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# A Literature Review on Comparative Analysis of Non-Contact AI Vision-Controlled Diameter Measurement vs. Conventional Methods in Flux Core Wire Drawing Measurement

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***Abstract***

*Ensuring precise diameter control in flux core wire drawing is crucial for maintaining welding wire quality and performance. Conventional measurement methods, which often rely on manual inspection or mechanical techniques, face limitations in accuracy, consistency, and responsiveness. This study explores the application of AI vision-controlled systems to address these challenges by enabling real-time, high-precision, non-contact diameter measurement. Through an extensive review of research papers and patents, this paper examines the advancements in AI-based monitoring techniques and their integration into industrial wire drawing processes. The AI-driven approach employs laser collimated transmission and CCD sensor technology to capture and analyze wire dimensions with micro-level precision. Unlike traditional methods, this system offers continuous measurement, adaptive corrections, and seamless integration into automated production lines, leading to enhanced process stability and reduced defect rates. The research highlights the advantages of AI-enhanced non-contact measurement, including increased efficiency, reduced material wastage, and improved compliance with stringent quality standards. Additionally, advanced predictive algorithms enable proactive parameter adjustments, optimizing production workflows and minimizing downtime. Experimental trials validate the effectiveness of this system, demonstrating significant improvements in accuracy and consistency. By leveraging AI vision technology, manufacturers can achieve superior quality control, minimize human error, and enhance the sustainability of flux core wire production. This study underscores the transformative potential of AI-driven measurement solutions in modern manufacturing, paving the way for intelligent automation and process optimization in the welding industry.*

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**Keywords:** Diameter measurement, optimization, automation, AI vision system, flux core wire drawing, non-contact measurement, process automation, quality control, real-time monitoring, digital image, welding wire industry

## INTRODUCTION

Flux core wire drawing is a fundamental process in welding wire production, where precise control over wire diameter [1, 2] directly influences welding performance and quality. Achieving dimensional accuracy in flux core wires is critical for ensuring optimal electrical conductivity [3], mechanical strength, and overall weld integrity. Various geometric parameters, such as diameter per unit length, eccentricity, outer diameter [4], and insulation integrity [5] are key quality indicators in this process. Traditional measurement methods often struggle to maintain these characteristics within strict tolerances, leading to inconsistencies and increased rejection rates. To overcome these limitations, modern manufacturing relies on advanced, real-time monitoring solutions to enhance precision and efficiency [6–13].

Among the various measurement approaches, optical methods have gained prominence due to their high accuracy [14] and non-contact nature. These techniques ensure minimal interference with the production process while providing continuous diameter assessment. Optical measurement technologies can be categorized into diffraction-based [15–17], interferometric [18], scattering-based [19], and shadow projection methods [20, 21]. Diffraction and interferometry leverage wave interactions to measure wire diameters at a microscopic level, while scattering techniques analyze light dispersion. Shadow projection methods, which capture wire profiles using collimated light beams, offer a wide measuring range and are particularly suitable for industrial applications.

This study focuses on an AI-integrated shadow technique for wire diameter measurement, harnessing real-time monitoring and adaptive control capabilities. By leveraging machine learning algorithms, this system dynamically adjusts process parameters, ensuring consistent wire geometry while minimizing material waste. AI-driven measurement solutions provide automated corrections, reducing human intervention and improving production efficiency. Furthermore, they mitigate environmental variations that often impact traditional measurement accuracy.

The research presents a comparative review of conventional and AI-driven diameter measurement methodologies, examining the effectiveness of contact and non-contact techniques. It assesses vision-based, wireless, and embedded sensor technologies, highlighting the advantages of AI-powered systems in maintaining strict tolerances, optimizing production workflows, and minimizing defects. Unlike traditional mechanical methods prone to variability, AI-controlled systems enable predictive adjustments, ensuring superior quality and operational consistency.

As industries transition toward intelligent automation, the integration of AI vision technology into flux core wire drawing processes marks a significant advancement in welding wire manufacturing. This study aims to showcase the potential of AI-driven solutions in enhancing quality control, reducing errors, and fostering sustainable production practices. By implementing machine-assisted monitoring and real-time data analysis, manufacturers can achieve precision engineering, drive innovation, and set new standards in welding wire production.

