The Automated Future of Material Removal

Automation streamlines manufacturing challenges and keeps people safe.

Contents

Abstract

Automating a deburring or surface finishing application is a smart, responsible, and effective way to improve a manufacturing process. There is a serious need for the automation of manual material removal and deburring tasks to help improve employees' health, combat manufacturing labor shortages, and increase product consistency and quality. The historical roadblocks for automated material removal are melting away as return on investment gets faster, more integrators and manufacturers cultivate hands-on experience, and technology advances to make processes easier.

Robots that are less expensive and easier to use, along with a growing network of knowledgeable integrators and tool developers, creates abundant support and drive for automated surface finishing. State-of-the-art, application-specific, end-of-arm tooling helps users tackle more and more deburring and surface finishing operations while software integrated robotic technologies help implement the new end effectors.

Why is There an Industry Need to Automate?

Automation eliminates hazards.

Manual material removal processes are found in a variety of manufacturing settings, from casting foundries to fiberglass molding facilities. In all of these environments, manual material removal operations create hazards for employees that could be mitigated with the help of robots. Limiting exposure to these conditions ensures safety for employees and minimizes lost-time instances that compromise the total output of the facility. Working near large, heavy machinery with dangerously hot materials all day creates a hazardous work environment with the potential for physical injuries. People are not always vigilant; constant repetitive tasks like the strain of maneuvering a heavy grinder or the constant vibration of a die grinder or sander could lead to ergonomic injuries that are accidental as well as due to overuse.

Deburring processes also generate dust particles or small chips that contaminate the environment. Some materials, like aluminum dust, are combustible, while other debris like fiberglass and resins are harmful if inhaled. Increasing employees' distance from hazardous particles and decreasing frequency of interaction with these environments is the best practice. Automation removes the dangers associated with these arduous tasks and harsh work environments. Robots are designed for repetitive tasks in tough environments and often work in enclosed cells thus limiting the rest of the plant from exposure to hazardous materials, flying debris, and high speed tools.

Skilled manufacturing labor is hard to find.

Many factors contribute to the current labor shortage. Human labor is more expensive than ever, and dull, dangerous, dirty jobs, like material removal, are not attractive for job seekers, resulting in high turnover rates."This means it is a challenge to find people who want to do the work and even harder to keep them in those jobs for more than a few months.

As the workforce dwindles, manufacturing plants lose experienced workers who have amassed years of tribal knowledge. These losses affect overall output, plant productivity, training, and process efficiency. According to the National Association of Manufacturers' most recent outlook survey, "Attracting and retaining a quality workforce constitutes one of the top challenges facing the manufacturing industry."(The Manufacturing Institute, 2019)

Recent technological developments enable automated processes to deploy a wide variety of media from carbide burrs to sanding discs.

In addition to lack of interest from new job seekers, the older generation that has been doing these jobs for years are retiring faster than they can be replaced. This is due to the ageing demographic of the United States as a whole; according to The Aging of the Manufacturing Workforce: Challenges and Best Practices, "By 2035, for the first time in U.S. history, retirement-age Americans will outnumber Americans under 18." (The Manufacturing Institute, 2019)

For many plants, institutional knowledge gained by veteran employees gets lost in the turnover, and new employees do not receive the practical training they need to be successful. When faced with difficult work and inadequate training, these new hires quickly lose interest and move on, further widening the knowledge gap as plants struggle to fill open positions.

Manual material removal processes are plagued by quality inconsistencies.

Even when workers have years of experience and proper training, they make mistakes occasionally. Under the best conditions, dull and repetitive work will inevitably create variations in process quality. For example, recent studies have shown that 100% inspections have a huge margin of error and usually result in only 87% of parts inspected. (Harish, 2015) These variations are sometimes due to fatigue, injury, or other physical issues, but can be caused by subconscious decisions as well.

