ENHANCING QUALITY EFFICIENCY IN INDUSTRY 4.0 THROUGH AUTOMATION TECHNOLOGIES IN AUTOMOBILE INDUSTRY

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Abstract—This project presents advent of Industry 4.0 signals a transformative era in manufacturing, marked by the incorporation of automation technologies. This explores the paradigm shift in the automobile industry within the framework of Industry 4.0, focusing on the integration of torque wrenches (WTM) with Programmable Logic Controllers (PLCs) and Human-Machine Interfaces (HMIs) to enhance quality efficiency. The methodology encompasses a thorough analysis of existing torque application processes, meticulous system architecture design, and calibration protocols ensuring precise measurements. Through PLC programming and HMI design, the integration facilitates real-time torque monitoring and adaptive control, providing a dynamic approach to torque application precision. Integration testing validates system performance, and data display on HMIs offers a comprehensive visualization of torque data. Ethical considerations, workforce training, and continuous improvement strategies are integral, ensuring a holistic approach to torque wrench integration in the automotive sector, promising sustained advancements in quality efficiency within the Industry 4.0 landscape.

Keywords—**Torque Wrench WTM, HMIs, PLCs.**

I. INTRODUCTION

In the dynamic landscape of the fourth industrial revolution, Industry 4.0, the automobile industry is experiencing a profound metamorphosis through the integration of automation technologies, heralding a new era of quality efficiency. This paradigm shift signifies a departure from traditional manufacturing methods, embracing a comprehensive digitization that permeates every aspect of production. At the core of Industry 4.0 lies the strategic utilization of automation, facilitating a seamless convergence of physical and digital realms within the automobile manufacturing ecosystem. This integration is not merely a technological upgrade but a transformative journey redefining manufacturing norms. Automation technologies, including robotics, artificial intelligence (AI), the Internet of Things (IoT), and advanced data analytics, serve as a foundational support for this evolution. They orchestrate a symphony of precision and efficiency, optimizing manufacturing processes, and elevating the quality of automobile production. The interconnectedness of smart devices and the utilization of real-time data enable proactive decision-making, ensuring stringent quality control measures are consistently met. In this context, the automotive sector is witnessing a renaissance in operational excellence through the strategic deployment of automated systems.

The synthesis of robotics and AI fosters a flexible and adaptive manufacturing environment, where robots collaborate seamlessly with human workers. In addition to enhancing efficiency, this collaborative approach contributes to creating a safer and more ergonomic workplace. Furthermore, the Industry 4.0 ethos in the automobile industry transcends the factory floor, extending to supply chain management, product design, and customer interactions. As we delve into the intricate web of automation technologies within Industry 4.0, it becomes evident that their application in the automobile industry is not just about augmenting production capabilities but fundamentally reimagining the concept of quality. The precision offered by automated systems ensures that each component and assembly meets exacting standards, reducing defects and enhancing the overall reliability of vehicles. This is not a mere enhancement; it is a revolution that promises heightened customer satisfaction, increased sustainability, and a resilient foundation for the future of automotive manufacturing. However, this transformative journey is not without its challenges. Ethical considerations, cybersecurity risks, and the imperative to reskill the workforce necessitate careful navigation. Organizations must grapple with these complexities to harness the full potential of automation in elevating quality efficiency. The automobile industry stands at the crossroads of innovation and adaptation, poised to redefine the benchmarks of quality through the seamless integration of automation technologies within the Industry 4.0 framework.

