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AI-Enhanced Product Quality & Machine Safety

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Abstract:

In modern manufacturing, with consistent product quality maintaining machine safety is also important parameter. To address this, we have developed an AI- Based Molded Fiber forming machine end product quality control system utilizing vision sensors integrated with robots. This system automatically monitors the process by inspecting the output from hot press section of forming machine by robot using a vision sensor. If any products stuck in hot press during drying process the vision sensor detects the issue and send the signals which further trigger an alarm and alerts the operator to investigate the hot press and remove the obstructed material. By preventing stuck products this will enhance consistent product quality with improved machine efficiency as this approach helps to increase the life of wire mesh used in forming and drying section which need to reduce frequent replacements. This paper highlights the integration of AI and vision sensor which offers an effective automated solution to quality control, enhancing both product consistent quality and machine efficiency while minimizing manual intervention.

Keywords: *AI-Based System, Product Quality, Machine Efficiency, Hot Press, Robot Integration.*

Introduction

In today's fast-paced manufacturing industry, achieving high product quality while ensuring the safety and efficiency of machines is a critical challenge. As an innovative technology, machine vision enables reliable and fast 24/7 inspections and helps producers to improve the efficiency of manufacturing operations [1]. As the demand for precision and consistency grows, traditional methods of quality control are often not enough to meet these needs. To address this, innovative technologies such as artificial intelligence (AI) and advanced sensors are transforming manufacturing processes. One such innovation is the development of an AI-based Molded Fiber forming machine system that integrates vision sensors with robots.

On the forming machine, product is formed mainly in two stages that is forming section and drying section. After forming in forming section, product is transferred to the drying section where it is compressed between hot presses at a particular temperature. In that section there are chances of product sticking action on hot press mold. Also, if this action continues to happen in various cycle led to damage to wire mesh which is the most critical parameter as these directly effects the product formation.

So, an AI-based Molded Fiber forming machine system that integrates vision sensors with robots automatically monitor detect the issue such as a plate or bowl or any other molded product stuck in hot press then the system alerts the operator by sending the signal which trigger an alarm. This prevents the sticking of products in hot press which significantly improves both quality control and machine performance as there is need for maintaining high products quality as well as machine safety during the manufacturing process. This prevents production delays and improves machine life by reducing wear and tear and minimizes the need for frequent replacements, mostly wire mesh. This integrated approach not only ensures consistent product quality but also reduces manual intervention, making manufacturing processes more efficient and reliable.

Materials and Methodology:

In this section, we describe the materials used and the methodology employed to develop and implement the AI-based molded fiber forming machine end product quality control system

with integrated vision sensors and robots. The goal of this approach is to ensure consistent product quality, enhance machine efficiency, and extend the longevity of the manufacturing equipment.

Materials

Molded Fiber Forming Machine: Primary Machinery which is used for manufacturing of various molded fiber products.

AI-Based Control System: The system is powered by an artificial intelligence (AI) algorithm designed to process input data from the vision sensors and make decisions about product quality. This AI system analyses the data in real-time to identify potential issues in the manufacturing process, such as blocked or improperly formed products.

Vision Sensors: High-resolution vision sensors are installed on the molded fiber forming machine to monitor the output products as they are picked up by the robot. These sensors capture detailed images of the products, enabling the system to detect irregularities, such as stuck plates or bowls or any other molded product in the hot press.

Robots: Industrial robots are integrated into the system to automate the inspection and material handling processes. These robots retrieve products from the hot press and transport them to the appropriate stages in the manufacturing process. Additionally, they are equipped with mechanisms to handle issues detected by the vision sensors, such as removing obstructed materials.

Hot Press: The hot press is a critical component of the molded fiber forming machine, responsible for shaping the products during manufacturing. It is closely monitored by the vision sensors to detect any potential blockages or issues.