## RESEARCH GAP

Despite notable progress in wire diameter measurement techniques for flux core wire drawing, several crucial aspects remain unexplored in the application of AI vision-controlled optimization. The transition from theoretical research to full-scale industrial implementation presents several challenges that require further investigation.

1. *Industrial Application and Real-World Testing:* Most studies on AI-driven wire diameter monitoring are confined to controlled laboratory conditions, with limited exploration of large-scale production environments. The practical deployment of these systems in dynamic manufacturing settings remains under-researched, raising concerns about reliability, adaptability, and long-term stability. Further investigation is required to assess AI-based solutions in real-world scenarios, addressing variables, such as environmental disturbances, system robustness, and production-line integration.
2. *Enhanced AI Algorithm Development:* While existing AI-based measurement methods improve precision, current models lack adaptive learning capabilities that can dynamically adjust to varying manufacturing conditions. There is limited research on the development of more sophisticated machine learning frameworks, such as self-optimizing neural networks and real-time anomaly detection, which could further enhance control accuracy and predictive maintenance. Future work should focus on refining AI algorithms to improve responsiveness and decision-making in unpredictable production scenarios.

3. *Integration with Conventional Manufacturing Systems:* A significant challenge in adopting AI vision-based monitoring is its compatibility with existing flux core wire drawing setups. Research on seamless interoperability with legacy machinery, data communication protocols, and integration with industrial automation systems is still in its infancy. A systematic study is needed to establish methodologies that ensure minimal operational disruptions and effective coordination between traditional and AI-enhanced monitoring systems.
4. *Economic Feasibility and Long-Term Sustainability:* While AI-driven monitoring systems show potential in minimizing material waste and improving efficiency, their cost-effectiveness and financial implications remain inadequately explored. Research focusing on cost-benefit analysis, return on investment (ROI), and overall economic justification is necessary to encourage widespread industrial adoption. Further investigation is required to determine the break-even point for AI integration and evaluate its long-term sustainability compared to conventional measurement techniques.

Addressing these research gaps will bridge the divide between theoretical advancements and industrial execution, enabling AI-driven optimization to revolutionize the flux core wire drawing process. By focusing on practical implementation, adaptive learning, seamless integration, and economic impact, future research can establish AI vision-controlled monitoring as a viable and transformative solution in welding wire manufacturing (Figures 1 and 2).

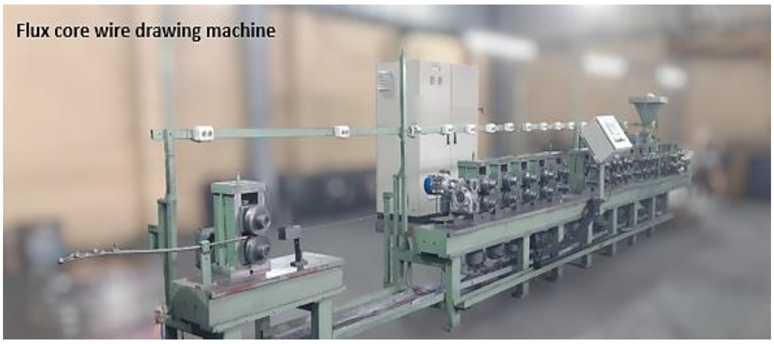


**Figure 1.** Flux core wire drawing machine.

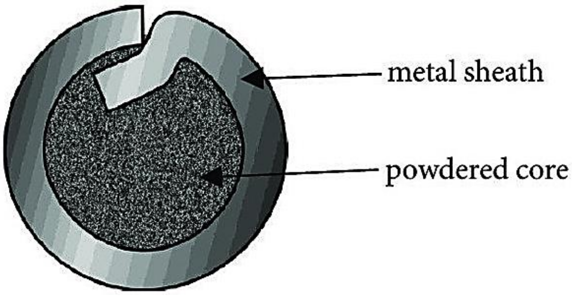


**Figure 2.** Cross section of flux cored wire.

## LITERATURE REVIEW

The evolution of flux core wire drawing has seen significant improvements, particularly with the adoption of non-contact measurement techniques for diameter optimization. Various methodologies have been explored to enhance precision, efficiency, and automation, underscoring the importance of real-time monitoring to address the shortcomings of traditional measurement approaches.