The work done on Monday morning might be executed methodically, without any haste or hurry. However, on Friday afternoon, when the plant feels pressure to deliver on their throughput goals, the work may be rushed or corners cut in an attempt to make up for any lost time during the week. This difference in quality is exaggerated with new or temporary employees. They are still learning and will perform with a variable quality as they learn how to deburr the part most effectively.

Implementing a repeatable automated process using a robot optimizes cycle times and increases output while maintaining quality. In automated material removal applications, training time is limited to the time it takes to program the equipment, and is only needed when a new part or process is introduced.

Automation can include the use of vision systems and process verification to better track quality and operate 'lights out', or without dependence on constant human supervision. The process consistency and quick ramp-up times achieved from automated applications help maintain quality and minimize downtime due to training or line changes.

Why You Can (and Should) Automate Material Removal Tasks

Flexible manufacturing operations are preferred.

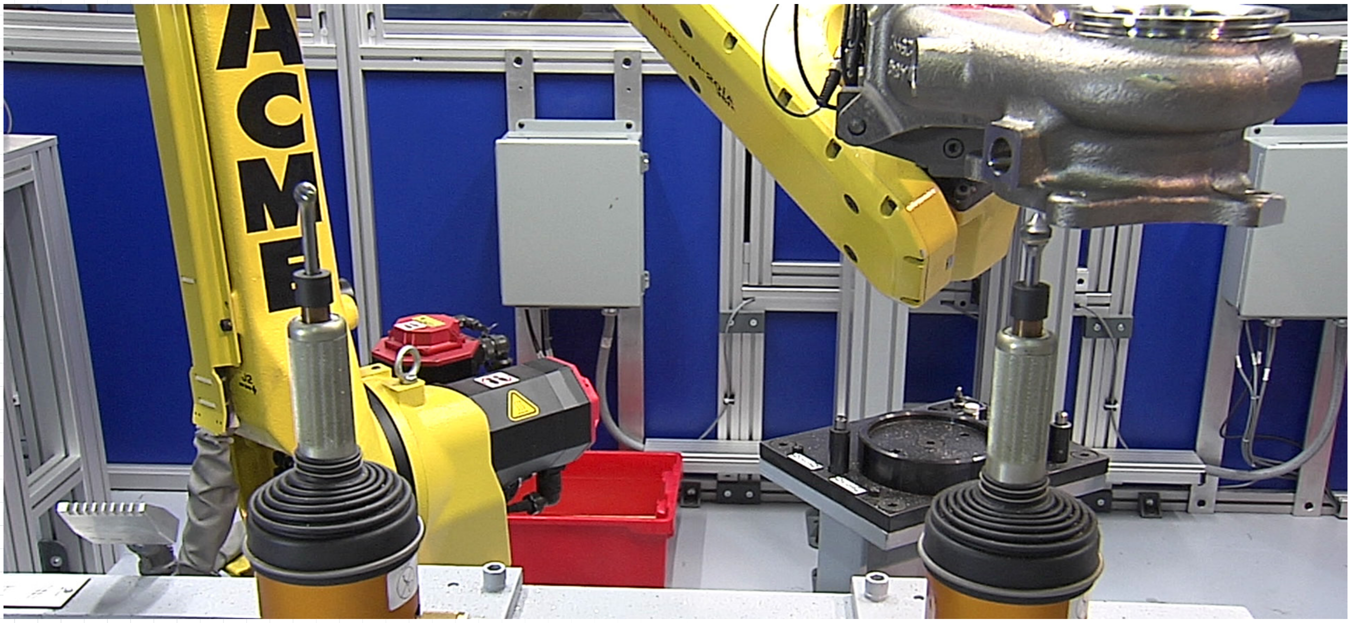
Automation allows for work to be done without the need for manual labor, using equipment that can often be repurposed. When you design a flexible robotic system, the robot is able to change its function by using a variety of different end-of-arm tools and programming parameters. This means when the current project or task is done the majority of the equipment can adapt to future projects.

