Flexxbotics™

Autonomous Process Control (APC) using Robots and Automated Inspection in Manufacturing

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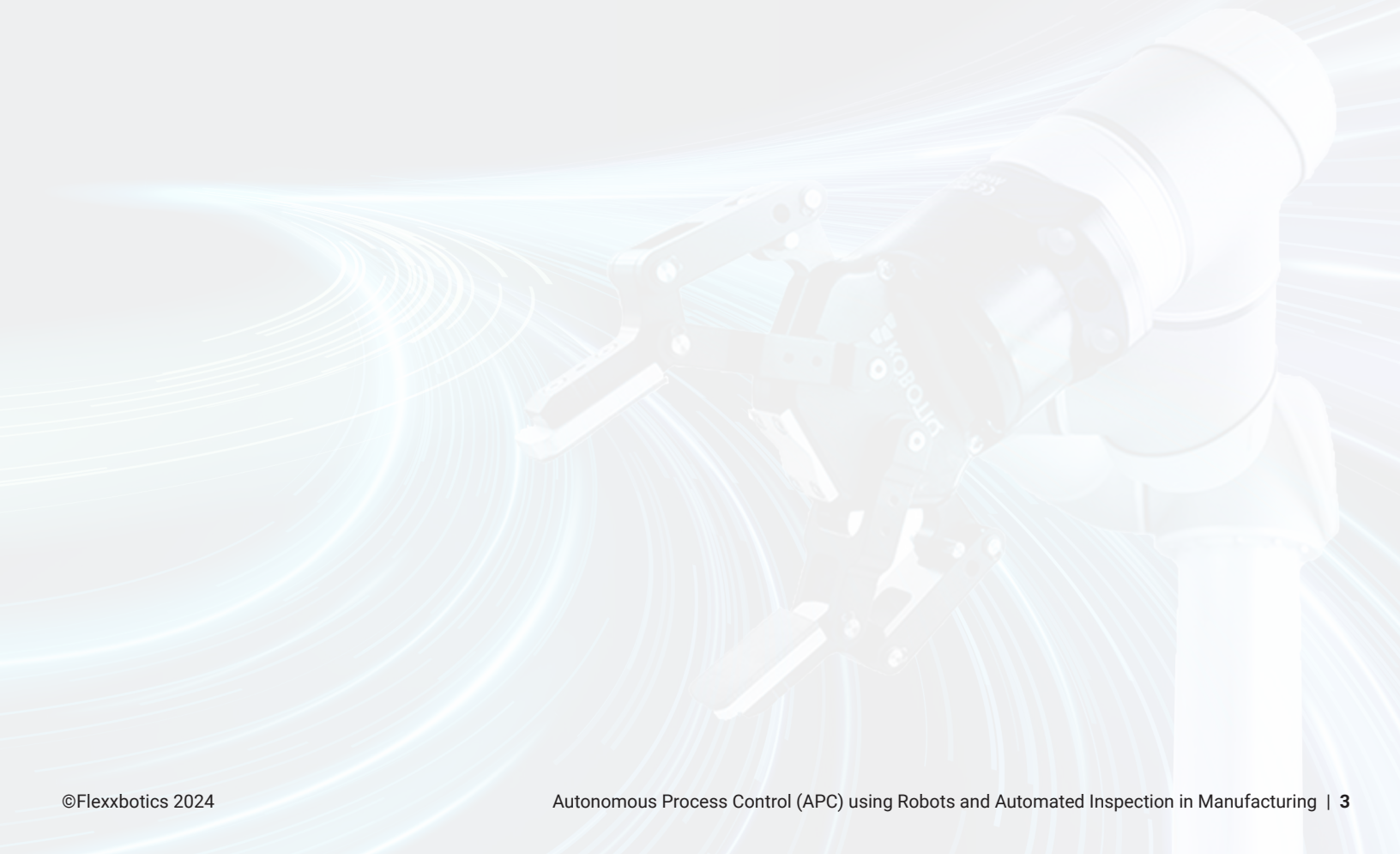
Contents

Executive Summary

Autonomous Process Control (APC) represents a transformative approach for manufacturing quality, leveraging robots and automated inspection technologies together to achieve repeatable, precision quality production without human intervention. This white paper details the approach of APC and the required technologies, emphasizing its critical role in modern manufacturing environments and regulated industries. Key benefits include improved quality, higher yields, and better margins with APC representing the foundational capability of fully autonomous manufacturing.



Introduction

Over the past several decades manufacturing has evolved significantly with advancements in production automation. The conventional factory automation approach is reliant on highly skilled engineers' and operators' involvement to maintain process capability. Today, factory automation is being transformed by standardized digital robotic production software solutions designed for increasing levels of autonomy in order to address the cost pressures associated with reshoring, supply chain restructuring, and labor shortages.