Magnus Ericson (WO9721073A1, 1997) introduced an optical-based contactless measurement technique, employing illumination and image reception technology to achieve high-precision diameter measurement. Despite its accuracy, the system lacked AI integration for dynamic adjustments, limiting its adaptability in fluctuating production conditions [22].

Keba Ges Mbh & Co. (GB2257512A, 1993) advanced optical scanning methods to measure elongate objects, contributing to automated quality control. However, this approach did not incorporate AI-driven corrective actions for real-time optimization, limiting its potential for adaptive industrial applications [23].

Wei Li, Hongbo Wang, and Zhihua Fenga pioneered an ultra-high-resolution, non-contact measurement system utilizing an eddy current sensor (ECS). Their study demonstrated superior resolution capabilities (0.42 nm static, 2.2 μm dynamic) compared to other techniques. However, ECS-based methods lack self-learning capabilities, which restricts their ability to dynamically adjust to production variables [24].

Sprecher Energie Osterreich Gmbh (US5212539A, 1993) introduced an apparatus leveraging optical sensors to determine object dimensions. Although this study contributed to advancements in precision measurement, it did not focus on AI-driven optimizations or real-time adaptive control [25].

Martínez-Anton, I. Serroukh, and E. Bernabeu investigated laser diffraction for wire diameter measurement, emphasizing its effectiveness in real-time applications. However, classical Fraunhofer diffraction models showed limitations when applied to three-dimensional objects, highlighting the need for refined mathematical approaches to improve adaptability in dynamic production settings [26].

MICROTEC S.r.l. (EP0626560A2, 1994) developed a high-speed measurement device for assessing transversal sections of moving longitudinal objects. While beneficial for rapid analysis, this method did not explore AI-based control mechanisms for process optimization, missing an opportunity for real-time diameter regulation [27].

Beltronics Inc. (US4697088A, 1987) proposed a method using optical scanning techniques to detect sharp edge transitions based on reflective variations. While effective in scanning-based inspections, it lacked integration with production monitoring systems and AI-driven enhancements [28].

Evgeny Fedorov and Alexander Koba from Tomsk Polytechnic University developed a three-axis laser-based measuring system for precise diameter calculations. Their approach involved mathematical modeling for object radii and center positions but was primarily designed for static measurements rather than dynamic process control in industrial settings [29].

Sebastian Tamayo Vegas and Khalid Lafdi of Northumbria University conducted an extensive review of non-contact tools for structural health monitoring. Their study highlighted the increasing reliance on AI-powered vision systems, deep learning, and sensor fusion for enhanced defect detection. This supports the argument for integrating AI-driven solutions into industrial measurement applications to improve quality control and process automation [30].

Tzyy-Shuh Chang and Hsun-Hau Huang introduced a portable imaging-based measurement system with self-calibration, enabling precise measurement of hard-to-access objects. Although useful for various applications, it was not specifically designed for high-speed manufacturing environments. Similarly, Yuki Kimura, Akira Matsui, and Shingo Inazumi developed an imaging-based inspection system for analyzing external features, though it lacked real-time adaptive feedback for process control [31].

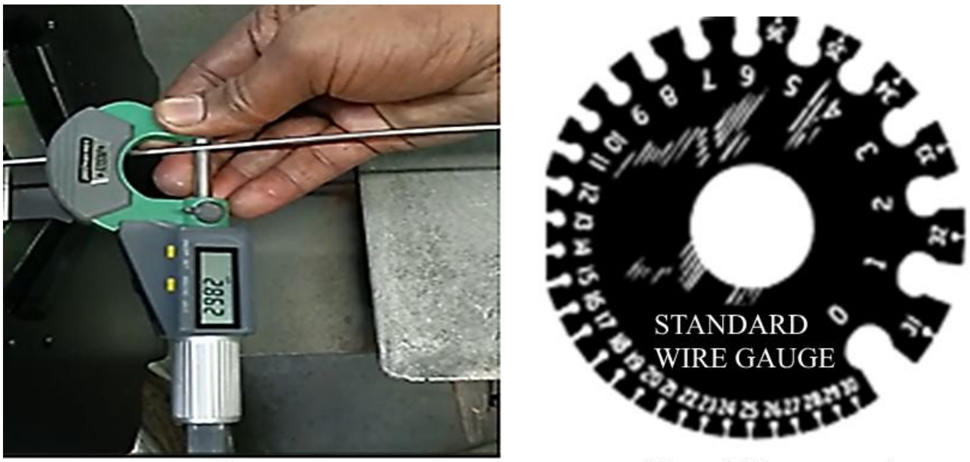
Despite these technological advancements, a critical research gap exists in the practical implementation of AI-driven vision-controlled diameter optimization in flux core wire drawing. While numerous studies focus on measurement accuracy, they often neglect real-time corrective capabilities essential for industrial automation. Integrating AI-driven vision systems with machine learning algorithms presents a transformative approach to enhancing precision, reducing human intervention errors, and ensuring continuous monitoring. Future research should focus on the development of adaptive AI models capable of dynamically adjusting to variations in wire diameter, enabling fully automated quality control in flux core wire manufacturing.