Automation provides flexibility so that if a product line changes or is discontinued, the robot can be reprogrammed to perform new deburring tasks or other functions like material handling or machine tending. Robotic end-effectors like tool changers enable robots to use many different end-of-arm tools. Tool changers come in a wide range of sizes and have modules that allow utilities and communication to pass through.

Robots are often used as a machine tending device for a CNC machining center, but while the CNC is machining the parts, the robots sit idle. Instead of sitting idle for that portion of the cycle, the robot could be used in the deburring process; either by bringing a part to the deburring tools, or using a tool changer to swap from a gripping device to a material removal device to work process-to-part. The versatility of a robot combined with a multitude of end-of-arm tooling is how robotic systems optimize manufacturing processes.

Implementing automation is easier than ever.

Across the globe, sales of robotic systems are increasing each year. "The rapid expansion in robot installations is driven in part by the plummeting real costs of the machines. As with other advanced technologies, exponential growth in the processing power of microchips, extended battery lives, and the benefits of ever-larger, smarter networks have all dramatically increased the per-unit value of many technological components…"(Cooper, 2019)



ACME Manufacturing optimizes effeciency with large. heavy parts by using the robot to bring the part to multiple stationary deburring tools. The cell deburrs multiple part features in one cycle.

As the cost of robots and advanced technological equipment decreases, the cost of labor is increasing. In markets like China, cost margins of labor are low to begin with, and the country is experiencing cost increases of more than 65% since 2008. Under these circumstances, automation with robots is the most economical choice. (Cooper, 2019)

Robots are achieving ROI quicker than ever, often within two years or less. This improvement offsets up-front costs and allows manufacturers to direct future savings to the entire facility. (Robotics in Manufacturing, 2019)

Perception technologies, such as vision and laser profiling, are quickly becoming standard. These systems make robotic cells more flexible in their capabilities and help reduce costs by eliminating the need for expensive tooling to hold parts.

Expert material removal integrators lead the charge.

Historically, many integrators stayed away from deburring processes. Growth into the automated material removal market has been discouraged by perceptions that tolerances for parts are too stringent, unknown variables are numerous, and industry knowledge is too sparse.

Carl Doeksen, Global Automation and Robotics Leader at 3M, recently echoed these sentiments by saying, "Material removal applications have this negative perception that they are mysterious and overcomplicated. Welding was the same case, and people claimed that humans could do it better, and they could do it cheaper, they could do it faster. What happened? The advent of preconfigured robots enabled standardized systems and reduced integration risk." (Doeksen, 2019

Integrators such as ACME Manufacturing in Michigan, USA, and SHLAG in Germany have vast experience with automated deburring and are considered the world's leading experts in material removal systems integration.

iA-Robotics pioneers a robotic system for high-precision, automotive wheel deburring.

Innovations in Robotic Hardware and Software

There is an ever-growing variety of solutions available.

Deburring processes are complicated with unique challenges in every application. Current manual methods can require several types of manual deburring tools on a single part. Currently there are countless types of media to handle an infinite combination of geometries, materials, and deburring needs.. Because of this, the volume and variety of available tools designed for use with robots has increased substantially in recent years.

Implementation is not always simple as there are some factors to consider. Moving from manual to automated deburring with a rigid tool creates a multitude of problems for programmers. For example, when a person uses a rigid tool, they are able to make constant adjustments using all their senses. They can actually see the change in geometry, feel resistance from thicker flash, and hear the sound of the motor functioning. Together, these context clues help them determine when and if they achieve the ideal results.

A robot alone possesses no judgment or memory. It is not aware of its behavior and thus cannot verify or correct itself. Robotic and automated processes must use tools to overcome this disconnection.

Robots are very precise when repeating the same task over and over again, but their accuracy is limited. A buildup of inconsistencies in fixturing, burr size variability, part tolerances, and robot path estimations often leads to inaccuracies in tool paths compared to the actual parts. A rigid tool is not designed to comply with these changes and can gouge parts, stall motors, or miss the burr entirely resulting in an incomplete process.

