Challenges and Solutions for Fastener and Fastening Tool Manufacturers in Implementing AI

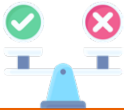
I. Introduction: From AI Blueprint Vision Back to the Factory Site

As AI is gradually adopted in traditional manufacturing such as fastening tools and fasteners, its applications encompass intelligent pricing, drawing recognition, mold adjustment, forging force monitoring, metallographic analysis, intelligent scheduling, and inventory forecasting, demonstrating benefits in shortening operation time, increasing equipment uptime, reducing missed inspections, and improving inventory turnover.

However, in practice, the fastening tool and fastener industry often experiences a gap between the feasibility of a "Proof of Concept" (PoC) and the difficulty in sustaining operation on actual production lines. A more pragmatic approach is to start with measurable, low-risk, and clearly beneficial areas, such as metallographic analysis, mold adjustment guidance, intelligent pricing, dynamic scheduling, or inventory forecasting, and then gradually connect data and solidify judgment logic, transforming on-site experience into usable models and knowledge assets. However, traditional production lines still commonly suffer from problems such as inconsistent equipment interfaces, insufficient process data, rush orders, manual scheduling, and cross-departmental information gaps. Many critical judgments still heavily rely on the experience of master craftsmen, making AI adoption face challenges in hardware, data, processes, and organization. This article will analyze the main challenges of AI implementation from a factory practice perspective, and propose actionable improvement strategies and future development directions.

II. Four Major Implementation Challenges for Traditional Businesses in Adopting AI

The implementation difficulties encountered by traditional fastening tool and fastener manufacturers in adopting AI are summarized in **Table 1** and explained in detail.



▼ Table 1. Four Major Implementation Challenges for Traditional Businesses in Adopting AI

Perspective	Common Situations	Why AI Doesn’t Work	How to Improve
Hardware	Old equipment lacks network connectivity and has insufficient signal.	Unable to monitor and issue early warnings in real time	External sensors, AOI, standalone pilot tests
Data	Paper-based, Excel, and ERP systems coexist	Incomplete annotations and difficulty in stable training	Field standardization, tags and knowledge base
Process	Small quantities of various types of goods, urgent orders	Scheduling rules are often interrupted by ad-hoc events.	Dynamic scheduling, material shortage simulation
Organization	Resistance to change, talent gap	The system has low usage and is difficult to distribute.	Quick Win, KPI management and training

Note: "Quick Win" refers to projects or strategies that yield quick results, characterized by low investment, low risk, and short execution period.

1. Hardware Challenges: Outdated Equipment Lacks Digitization

a. Machine offline and process signal breakpoints: The bottleneck of traditional fastener production lines is the lack of real-time digital acquisition capabilities of the equipment. If the heading, thread rolling, heat treatment, and surface treatment equipment do not have standard interfaces, AI will find it difficult to reliably obtain signals such as pressure, temperature, cycle time, vibration, and operation. It can only identify defective results but cannot trace the formation process. Therefore, practical implementation usually starts with single-machine signal acquisition, mold monitoring, or online visual inspection, rather than assuming that directly building a whole-plant central control system completes the hardware construction.

b. Black-box equipment and real-time interpretation are limited: even if data is obtained, effective interpretation is not guaranteed. Image recognition must first solve the problem of "seeing" before proceeding to "judgment"; optical conditions determine signal quality, while the model is responsible for interpretation. If lens position, lighting, ROI (Region of Interest), judgment threshold, and anomaly rules are not integrated into the design, even if YOLO (You Only Look Once) or AOI (Automated Optical Inspection) is introduced, it will be difficult to form a reliable on-site judgment.

2. Data Dilemma: Low Data Quality and Difficulty in Structuring Experience

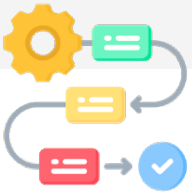
a. The experience of technicians is difficult to translate into data: Traditional production lines rely on experienced technicians' judgment of mold wear, heat treatment abnormalities, metallographic structures, and equipment noise. However, this knowledge cannot be clearly broken down into labelable and traceable data fields. Practical cases show that the key is not just model identification, but to first establish an image database, interpretation rules, and quality monitoring indicators. This can reduce inspection time from 1-2 hours to 15-30 minutes and reduce the need for inspection manpower by 70-80%.

b. Inconsistent records make it difficult for models to be stable: If abnormal records lack standardized classification, and photos, batch numbers, process conditions, equipment status and reasons for rejection are scattered across paper, Excel, or different production management systems, the data is difficult to correspond to each other, and AI will also have difficulty correctly learning the characteristics and judgment rules of various abnormalities from these scattered data.