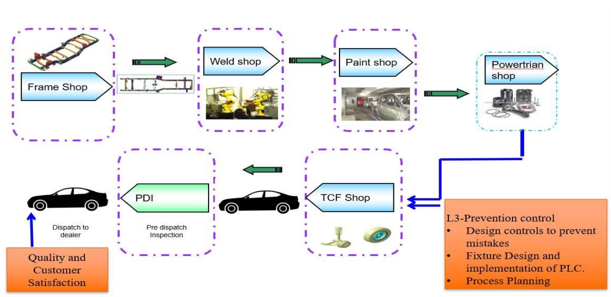

Figure 1.1:Vehicle Flow

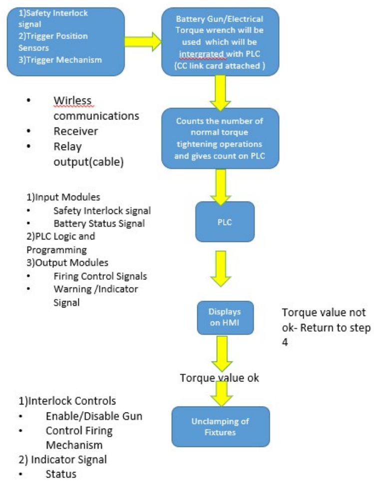

Figure 1.2: Process of Interlocking

II. Literature Review

This paper[2] introduces an innovative modular intelligent fixture system designed to provide adaptable clamping solutions for large components. The fixture modules feature a hybrid mate- rial composition, incorporating both metal frame elements and mineral casting. These modules are designed to be interconnected and combined, facilitating the creation of fixtures customized to the specific geometry of the workpiece and the demands of machining processes. The in- corporation of integrated pipes and interfaces enables an internal hydraulic supply and active cooling, even when modules are combined. Temperature and acceleration sensors are integrated to enable active thermal control and real-time process monitoring. Experimental investigations are conducted on both the modules and initial test fixtures to assess their performance and functionality. This paper[3] address the issue of collisions between the cutter and clamping points, a solution is presented in the form of a multi-point fixture system specifically tailored for aircraft beams frame components. This system adopts a modular design for versatility and operates in-dependently of the Computer numerical control (CNC) system, ensuring practical applicabilityin diverse scenarios. A straightforward, real-time, and precise cutter position detection method is introduced, employing three laser sensors and dedicated detection planes. The identification of potential clamping modules prone to collision with the cutter is expedited through the virtual grid net approach. Subsequently, the proposed collision model and Back Propagation Neural Network methods are employed to assess and manage the clamping modules. The effectivenessof the devised control method and fixture system is affirmed through machining experiments, demonstrating a notable 38.8. This paper[1] As science and technology advance and intelligent manufacturing technology expands, the prevalence of automatic production lines in China has increased. However, the complexity of the overall structure and the lengthy research and development investment cycle have led to diminished production efficiency. This paper addresses these challenges by examining the simulation control debugging system of automatic production lines driven by PLC data. By utilizing PLC data, developers can engage in virtual commissioning of automaticproduction lines and validate the production line's timing, providing a more efficient approachto development and testing. This paper[4]In the manufacturing industry, maintaining smooth workflows throughout the entire product lifecycle is imperative for sustained success. While creating a single super- system by integrating all utilized systems may not be practical, the integration of data remainsa critical necessity. This contribution presents a model-based concept aimed at integrating data elements from various distributed data systems and sources into a unified virtual database. Specific view models are employed to capture information about data, their relationships, proper- ties, and environments. By combining these pieces of information, a middleware platform can be configured to establish interconnections among related data elements across distributed IT systems. This approach addresses the gap between the successful enterprise application integration concept, advanced XML-based technologies, and established graphical description languages. Instead of a rigid development environment, this method outlines how to adapt and leverage UML and BPMN for a modular and parallelizable integration process, creating a highly company-specific yet user-oriented data integration environment. This paper[6]introduces a framework for the automated formulation of fixture designs, employing a fusion of design automation (DA), multidisciplinary optimization (MDO), and robotic simulation. The MDO aspect requires concurrent and parametric designs generated through DA and knowledge-based engineering tools. The primary objective is to streamline the fixture design process, reducing both time and costs by elevating the level of automation. and spectral analysis are effective tools for predictive maintenance. AutoFix offers techniques and tools geared towards the automatic optimization of resource- intensive fixture designs, leveraging digital tools across various disciplines. This paper[5] outlines the comprehensive process of developing an automated testing ma- chine designed to detect wiring errors that may occur during the manufacturing of ICT (in- circuit test) and FCT (functional test) fixtures. The machine, adopting a Flying-Probe configuration, utilizes a probe to make contact with each test pin on the fixture. Control of the machineis executed by a PC functioning as a soft PLC (programmable logic controller) running Twin-CAT 3. The user interface (UI) is crafted using NI LabVIEW, establishing communication with the soft PLC through an ADS(Automation Device Specification) library. To measure continuity between the test pins and the backside interface of the fixture, a specialized 2112-channel switching device was developed, incorporating analog integrated circuits and an STM32 micro-controller. The performance of the newly developed automated testing machine demonstrated its ability to fulfill all requirements, simplifying, expediting, and enhancing the efficiency of fixture testing. This paper[7] This paper present