## MATERIALS AND METHOD

The developed system integrates high-resolution imaging technology with advanced AI-driven analysis to continuously track and control the wire drawing process. The AI model is trained using an extensive dataset that includes variations in wire diameter and corresponding process conditions. By processing this data in real-time, the system identifies any deviations from the predefined specifications and autonomously modifies drawing parameters to maintain consistency.

To achieve precise and non-intrusive measurement, the system employs contactless sensing techniques that facilitate rapid data acquisition without interfering with production flow. This real-time approach enhances accuracy and responsiveness, significantly reducing defects and material wastage.

Conventional wire diameter control in flux core wire drawing relies on manual inspection and mechanical dies, which involve periodic checks to ensure dimensional accuracy. However, data analysis over a one-month period has revealed considerable diameter fluctuations, demonstrating the limitations of these traditional techniques. Since these inconsistencies are often detected only after production is completed, manufacturers are unable to implement immediate corrective actions. This underscores the necessity for an AI-integrated, real-time monitoring system that ensures continuous precision, optimizes efficiency, and eliminates defects before they affect final product quality.



Manual Measurement

Manual Measurement

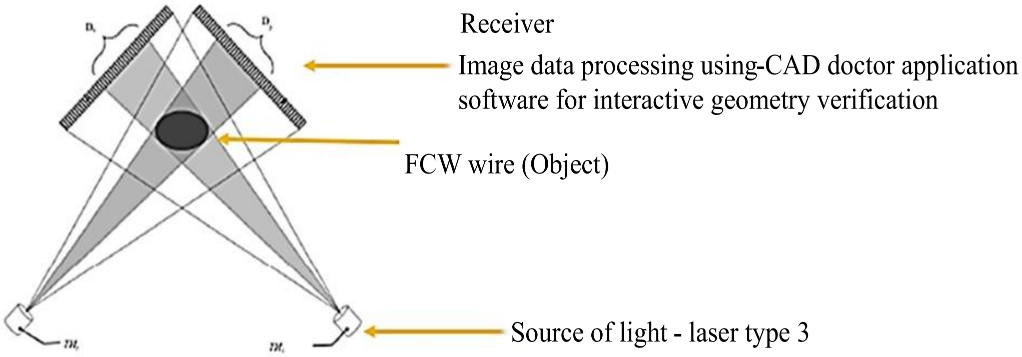


**Figure 3.** For output display and data processor selection logic principle in TVGD5000 series.

The TVGD5000 series represents a cutting-edge advancement in AI-driven, vision-controlled diameter measurement technology. This system incorporates a laser-collimated transmission mechanism in conjunction with a CCD line sensor to achieve precise, non-contact measurement. A finely focused laser beam is projected across the CCD sensor's detection range. When a wire or similar object intercepts the beam, it casts a shadow onto the sensor, which is captured at a high sampling rate of 1.2 kHz with an exposure time of approximately 2 microseconds. This rapid acquisition ensures high-resolution imaging while mitigating errors caused by wire vibrations (Figure 3).

The microprocessor embedded within the gauge processes the acquired data using a sophisticated algorithm capable of handling 1,200 measurements per second. These measurements are analyzed and synthesized to generate precise diameter reading, which is then digitally converted for real-time display. Furthermore, the system enables seamless data communication via an RS485 interface, allowing integration into automated production environments for comprehensive monitoring and analysis.