3. Process Challenges: Urgent Orders Being Placed in Advance Cause Scheduling Failures

a. Small-batch, high-variety production causes static scheduling to quickly become distorted: Fastener scheduling must simultaneously consider the arrival of wire rod, mold availability, upstream and downstream capacity, external supplier schedules and delivery commitments, and cannot be operated solely based on first-in, first-out (FIFO). Once urgent orders are inserted, materials are scarce, or processes are abnormal, scheduling will quickly become distorted and directly affect material availability, on-time delivery rate, and production line utilization.

b. Manual order modifications weaken model stability: Many factories rely on on-site coordination and manual order modifications by production managers. While this offers flexibility, it also hides scheduling logic and decision-making rules within individual experience. If Gantt chart rules, process constraints, material conditions, and production rules are not structured beforehand, AI, relying solely on scheduling results, cannot adequately grasp the decision-making logic, thus reducing model stability and sustainability.



4. Organizational Dilemma: Grassroots Resistance and Shortage of Cross-Domain Talent

a. Anxiety about AI replacing jobs: Frontline staff remain concerned about being replaced by AI. For example, QC personnel worry that AOI will replace manual inspections, production control personnel worry that intelligent scheduling will weaken their professional judgment, and technicians worry that their process experience will be replaced by the system. Therefore, training in generative AI, automated collaboration, cross-departmental applications, and non-programmed visual inspection is fundamental to reducing resistance.

b. Lack of cross-domain technology and management: When industries face problems such as insufficient digital infrastructure in the supply chain and a shortage of technical talent, the key deficiency is the lack of cross-domain talent who can understand process, data structure, equipment logic and field management at the same time. As a result, AI systems will find it difficult to move from PoC (proof of concept) to field deployment, maintenance and improvement mechanisms.

III、Four Solutions for Successful AI Implementation

1. Lightweight Digital Transformation

a. Establishing digital visibility using add-on sensors and vision modules: A pragmatic approach is not to completely replace equipment, but to supplement the process signals of existing equipment through add-on sensors, industrial cameras, AOI, and standalone data acquisition. After obtaining stable images and process data, visual AI can be further introduced to support tasks such as classification, detection, segmentation, and tracking. On-site, the focus can start with high-speed inspection of controlled areas, defect identification, and quality screening.

b. Improving equipment uptime and decision-making efficiency: Production line images and multiple real-time process signals can be used for inference directly on the production line via Edge AI, reducing data transmission latency and synchronizing judgment results with the process. In addition to model accuracy, the effectiveness of implementation should be evaluated by assessing end-to-end KPIs such as false negative rate, false positive rate, inference latency, and equipment cycle time to support real-time rejection, alarms, downtime, or parameter tuning suggestions.

2. Digitalization of Human-Machine Collaboration Experience Transfer

a. First, the judgments of experienced craftsmen are transformed into labeling rules: digitizing the transmission of experience does not replace senior craftsmen, but rather structures their judgment logic. For example, the criteria for crack rejection, the conditions for metallographic structure re-judgment, the wear characteristics of molds, and the mold adjustment sequence can be transformed into anomaly codes, image tags, equipment conditions, and handling rules, forming data that can be used for AI training and verification, thus standardizing the process knowledge that originally relied on oral transmission and intuition.

b. Building AI as a tool for technology transfer and decision support: AI is suitable for first handling SOP queries, historical data comparison, anomaly alerts, and preliminary diagnosis, and then for on-site personnel to make the final judgment. By combining a knowledge base with RAG (Retrieval-Augmented Generation), process specifications, mold adjustment experience, anomaly handling, and quality judgment can be centralized in the knowledge base management, and relevant process judgments can be made based on the content.

3. Establishing a Dynamic and Flexible Scheduling Mechanism

a. AI provides scheduling suggestions first, and then production management makes decisions: AI scheduling should not directly replace production management. Instead, it should integrate orders, materials, equipment capacity, molds, working hours and outsourcing schedules to generate feasible scheduling suggestions. Then, production management can make fine adjustments based on urgent orders, customer needs and on-site conditions to achieve a human-machine collaborative model that can take into account both the data analysis of the algorithm and the practical judgment of production management personnel.

b. Incorporating material shortages, anomalies, and rush orders into the simulation: The value of intelligent scheduling lies not only in generating Gantt charts, but also in responding to exceptional situations such as material shortages, equipment malfunctions, urgent orders, and outsourcing delays. By integrating orders, material requirements, delivery dates, inventory baselines, and equipment status, the priority of work orders and start times can be dynamically adjusted, taking into account material availability, inventory turnover, equipment utilization, and on-time delivery rate. This transforms scheduling from static planning to a real-time production decision-making mechanism. **Table 2** compares the maturity of AI application implementation and priority activation scenarios in a fastener factory.