Intelli-Wrench, a smart tool for providing timely information for mechanical assembly and maintenance workers, that frees workers from error and the hassle of manual documentation. The Intelli-Wrench captures the image of a bolt head as its "fingerprint" by using FIBAR (Fingerprint Imaging by Binary Angular Reflection) imaging method. The fingerprint image is then uploaded to a cloud server and matched with parts databases in order to provide the specific information associated with the bolt. Receiving the information, the Intelli-Wrench informs the workers about the designated locationand torque requirements of the bolt. This direct integration of information retrieval into a tangible tool provides immediate access to relevant information otherwise found in manual documents. Furthermore, the Intelli-Wrench automatically logs the interaction and eliminates the annoying pointing-and-calling procedure which is the conventional method of secure servicing. We demonstrate a working prototype and interaction scenario….

III. PROPOSED SYSTEM

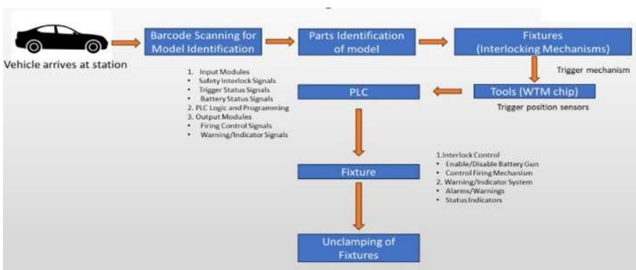

Figure 3.1: Proposed Layout

A. METHODOLOGY

In the relentless pursuit of elevating quality efficiency within the framework of Industry 4.0, this methodology unfolds as a meticulous roadmap for seamlessly integrating wireless torque wrenches with Programmable Logic Controllers (PLCs) and Human-Machine Interfaces (HMIs), particularly within the intricate landscape of the automobile industry. The inception of this methodology is rooted in a detailed examination of existing torque application processes, strategically designed to uncover specific challenges and inefficiencies impeding optimal manufacturing performance. This initial analysis serves as the cornerstone for scoping the project, meticulously defining parameters, and establishing a profound understanding of the integration's objectives, all harmonized with the overarching goal of advancing quality efficiency in torque-related operations.

Embarking on the system architecture design phase, the methodology orchestrates the calibration of wireless torque sensors, a pivotal element in achieving precision and accuracy in torque applications without the constraints of physical connections. Simultaneously, attention is dedicated to the programming of PLCs, encompassing the formulation of algorithms for torque control and real-time data processing. Concomitantly, an intuitive HMI interface is meticulously crafted, not only to enhance the user experience but also to provide a comprehensive wireless display of torque data. This phase seamlessly combines technological prowess with ergonomic design principles, laying the groundwork for a cohesive and synchronized system architecture that leverages the wireless capabilities of modern torque wrenches.

Transitioning to the implementation of the wireless integrated system, the methodology emphasizes the fine-tuning and calibration of wireless torque sensors, ensuring optimal functionality in the absence of physical connections. The programmed PLCs, now equipped with wireless torque control algorithms, seamlessly interface with the HMI. Rigorous testing ensues to validate the system's performance under diverse torque application scenarios, providing invaluable insights into its accuracy, responsiveness, and overall efficiency. This phase bridges the theoretical underpinnings of the wireless integration with the practical application, allowing for real-world validation and refinement.

Advancing further, the methodology introduces robust quality control measures to consistently meet stringent standards in wireless torque-related operations. Specific metrics are defined to monitor torque parameters, ensuring that the integrated system consistently delivers precision and reliability without the constraints of physical connections. This phase is characterized by the implementation of real-time quality monitoring mechanisms, offering continuous insights into wireless torque precision and reliability. Ethical considerations are given prominence, addressing issues such as data privacy and worker safety within the wireless ecosystem. Strategies are devised to navigate potential ethical dilemmas, fostering a work environment that prioritizes both technological advancement and ethical responsibility, now in the context of wireless connectivity.

Simultaneously, the methodology recognizes the paramount importance of the human element in this wireless technological integration. Comprehensive workforce training programs are introduced, ensuring that the human workforce is adept at interacting effectively with the wireless integrated technology. This training not only facilitates a seamless transition but also establishes a foundation for a workforce capable of optimizing and adapting to the wireless torque application system.