The purpose of this white paper is to explain the methodology and related technologies required for Autonomous Process Control (APC) in the context of production robotics, a pivotal technology for achieving autonomous manufacturing. By automating production processing adjustments based on real-time inspection results, APC aims to enhance precision, reduce waste, and improve the overall cost of quality, particularly in industries with stringent regulatory compliance. This document is for executives in quality and operations, as well as, personnel at all levels seeking to understand and implement APC in their factories worldwide.

Flexxbotics's ability to use the robot to coordinate multiple machines and have in-line inspection results automatically correct the machining operations is totally unique and was key for us."

John Mitchell
VP of Operations
Heckler & Koch USA

Problem Statement

Achieving consistent quality and yields are longstanding challenges in automation-intensive industries like automotive, electronics, and consumer goods and sectors with significant compliance requirements such as aerospace, defense, and life sciences. Numerous factors introduce variability into factory processes, which lead to inconsistencies in product quality and reduced production efficiency. The need for scalable, repeatable processes is more pressing than ever as manufacturing environments include increasing levels of automation complexity. Utilizing production robotics with autonomy both mitigates variability and also enables higher levels of precision and consistency for greater profitability.

Objectives

The primary objectives of APC are:

- Achieving Repeatable Production - Utilize robotic automation and digital robotic production software to assure consistent production
- Ensuring Precision Quality - Attain high levels of product quality without human intervention
- Improving Compliance & Traceability - Comprehensive data collection and revision tracking to provide digital thread traceability with quality records for compliance, especially important in regulated environments
- Increasing Yields and Improving Margins - Enhancing production yields and profit margins through optimized processes
- Enabling Autonomous Manufacturing - Achieving APC is the foundational prerequisite to fully autonomous manufacturing

Methodology & Technology Overview

What is Autonomous Process Control?

Autonomous Process Control (APC) refers to a methodology that would not be possible without modern robotics, machine-based inspections, and smart factory robotic production digitalization software. APC is the ability for robots to autonomously adjust production processes based on results from automated inspection technologies and other real-time data sources such as sensors. This type of closed-loop system enables continuous monitoring and proactive processing corrections, assuring consistently high-quality production output without human intervention.

Key technology components for APC include:

- Production robotics, both industrial robots and power & force-limiting robots, also known as collaborative robots
- Automated inspection technologies and other machine-readable feedback sources such as probes, sensors, vision systems, telecentric measurement equipment, coordinate measuring machines (CMMs), and others
- Standardized robotic production software solution with capabilities for:
  - Bi-directional communication and interoperability between the robots and all the different types of machines involved in the process or scenario
  - Coordinated orchestration of multiple robots, machines, and other types of factory equipment
  - Big data collection, storage and analysis to capture all inputs, calculated values, and output commands
  - Embedded Statistical Process Control (SPC) functionality with algorithmic calculation and decision-based logic
  - Ability to connect to existing IT business systems for synchronized operation in the smart factory

> “We’re particularly impressed with Flexxbotics compatibility with all makes and models of machines in our factory enabling us to roll out automation across our workcells quickly and efficiently.”
>
> Scott Kroeger
> President & CEO
> **Darmann Abrasive Products**

Why is APC Important?

APC is essential for enabling Industry 4.0 'lights out' manufacturing where operations continue indefinitely without human involvement. As automation levels increase in smart factories, the ability to produce high-quality products with autonomy becomes critical. Without consistent APC autonomous production is not feasible. Process control autonomy is the critical condition that must be achieved to attain autonomous manufacturing.

APC Implementation Steps

1 **Business Goals & Outcomes**
Identify the business case and objectives with desired business outcomes prior to undertaking any APC initiative.

2 **Quality Planning**
Define product's critical characteristics, tolerances, and compliance requirements with inspection & test control plan focused on in-process or in-line inspections.

3 **Processing Design**
Map processing inspection approaches and appropriate automated inspection technologies based on the type of inspection and accuracy required.

4 **Robotic Production Digitalization**
Configure robots, machines, inspection equipment, and standardized robotic production digitalization software solution for communication and orchestration of closed-loop processes.

5 **Validate & Optimize**
Perform first article inspection, verify APC control limits, establish APC processing requirements, and ramp production to volume making iterative adjustments.

NOTE: No prior data are required to implement APC and there is no AI training necessary to achieve APC.

> "Scalability was a key criteria in our selection process as we plan to roll-out the solution across more than 100 machines in our factory, which Flexxbotics makes possible."