By leveraging laser-collimated transmission and CCD sensor technology, the TVGD5000 series ensures high-speed and ultra-precise diameter measurements. This approach is essential for manufacturing processes requiring stringent quality control. Similar principles are employed in advanced CCD laser micrometers, such as the IG Series, which offer high-resolution differentiation regardless of the target's optical properties.

In practical application, the AI-powered TVGD5000 series has demonstrated its ability to maintain flux core wire diameters within the specified range of 2.80mm (+0, -0.05mm) (Figure 4). This precision control has led to improved product quality, minimized material wastage, and enhanced sustainability in welding wire manufacturing, contributing to efficient and reliable production workflows (Tables 1, 2, and 3) showed the measurement data from AI monitoring measurement methodology.

**Table 1.** Measurement data from traditional monitoring measurement methodology.

| Date | Measurement | Average | Date | Measurement | Average |
|---|---|---|---|---|---|
| 01.10.2024 | 2.62,2.70,2.80,2.83 | 2.74 | 17.10.2024 | 2.80,2.84,2.80,2.79 | 2.81 |
| 02.10.2024 | 2.65,2.85,2.9,2.75 | 2.79 | 18.10.2024 | 2.78,2.83,2.79,2.75 | 2.80 |
| 03.10.2024 | 2.81,2.80,2.74,2.63 | 2.75 | 19.10.2024 | 2.73,2.69,2.79,2.82 | 2.79 |
| 04.10.2024 | 2.88,2.90,2.74,2.68 | 2.80 | 20.10.2024 | 2.81,2.77,2.79,2.80 | 2.79 |
| 05.10.2024 | 2.76,2.82,2.88,2.78 | 2.81 | 21.10.2024 | 2.79,2.82,2.83,2.74 | 2.80 |
| 06.10.2024 | 2.78,2.9,2.75,2.82 | 2.81 | 22.10.2024 | 2.73,2.75,2.80,2.84 | 2.78 |
| 07.10.2024 | 2.80,2.77,2.82,2.76 | 2.79 | 23.10.2024 | 2.82,2.74,2.75,2.79 | 2.78 |
| 08.10.2024 | 2.73,2.78,2.81,2.85 | 2.79 | 24.10.2024 | 2.80,2.83,2.79,2.75 | 2.79 |
| 09.10.2024 | 2.80,2.83,2.78,2.76 | 2.79 | 25.10.2024 | 2.78,2.81,2.79,2.83 | 2.80 |
| 10.10.2024 | 2.73,2.77,2.82,2.83 | 2.79 | 26.10.2024 | 2.80,2.76,2.77,2.82 | 2.79 |
| 11.10.2024 | 2.75,2.85,2.77,2.76 | 2.78 | 27.10.2024 | 2.79,2.82,2.77,2.80 | 2.79 |
| 12.10.2024 | 2.80,2.74,2.76,2.83 | 2.78 | 28.10.2024 | 2.80,2.82,2.79,2.80 | 2.80 |
| 13.10.2024 | 2..81,2.83,2.85,2.78 | 2.82 | 29.10.2024 | 2.74,2.75,2.76,2.83 | 2.77 |
| 14.10.2024 | 2.77,2.76,2.80,2.78 | 2.78 | 30.10.2024 | 2.80,2.82,2.81,2.78 | 2.80 |
| 15.10.2024 | 2.69,2.75,2.77,2.78 | 2.74 | 31.10.2024 | 2.77,2.76,2.80,2.82 | 2.79 |
| 16.10.2024 | 2.85,2.80,2.81,2.82 | 2.82 | | | |

**Table 2.** Device model for TVGD5000.

| Device Model | TVGD5000 |
|---|---|
| Measuring Range | 0.2 mm~45 mm |
| Measuring frequency | 800/axis |
| Accuracy | 0.002 |
| Repeatability | 0.5 microns |
| Resolution | 0.001 mm |
| UOM | mm/Inch |
| Temperature | –10 to 50*C |
| Humidity | <90% Relative |
| Outputs | RS485 as standard, RS232, Profinet, OPC, Anybus |