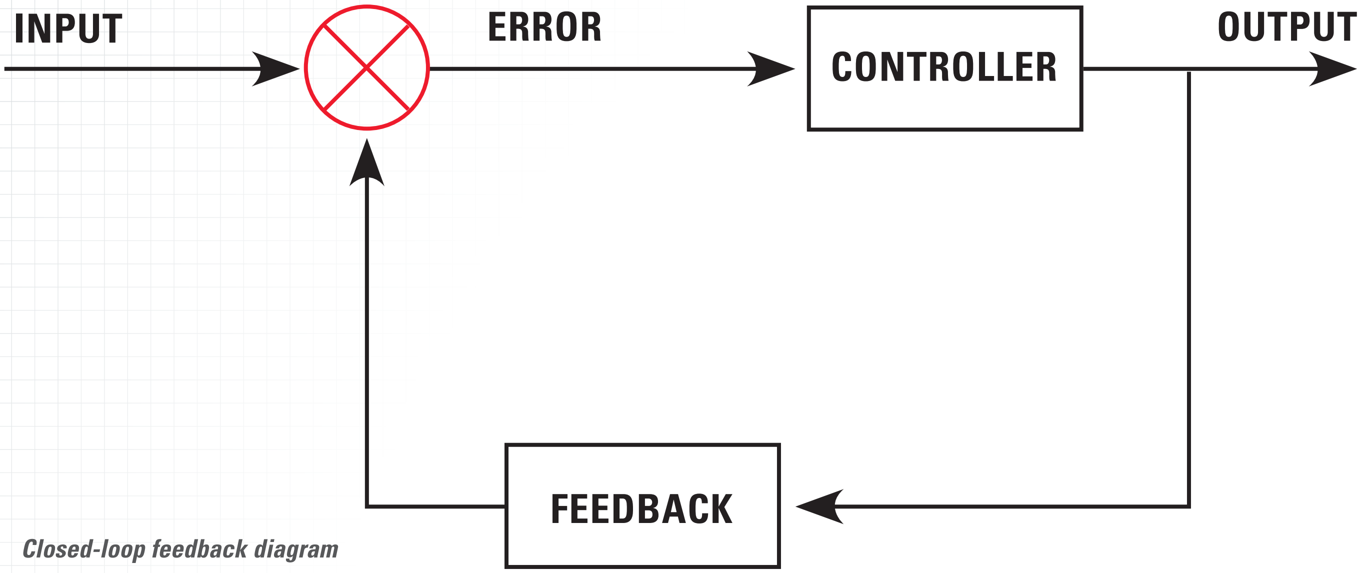
To successfully automate material removal tasks with robots, compliance is integral. Like a human using a rigid tool, integrated compliance allows the robot to adapt to changes in the part path in real-time. There are a wide variety of techniques and tools available to bring compliance into automated material removal processes.

Gouging and motor stalling can be overcome.

Compliance like anything else needs to be balanced to avoid damaging the work piece or stalling the equipment. There are two main methods of compliance: active and passive.

Active compliance uses a closed loop system where a force sensor monitors the force being applied by the tool compared to the desired force. This data is used to help adjust the theoretical path to the actual path needed to maintain that force. Using a multi-axis force and torque sensor gives an added benefit of measuring planarity as well as loads not in line with the wrist of the robot.

There are solutions to accomplish the active feedback loops needed for deburring applications at the heaviest and lightest ends the spectrum, but they are expensive and highly-technical. End-of-arm solutions for active force control like the Ferrobotics Active Orbital Kit, can detect and deflect to maintain a constant force without the need to control the much larger robot arm. These tools can produce near zero newtons of force, complying in both push and pull directions. Extreme applications like heavy grinding require powerful end-effectors, some are available that can produce up to 800 newtons.



Closed-loop feedback diagram

Most applications fall between the extremes and are satisfied with passive compliance, which uses air pressure to maintain a constant compliance force. These tools adjust the force by changing the air pressure by way of a regulator in the compliance pneumatic system. In an open-loop control system, the end effector reacts to the part, simply moving within its stroke without any feedback delay or complicated programming needed. This allows for instantaneous reaction without the latency of an a closed-loop, active compliance system.