William Hoose
Plant Manager
Engineered & Industrial Solutions

Implementation Guidelines

Requirements for Successful Implementation:

- Orient quality plans for in-process / in-line inspections and automated inspection technologies.
- Utilize a standardized, modern robotic production software solution such as Flexxbotics with bi-directional communication interoperability between robots, machines and inspection equipment.
- Establish real-time, closed-loop feedback from automated inspections to the robots to update the machines programmatically.

Best Practices

- Regularly calibrate inspection equipment to maintain accuracy.
- Monitor and adjust quality plan based on APC-enabled processing results.
- Perform periodic optimization reviews to identify APC processing improvements.

Common Pitfalls:

- Relying on final inspection for APC - instead of multiple in-process or in-line inspections - resulting in feedback loops that are too long for effective processing adjustments.
- Attempting to utilize multiple legacy IT systems to enable APC resulting in integration complexity and in-effective implementation.
- Creating custom system software that is unsustainable and cannot be extended to new machines, robots, or inspection equipment limiting factory flexibility.

> "Flexxbotics solution provides complete coordination of our robots with our CNC machines and inspection equipment for direct feedback and autonomous adjustments enabling 24/7 production."

Dustin Vinci
Engineering Manager
Ruland Manufacturing

Benefits & Advantages

APC provides a range of benefits, including:

- Greater Accuracy and Precision - APC reduces variability for improved consistency resulting in higher levels of quality.
- Defect Reduction - APC provides better nonconformance capture and avoidance to reduce defects by more than 30%.
- Yield Improvement - APC optimizes processing to increase production yields between 25-45% depending on the nature of the process.
- Improved Quality Control - Fewer bad part escapes resulting in greater control and compliance.
- Tighter Feedback Loops - Autonomous real-time process adjustments maintain quality specifications and standards.
- Reduced Scrap & Rework - Decreased amount of scrap and rework resulting in less material cost and value add waste.
- Lower Cost of Quality - Reduced cost of quality by 20% or more leading to higher profit margins.
- EBITDA Improvements - Improved earnings before interest, taxes, depreciation, and amortization (EBITDA) through lower manufacturing costs, higher productivity, and greater profit per part.

> “We are impressed with Flexxbotics’ autonomous process control using robots, and the ability to close-the-loop by alerting upstream and downstream workcells of quality problems based on automated inspection results which is quite unique.”

Brett Gopal
Senior Vice President of Operations
SpiTrex Orthopedics

APC Benefits Over Time

Immediate	Near-Term	Long-Term
Improved accuracy and precision	Determine level of process control and establish baseline	Make products with tight control limits at consistent quality levels
Robotic consistency reduces processing variability	Ability to make a process change and immediately measure impact	Minimize inspection points and types
Real-time nonconformance identification at the point of processing	Processing correction adjustments occur autonomously improving quality	More accurately specify to customers the process capability (Cpk)
Autonomous defect sorting and segregation	Defect reduction and nonconformance avoidance improve yield	Reduced final inspection while achieving higher yields
Quality data on parts vs tolerance limits	Continuous operation increases throughput capacity to specification	Reduced Cost of Quality (COQ) by greater than 20%
Reduction in scrap & rework	Improved profit per part	Improved EBITDA margins

Future Directions

- Continued advancement of inspection technologies for ever greater precision in measurements.
- Option to include advanced Machine Learning for automated APC algorithmic adjustment routines.
- Use Artificial Intelligence for adaptive APC algorithms to enable self-learning process control.

Conclusion

Autonomous Process Control (APC) is the necessary foundational capability for achieving autonomous manufacturing. By leveraging robots and automated inspection technologies that are all enabled by a standard robotic production digital software solution such as Flexxbotics, APC can achieve repeatable, precision-quality in production without human involvement. This white paper outlined the APC methodology, underlying technologies, and business benefits of the approach. Adoption of APC enables significant improvements in product quality, production yield, and corporate profitability providing a clear return on investment justification.

Manufacturing & quality executives are encouraged to explore and implement APC to stay competitive in increasingly automated smart factory environments. Steps to initiate an APC implementation include assessing current capabilities, investing in necessary technologies, and developing a strategic plan for roll-out and optimization.

Endnotes

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About Flexxbotics

Flexxbotics enables robot-driven manufacturing at scale. Flexxbotics solution digitalizes robotic production with autonomous process control for next generation smart factory environments. Flexxbotics breakthrough, the unique FlexxCORE™ technology, seamlessly connects and coordinates robots with existing automation equipment, IT systems and people. More powerful, flexible and open, Flexxbotics revolutionizes the use of robotics in complex production.

Visit **www.flexxbotics.com** to learn more and follow us on LinkedIn.