Alarm System: An alarm system is integrated into the AI-based system. When a potential issue, such as a stuck product, is detected by the vision sensors, the alarm system alerts the operator to take corrective action.

Methodology

System Integration: The first step in the methodology involves integrating the AI-based control system, vision sensors, and industrial robots into the molded fiber forming machine. The AI system is connected to the vision sensors, which continuously monitor the products as they move through the hot press. Robots are programmed to retrieve the products from the press and place them in the next phase of production.

Real-Time Product Monitoring: The Machine learning algorithms can effectively detect and control product formation by leveraging a combination of controller programming software TIA V17 and neural network architectures [2]. The vision sensors capture high-resolution images of each product after it is picked by the robot from the hot press. The AI system processes these images in real-time to detect any issues, such as products that are stuck or improperly formed. If a problem is detected, the system sends a signal to the alarm, alerting the operator to investigate the hot press.

Issue Detection and Response: When a stuck product is identified, the vision sensor triggers the alarm, notifying the operator. The operator then investigates the hot press to remove the obstructed product. The AI-based system continuously monitors the process, adjusting its responses based on ongoing data, ensuring minimal disruption to the manufacturing process.

Preventive Maintenance and Efficiency Monitoring: The system also tracks the performance of the hot press and other critical components, identifying potential maintenance needs before they lead to machine failure. By detecting early signs of wear or malfunction, the system helps reduce the frequency of equipment breakdowns and extends the life of the press mesh.

Data Logging and Reporting: The AI system logs all data related to product quality, machine performance, and detected issues. This data is used for generating reports, which are reviewed by operators and management to assess the overall effectiveness of the system and identify areas for improvement.

Continuous Improvement: The system is designed to learn and improve over time. Data pre-processing refers to any operation carried out on the original data to prepare it for further analysis [3]. The AI algorithm adapts based on data collected from previous inspections, refining its ability to detect issues and make real-time adjustments to improve product quality and machine efficiency.

By using this methodology, the AI-based system ensures a high level of automation, minimizes human intervention, and improves the overall manufacturing process. The integration of vision sensors and robots allows for precise quality control, faster detection of issues, and enhanced machine performance, ultimately leading to higher product consistency and efficiency. Below is the flowchart (Figure 1) containing a detailed description of the entire process [4],