Passive compliance is easier to integrate and less expensive than active compliance. ATI Industrial Automation's radially-compliant and axially-compliant products have passive compliance and generous stroke allowing them to satisfy a broad range of applications. A programmable regulator helps optimize processing for larger parts or parts with recurring areas of heavy burrs or flash. These systems are simpler to integrate and typically less expensive, but do not account for the accuracy and force extremes that active compliance does.

Process verification helps users close the loop.

Automating a material removal process works best with process verification systems which limit downtime and increase quality. Upstream processes, like wear of casting molds and CNC bit wear, lead to larger flash and burrs from machining. When using an abrasive media like a 3M Scotch-BriteTM unitized wheels, wear can occur and change the diameter of the wheel. With a rigid tool additional programming is needed to accommodate for these subtle changes. With a compliant system, the distance is automatically accounted for when the wear is within the stroke of the tool.

A manufacturing system that "checks itself" allows for longer periods of uninterrupted work while maintaining quality standards.

Tools like ATI's ACT-390, a passive device with built-in proximity sensors, allows the user to confirm that the stroke of the compliance is engaged.

It signals the system when the compliance has bottomed out and allows users to prevent issues such as further damage to the tool or a crash with the robot.

Another method of process verification is position sensing, which indicates whether the compliance is fully extended or bottomed out, and also tracks the position of the tool within its stroke. Using these and other methods for more precise media wear monitoring can help maximize efficiency of media and the process as a whole.

Plug-and-play solutions for cobots are emerging.

The value in robots is not in the replacement of people. Rather it is in the ability to utilize special human characteristics alongside automated technology to complete more complicated tasks such as those that need creativity or problem solving. It's possible that in order to meet cycle times or tolerances, an entire process cannot be automated. With the emergence of collaborative robots, people can work closer to automated processes and add value without compromising their safety. This allows for less time wasted with transportation, more efficient utilization of space, and for robots to do the repetitive, dull, dirty work. Cobot manufacturers are putting in the effort to create plug-and-play solutions that include everything the user needs to get started. There are deburring solutions that make collaborative robots simple to integrate, and safe and easy to use.

CAD to Path Programming streamlines the installation process.

CAD to Path Programming allows users to quickly teach robots. The Automated Manufacturing Research Facility (AMRF) was investigating this topic as far back as the 1980s. Of particular interest, were successful deburring applications using abrasive brushes on aluminum.

Newer research has led to software specifically designed for CAD to path deburring that further limits the amount of manual programming needed for each part. This has been aided by advancements in vision systems and force sensing technologies.

Research from the IEEE/ASME International Conference on Advanced Intelligent Mechatronics shows how robots can verify the location of the part using the CAD data and touch points, ensuring it correctly locates and follows its programmed path in relation to the part. Now, the compliant spindle only needs to accommodate for the variations in the burr size and thickness.

A vision system can also be used post-process to identify additional areas that need to be processed manually or as a preliminary process to scan for larger burrs or flash. Vision systems such as FANUC's IRVision image-to-path software can identify the part and features that need deburring without requiring the CAD data. This is beneficial as it eliminates some manual programming and allows the robot to generate the path as it sees it, instead of trying to adapt to an existing CAD path.

There are many reasons why you should automate material removal processes.

Manual labor is difficult and dangerous, making it hard to fill these jobs with reliable motivated employees. Advances in technology have led to the development of equipment and software specifically designed for robotic use. Robots themselves are becoming less expensive and easier to integrate.

Automated material removal does not have to be a complicated or risky undertaking. Experts like those at ATI Industrial Automation, 3M, FANUC, ACME, and other organizations are available to help make your journey easier.

Resources like 3M's CAM Center, ATI's Material Removal Testing Lab, and other facilities are dedicated to advancing material removal processes and helping customers develop automated solutions for their material removal needs.

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