In the final stretch, the methodology unfolds strategies for continuous improvement, emphasizing ongoing monitoring of wireless system performance through data-driven insights. The agility of the integrated wireless system is underscored, allowing for the adaptation of torque control algorithms and HMI interfaces to optimize efficiency continually. By fostering a culture of continuous improvement within the wireless torque ecosystem, the methodology ensures that the integrated system remains dynamic and responsive to evolving manufacturing requirements, now unencumbered by physical connections.

In conclusion, this holistic methodology stands as a testament to the nuanced and meticulous approach required to seamlessly integrate wireless torque wrenches with PLCs and HMIs in the

pursuit of enhancing quality efficiency within the Industry 4.0 landscape, particularly in the dynamic realm of the automobile manufacturing industry. Beyond immediate improvements, the methodology serves as a catalyst for the ongoing evolution of torque-related operations, now liberated by the capabilities of wireless connectivity and seamlessly aligned with the dynamic and transformative nature of Industry 4.0.
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B. PROCESS PLANNING

Process mapping in the automobile industry holds immense advantages, serving as a criticaltool in enhancing efficiency, quality, and overall operational effectiveness. One of the primary benefits lies in its ability to provide a visual representation of complex workflows. In the intricate landscape of automotive manufacturing, where various components come together ina synchronized manner, process mapping offers a clear and comprehensive illustration of eachstage, fostering a deeper understanding among stakeholders.
This proactive approach allows for strategic interventions to streamline workflows, optimize resource allocation, and ultimately enhance the overall speed and responsiveness of the manufacturing process. This is particularly crucial in the automotive industry, where timely production is essential for meeting market demands.

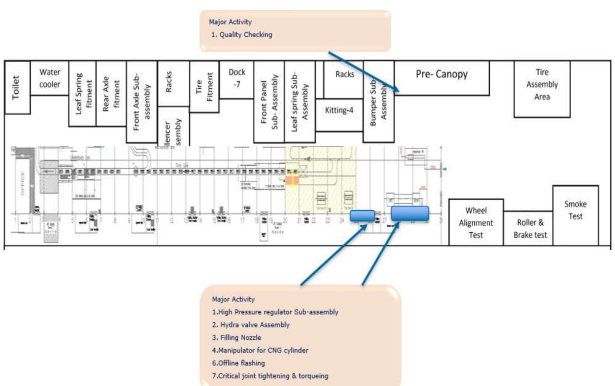

Figure 3.2: Process Mapping of

C. RFQ PREPARATION

The Request for Quotation (RFQ) stands as a critical document in the landscape of procurement, serving as a formal invitation from a buyer to potential suppliers. Its significance goes beyond the mere exchange of pricing information; the RFQ plays a multifaceted role in initiating transparent communication, defining requirements, fostering fair competition, and laying the groundwork for collaborative partnerships. In this comprehensive exploration, we delve into the nuanced layers of the RFQ, examining its various functions, impact, and the strategic considerations it introduces into the procurement process.

1. Initiating Procurement Conversations
2. Defining Requirements and Expectations
3. Fostering Transparency and Fairness
4. Facilitating Competitive Bidding
5. Facilitating Competitive Bidding

D. 3D MODEL

A 3D model is a digital depiction of a three-dimensional object or scene, generated using specialized computer software. These intricate virtual constructs simulate the depth, width, and height of real-world entities, enabling a more immersive and realistic visual experience. Whether utilized in animation, gaming, architecture, or virtual reality, 3D models serve as the foundation for lifelike simulations and designs. Artists and engineers meticulously craft these models, defining every detail to convey precision and authenticity. The versatility of 3D modelling extends across various industries, revolutionizing the way we visualize and interact with virtual environments. CATIA's parametric modeling is a standout feature, enabling the creation of intelligent and customizable 3D models for enhanced flexibility and efficiency. The software's robust assembly design capabilities are crucial in simulating the interaction of multiple components, particularly beneficial in complex engineering projects. CATIA's advanced surface modeling tools contribute to the development of intricate and visually appealing designs. Moreover, it facilitates simulation and analysis, predicting and optimizing product performance, ultimatelyvalidating designs and reducing costs.