▼ Table 2. Comparison of AI Application Implementation Maturity and Priority Launch Scenarios in Fastener Manufacturers

Solution	Priority Launch Scenario	KPI Indicator	Suitable Maturity
Lightweight transformation	AOI, forging force, stand-alone monitoring	Missed detection rate, downtime rate, and utilization rate	Low to medium
Digitalization of experience transfer	Metallographic analysis, mold adjustment, and SOP inquiry	Testing time, learning time, hit rate	Medium
Dynamic scheduling	Wire inventory, complete materials, and rush order simulation	Inventory days, on-time delivery rate, material availability rate	Medium
Agile Transformation	AI-powered pricing, customer service, and predictive maintenance	Response time, customer complaints, and maintenance costs	Low to medium

4. Agile Transformation and Profit-sharing Mechanism

a. Find successful scenarios through Quick Wins: AI transformation should prioritize "Quick Win" projects with clear benefits and low risks, such as smart pricing, AI customer service, forging force monitoring, and quality inspection. By shortening processing time, improving yield, and reducing defects, the benefits of implementation can be quickly verified, on-site trust can be established, and then gradually expanded to other processes and management links.

b. Measure effectiveness and promote cross-departmental AI applications with clearly defined KPIs: AI implementation should be based on quantifiable KPIs, such as quote delivery time, customer complaint resolution time, yield rate, missed inspection rate, equipment utilization rate, inventory turnover, and manpower hours. Continuously review effectiveness through production and operational metrics, transforming AI from an IT project into a decision-making support tool used jointly by sales, production, quality assurance, and equipment departments, and serving as a basis for subsequent expansion and resource allocation.

IV. Future Prospects for AI in the Fastener Industry

1. AI-powered energy management and carbon emission prediction

a. Establishing energy data management for high-energy-consuming processes: AI applications in the fastener industry can extend from quality and scheduling to energy management. Heat treatment, surface treatment, compressed air systems, and large forming equipment are all major energy-consuming processes. Energy data for substations and sub-machines should be established, connecting electricity consumption, equipment status, process parameters, output, and rework rate as the data basis for analyzing process energy efficiency and product carbon footprint.

b. Extending from carbon management to cost and order competitiveness: By linking energy data with production batches, process conditions and equipment status, AI can be used to predict carbon emissions, provide early warnings of abnormal energy consumption and optimize energy, and incorporate energy consumption into scheduling and cost analysis, thereby improving energy conservation and carbon reduction, product carbon footprint management and cost estimation capabilities, and strengthening pricing and order competitiveness.

2. From Single-Point AI to Industry Chain AI

a. Similarities and differences between fasteners and fastening tools: Both fasteners and fastening tools can utilize drawing recognition, AOI inspection, intelligent scheduling, knowledge retrieval, and inventory management, but their process focuses differ. Fasteners emphasize process monitoring and quality assessment of cold forging, thread rolling, heat treatment, and surface treatment; fastening tools, on the other hand, emphasize part identification, assembly consistency, torque correction, functional testing, and lifespan management. The former prioritizes process parameters and micro-quality, while the latter focuses on assembly, performance testing, and product traceability. The differences in processing characteristics and AI foundations between fasteners and fastening tools are summarized in **Table 3** below.

b. Upgrading from smart factories to smart supply chains: AI's overall benefits are limited if applied only to single machines or in-plant systems. In the future, it can be gradually integrated with upstream materials, molds and die plates, midstream forming and processing, and downstream heat treatment, surface treatment, and logistics information to establish a cross-process and cross-plant data collaboration mechanism. Through supply chain information sharing and AI analysis, efficiency in anomaly response, delivery coordination, and resource allocation can be improved, propelling smart manufacturing from single-point applications to a smart supply chain.

▼ Table 3. Similarities and Differences Between Fasteners and Fastening Tools

Perspective	Fastener	Fastening Tool	Same AI Foundation
Process Core	Forming, thread rolling, heat treatment, surface treatment	Parts machining, assembly, torque and functional testing	Visual recognition, data integration, and traceability
Quality Focus	Metallography, dimensions, surface defects	Correct assembly, abnormal torque and lifespan	AOI, early warning, knowledge base
Management Focus	Scheduling, material availability, wire rod and associate suppliers	BOM, parts version, after-sales maintenance	Quotation, scheduling, customer service, inventory

V. Conclusion: Data Flow Speed Determines Future Competitiveness

1. AI does not replace traditional manufacturing, but rather enhances manufacturing experience: AI does not completely replace on-site personnel, but rather **transforms long-accumulated process experience into digital capabilities that can be inherited, traced, and sustainably applied through digitization and AI tools**; applications such as metallographic inspection, mold adjustment, SOP query and intelligent quotation show that the core value of AI lies in systematizing the experience and knowledge scattered among personnel and processes, thereby improving the efficiency of technology transfer and production decision-making.

2. The fastener industry should gradually adopt this approach in small-scale, low-risk settings: **Starting with measurable single-point applications and then gradually expanding to entire production lines, factories, and the supply chain. This is currently the most suitable path for traditional fastener manufacturers.** This method reduces implementation risk and is also the easiest way to build trust on-site.

3. Future competitiveness will depend on data, models, and organizational responsiveness: **Differentiation in the future fastener industry will not only lie in equipment or price, but also in who can quickly create a closed loop connecting data flow**, decision flow, and feedback flow. When data flow is faster than competitors, AI will truly translate into long-term advantages in delivery time, quality, cost, and service, as well as a competitive edge in the industry. ■