.

#### 7. Challenges and Research Gaps

Despite significant advancements, challenges still exist in universalizing staking systems across various motor types and sizes. One major challenge, as noted by Zhang et al. (2022), is designing modular and reconfigurable staking machines that can adapt to different geometries without requiring major tooling changes. Additionally, there is ongoing research into real-time force feedback, AI-driven defect detection, and energy-efficient actuator systems to further enhance performance.

### **III. METHODOLOGY**

The methodology adopted for the design and development of the Automatic Core Yoke Staking Machine follows a systematic engineering approach, combining mechanical design, electrical integration, control systems, and automation principles. The goal is to create a machine that can accurately, consistently, and safely stake the stator core and yoke of an electric motor with minimal human intervention. The development process is divided into several key stages:

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#### 1. Requirement Analysis

Define the specifications for the motor cores and yokes to be staked (dimensions, materials, staking points).

Determine production goals such as cycle time, precision requirements, and batch size.

Identify key constraints such as budget, available workspace, safety standards, and power requirements.

## 2. Conceptual Design

Develop initial design concepts for the staking mechanism.

Select between hydraulic, pneumatic, or servo-based actuators depending on required force and precision.

Choose the type of indexing mechanism (e.g., rotary table) to enable multiple staking points.

Prepare design sketches and 3D models using CAD software.

## 3. Mechanical Design and Fabrication

Create detailed mechanical designs of the staking frame, fixtures, clamps, and actuator mountings.

Design a modular work-holding system to accommodate various sizes of stator cores and yokes.

Fabricate components using CNC machining, welding, and laser cutting.

Assemble the mechanical system and test for fit, motion range, and structural integrity.

## 4. Electrical and Control System Integration

Select and program a PLC (Programmable Logic Controller) to control the sequencing and logic of operations.

Interface sensors (proximity, pressure, limit switches) for process monitoring and feedback.

Integrate HMI (Human-Machine Interface) for operator interaction, parameter setting, and diagnostics.

Design and implement the electrical panel with proper circuit protection, relays, and communication systems.

## 5. Software Development and Programming

Write ladder logic or structured text programs for PLC to control the machine sequence:

Core and yoke positioning

Clamping

Staking operation

Indexing to next point

Completion and reset

Configure the HMI with graphical controls, alarms, and user-friendly interface layouts.

Implement safety interlocks, emergency stop logic, and fault detection systems.

## 6. Testing and Calibration

Perform dry runs to test mechanical motion and control sequence without load.

Load test with actual stator cores and yokes to validate alignment, staking force, and positioning accuracy.

Calibrate sensors and actuators to achieve desired performance.

Record operational parameters such as force applied, time per cycle, and error rates.

#### 7. Validation and Performance Evaluation

Compare output quality with motors assembled using traditional methods.

Evaluate improvements in cycle time, consistency, and precision.

Analyze maintenance requirements and downtime statistics.

Modify the design or control logic based on feedback and test results.

#### 8. Documentation and Final Report

Document design drawings, electrical schematics, and PLC programs.

Prepare a user manual for machine operation and troubleshooting.

Compile results, performance analysis, and conclusions into the final project report.

### IV. EXPERIMENTAL RESULTS

The performance of the Automatic Core Yoke Staking Machine was evaluated through a series of tests conducted on small industrial AC motor stators. Each test unit had a core diameter of 120 mm and was fitted into a cylindrical steel yoke, with staking performed at six equidistant points using a pneumatic actuator operating at 80 psi. The system was controlled by a Siemens S7-1200 PLC, and equipped with proximity sensors for precise positioning and a pressure sensor for staking force monitoring. The results showed that the average staking force achieved was 820 N, which is within the acceptable range of the 800 N target, indicating consistent and controlled operation. The positioning accuracy was measured at  $\pm 0.3$  mm, outperforming the design tolerance of  $\pm 0.5$  mm, thanks to the stable indexing mechanism and precise clamping system.

The average cycle time per unit was recorded at 26 seconds, significantly faster than the 65 seconds typically required in manual staking, demonstrating an improvement of over 60% in operational speed. Core alignment was consistently within  $\pm 0.5$  mm, and out of 100 units tested, none exhibited defects such as misalignment, deformation, or inconsistent staking, validating the system's repeatability and precision. The machine also required minimal operator intervention—only once every 50 units for minor core loading adjustments—which further enhances its suitability for mass production.

When compared to the manual staking process, the automated machine showed substantial improvements in cycle time, defect rate, and operator workload. While manual methods often resulted in a defect rate of 6 per 100 units due to human error and inconsistent force application, the automated system maintained a 0% defect rate in testing. Additionally, the level of operator fatigue and skill dependency was significantly reduced, as the machine performed most tasks autonomously. These experimental outcomes clearly demonstrate the effectiveness of the developed staking machine in achieving high-quality, efficient, and reliable core-yoke assembly, making it highly suitable for integration into modern electric motor production lines.



## V. CONCLUSION

The development of the Automatic Core Yoke Staking Machine marks a significant advancement in the field of electric motor manufacturing. This project successfully addressed the limitations of traditional manual and semi-automated staking processes by introducing a fully automated solution that ensures high precision, consistency, and efficiency. The integration of PLC-based control systems, pneumatic actuation, and accurate indexing mechanisms resulted in a robust machine capable of performing staking operations with minimal human intervention.

Experimental results validated the machine's performance, demonstrating improvements in cycle time, staking accuracy, and overall product quality. The system maintained uniform force application, precise alignment, and defect-free assembly across multiple test cycles. Compared to manual methods, the automated machine achieved substantial gains in productivity while reducing labor dependency and operational errors.

The project also reflects the growing importance of smart manufacturing and Industry 4.0 principles, integrating automation, sensor feedback, and human-machine interfaces to enhance reliability and control. Its modular and scalable design allows for future upgrades and adaptability to various motor sizes and staking requirements.

In conclusion, the Automatic Core Yoke Staking Machine not only meets industrial expectations for speed and quality but also sets a strong foundation for further innovations in automated motor assembly systems. It offers a cost-effective, efficient, and industry-ready solution that can significantly contribute to modernizing electric motor production processes.

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