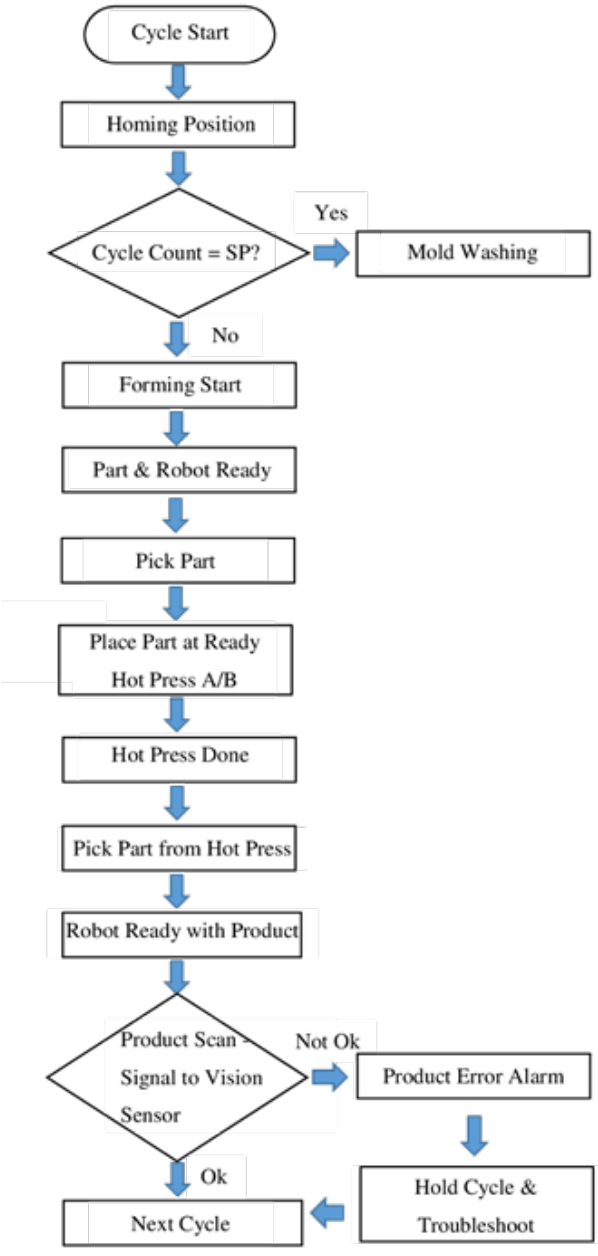

Figure 1: Process Flow

To effectively illustrate errors and the correct process in a Vision Sensor and Robot-integrated automatic forming machine system, visual representations are highly impactful. Figure 2 is a description with images of how these images structured to highlight common errors versus the correct process:

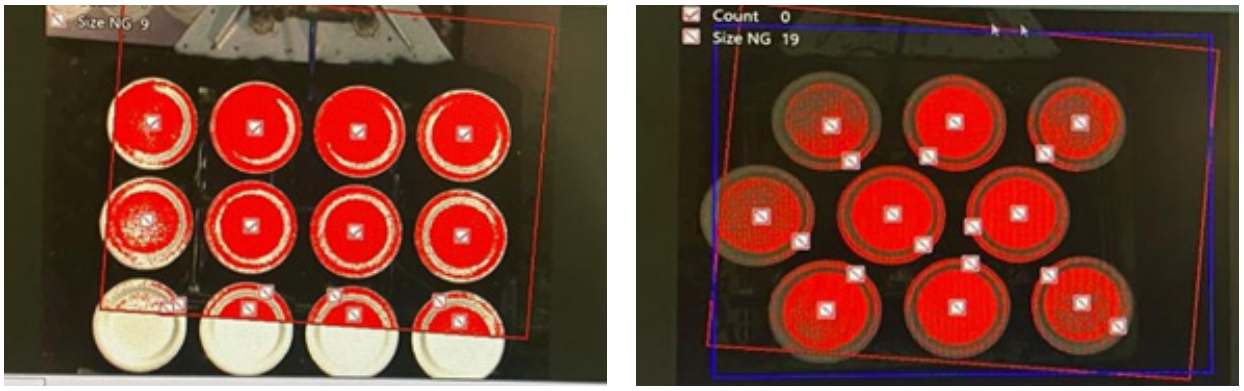

Figure 2: Incorrect Alignment and Product Availability i.e., Error

The first image depict a scenario where the product is misaligned during the process. This could include the material being slightly off-centre or rotated incorrectly. The vision sensor in the system detects this misalignment and flags it as an error. The product might appear at an angle, with the edges misaligned with the forming machine's work surface. The vision sensor is shown scanning the product, detecting the misalignment. An alarm or warning will be shown on the screen of the control system, showing an error and does not allow robot or cycle to start until error is corrected or cleared.

Error Impact:

If the misalignment isn't corrected and all the end products has not been detected, then forming process could result in production loss as the missing products will be stuck in the wire mesh and again at other cycle one more product will be sticking on previous one, leading to waste material, rework and maintenance (Figure 3).