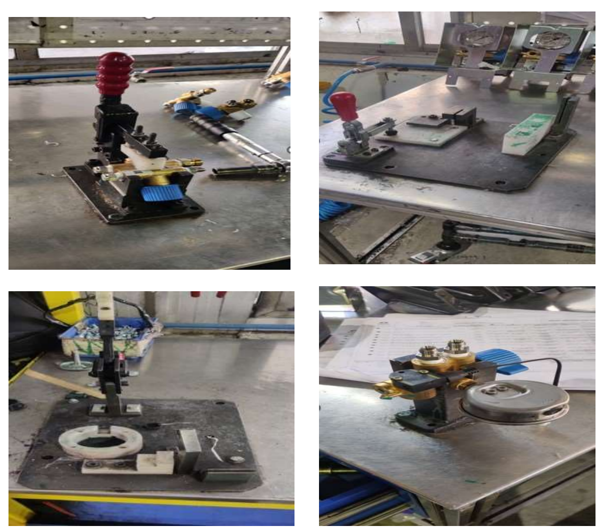

Figure 3.3: 3D in CATIA

FIXTURE 1	FIXTURE 2
There are total 4 Joints	Total 4 Bolts
Torque value for 2 (2.5kgm and 3.2kgm)	Torque value (1.8kgm)
Jidoka Torque Wrench	Wireless Torque Measure

Table 1: Torque Value

FIXTURE 3	FIXTURE 4
Total 2 connector	Total 4 Bolts
Torque value (2kgm and 3.5kgm)	Torque value (2.5kgm to 3kgm)
Jidoka Torque Wrench	Wireless Torque Measure

Table 2: Torque Value

IV. RESULT AND DISCUSSION

The implementation of a dedicated process planning area for the assembly of critical parts in the automobile industry yielded significant positive results. The specialized workspace allowed for meticulous planning, streamlined workflows, and enhanced coordination among assembly teams. This targeted approach ensured that critical parts, vital for the overall functionality and safety of the automobile, were handled with the utmost precision and attention to detail. The implementation of efficient assembly processes in this dedicated area contributed to a notable reduction in production time, minimized errors, and ultimately enhanced the quality of the assembled vehicles.
Simultaneously, the importance of Request for Quotation (RFQ) preparation emerged as a pivotal factor in optimizing the procurement process for the required parts and components. A well-prepared RFQ served as a comprehensive document outlining specifications, quality standards, and delivery requirements. This not only facilitated a transparent and competitive bidding process but also enabled suppliers to align their offerings with the precise needs of the assembly process. The strategic preparation of RFQs played a crucial role in fostering effective communication with suppliers, ensuring the timely availability of critical components, and ultimately contributing to the overall efficiency and success of the automobile assembly operations.

VEHICLE	Time Before Planning (mins)	Time After Planning(mins)
VEHICLE 1	12	8
VEHICLE 2	14.2	9
VEHICLE 3	12.6	8
VEHICLE 4	12	8.2
VEHICLE 5	14	9
VEHICLE 6	13.1	10

Figure 4.1: Time Planning.

V. CONCLUSIONS

The In conclusion, the amalgamation of process planning, the meticulous preparation of Requests for Quotation (RFQ), and the integration of automation within the framework of Industry 4.0 has ushered in a transformative era for the automobile industry. At the heart of manufacturing efficiency lies process planning, a dynamic blueprint that navigates the intricate journey from conception to the final product. Its role in ensuring streamlined workflows, optimal resource utilization, and the production of high-quality vehicles cannot be overstated. Beyond being a static document, process planning adapts to technological advancements and market demands, continuously evolving to uphold the principles of operational excellence and innovation.
The preparation of RFQs acts as a crucial juncture in the procurement process, representing more than a formal request for pricing. The infusion of automation, particularly through Programmable Logic Controllers (PLCs), signifies the dawn of Industry 4.0 in the automobile industry. PLCs serve as the digital orchestrators, harmonizing complex manufacturing processes with precision and efficiency. In this interconnected ecosystem, PLCs facilitate real-time data exchange, enabling predictive maintenance, adaptive manufacturing, and seamless communication between various components within the production line. The integration of automation and Industry 4.0 principles propels the automobile industry forward, not just keeping pace with technological advancements but emerging as a leader in pioneering intelligent manufacturing practices.

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