**Table 3.** Measurement data from AI performance measurement methodology.

| Date | Measurement | Average | Date | Measurement | Average |
|---|---|---|---|---|---|
| 01.11.2024 | 2.65,2.75,2.81,2.80 | 2.75 | 16.11.2024 | 2.80,2.74,2.75,2.79 | 2.78 |
| 02.11.2024 | 2.67,2.80,2.80,2.74 | 2.78 | 17.11.2024 | 2.80,2.80,2.79,2.75 | 2.79 |
| 03.11.2024 | 2.80,2.80,2.75,2.65 | 2.74 | 18.11.2024 | 2.78,2.80,2.79,2.75 | 2.80 |
| 04.11.2024 | 2.80,2.80,2.75,2.67 | 2.80 | 19.11.2024 | 2.73,2.69,2.79,2.80 | 2.79 |
| 05.11.2024 | 2.77,2.83,2.80,2.77 | 2.80 | 20.11.2024 | 2.81,2.77,2.79,2.80 | 2.79 |
| 06.11.2024 | 2.74,2.80,2.70,2.80 | 2.80 | 21.11.2024 | 2.79,2.80,2.80,2.74 | 2.80 |
| 07.11.2024 | 2.79,2.78,2.80,2.74 | 2.79 | 22.11.2024 | 2.74,2.89,2.70,2.80 | 2.80 |
| 08.11.2024 | 2.74,2.79,2.80,2.80 | 2.79 | 23.11.2024 | 2.79,2.78,2.80,2.74 | 2.79 |
| 09.11.2024 | 2.79,2.80,2.76,2.74 | 2.79 | 24.11.2024 | 2.74,2.79,2.80,2.80 | 2.79 |
| 10.11.2024 | 2.70,2.78,2.80,2.80 | 2.79 | 25.11.2024 | 2.79,2.80,2.76,2.74 | 2.79 |
| 11.11.2024 | 2.70,2.80,2.78,2.77 | 2.78 | 26.11.2024 | 2.80,2.76,2.77,2.80 | 2.79 |
| 12.11.2024 | 2.80,2.75,2.76,2.80 | 2.78 | 27.11.2024 | 2.79,2.80,2.77,2.80 | 2.79 |
| 13.11.2024 | 2.81,2.77,2.79,2.80 | 2.79 | 28.11.2024 | 2.80,2.80,2.79,2.80 | 2.80 |
| 14.11.2024 | 2.79,2.80,2.80,2.74 | 2.80 | 29.11.2024 | 2.74,2.75,2.76,2.80 | 2.77 |
| 15.11.2024 | 2.73,2.75,2.80,2.80 | 2.78 | 30.11.2024 | 2.80,2.80,2.80,2.78 | 2.80 |

**Figure 4.** TVGD5000 series AI vision controlled diameter optimization.

## CONCLUSIONS

This study underscores the transformative impact of AI vision-controlled diameter measurement in flux core wire drawing. By integrating real-time monitoring and adaptive control, the system effectively overcomes the challenges associated with traditional measurement methods, which often suffer from inconsistencies and reliance on manual intervention. The AI-driven approach ensures precise diameter regulation, significantly reducing material wastage while enhancing production efficiency.

The results demonstrate that incorporating AI vision technology into manufacturing not only strengthens quality control but also minimizes defects and optimizes resource utilization. The automation of diameter measurement and correction enhances operational reliability and cost-effectiveness, positioning AI-driven systems as a practical and scalable solution for modern wire production industries.

These insights establish a strong foundation for the wider adoption of contactless measurement technologies in flux core welding wire manufacturing. Leveraging AI-powered precision measurement allows manufacturers to streamline production processes, improve quality control, and achieve near-zero defects – paving the way for the next generation of industrial automation.

Future advancements will focus on refining AI algorithms to improve predictive capabilities and adaptability. Additionally, extending the system's applicability to diverse wire materials and varying production conditions will further enhance its industrial relevance, ensuring continuous innovation in manufacturing automation and quality assurance.

## Declaration of Interest

The author(s) declare that there is no conflict of interest regarding the publication of the manuscript The research was conducted independently, and no financial, commercial, or personal relationships have influenced the preparation or outcomes of this work.

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