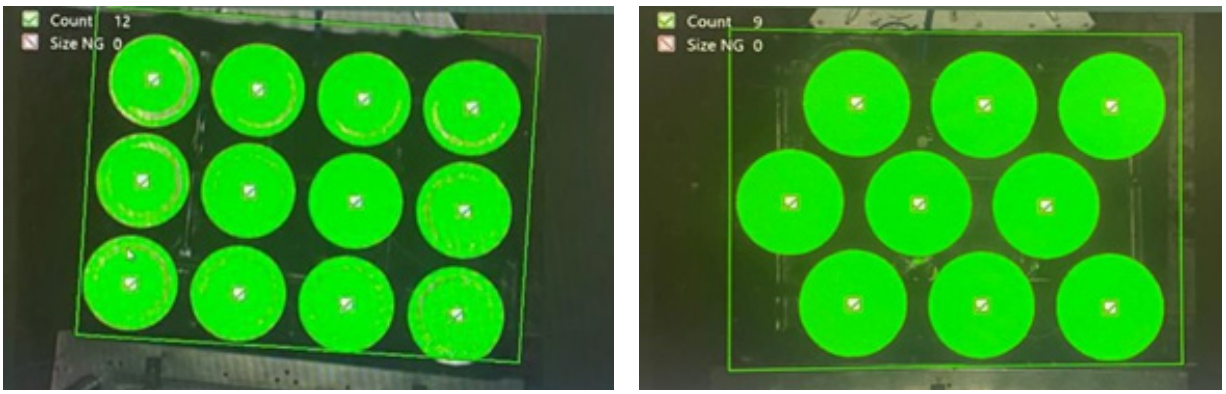

Figure 3: Correct Alignment and Product Availability Checked

The second image shows the product properly aligned and positioned within the machine surface. The vision sensor detects the correct alignment, sending feedback to the robot to assist with positioning the product exactly where it needs to be plus availability of all number of products. The product is placed perfectly within the machine's working area, with its edges flush and centred. The vision sensor shown scanning of the material, confirming proper alignment and all product availability. The control system displays a "Ready" message and gives ready signal to robot to proceed for further cycle sequence.

Impact of Correct Process:

With correct alignment and availability of all product count, the forming process can proceed without issues, ensuring high-quality, defect-free products and maintenance free solution.

Results and Discussion:

We analyse the performance and outcomes of the AI-based molded fiber forming machine end product quality control system, which integrates vision sensors and robots. The system's impact on product quality, machine efficiency, and longevity is evaluated, and the results are compared to traditional methods of quality control and machine monitoring. Some of the observed key points are mentioned below:

1. Improved Product Quality 15-20%, by detecting defect and improves consistent output.

2. Enhanced Machine Efficiency by prevention of production delays with optimal utilization of resources around 12-15%.

3. Enhanced Machine Longevity by 20%, reducing wear and tear with low maintenance frequency.

4. Reduced Manual Intervention by 95%, only need to troubleshoot when vision sensor give an alarm.

5. Cost Reduction: Due to less defective products, by extending the life of the wire mesh, reducing the frequency of mesh replacement, the system helped to decrease maintenance costs by around 10-15%.

6. Challenges and Limitations:

Initial Setup and Integration: The initial integration of the AI-based system, vision sensors, and robots with the existing machinery required substantial setup time and resources.

Sensor Calibration: Ensuring that the vision sensors were calibrated correctly to detect specific product defects without triggering false alarms was an ongoing process. Continuous fine-tuning and regular updates to the AI algorithms were necessary to maintain optimal system performance.

Cost of Technology: The upfront cost of implementing such an advanced system, including the purchase of robots, vision sensors, and AI software, was high. However, these costs were offset by the long-term savings in maintenance and improved product quality.

Conclusions:

The AI-based molded fiber forming machine end product quality control system, utilizing vision sensors and robots, significantly improved product quality, machine efficiency, and overall system performance. The automation of monitoring and issue detection reduced the need for manual intervention, minimized downtime, and extended the longevity of the equipment. While the initial setup costs were high, the long-term benefits, including cost reductions and enhanced operational efficiency, provided a strong return on investment. This system represents a promising advancement in modern manufacturing, offering a scalable and reliable solution to quality control challenges.

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Conflict of Statement: The authors declare that they do not have any conflict of interest.

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