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Role of Industrial Robots in Lean Manufacturing System

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ABSTRACT

Robots, if used correctly, can enhance a lean manufacturing environment. Robots offer speed and accuracy that can't be achieved with human labor. Robots can also reduce operating costs, reduce scrap – and are flexible for future changes. Few other manufacturing solutions can reduce waste as well as robots when designed into the system properly. Robotics' capabilities have only increased with time, while costs have continued to fall. Major robot manufacturers are constantly upgrading their robots with increased payload capacity, greater accuracy, increased reach and range of motion, improved speed and acceleration, faster communication with external equipment, better safety features, and lower operational costs.

Keywords: Robot, Lean System, Applications, Vision System

1. INTRODUCTION

An industrial robot is defined as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. Typical applications of robots include welding, painting, assembly, pick and place (such as packaging, palletizing and SMT), product inspection, and testing; all accomplished with high endurance, speed, and precision. The most commonly used robot configurations are articulated robots, SCARA robots, Delta robots and Cartesian coordinate robots, (aka gantry robots or x-y-z robots).

Traditionally, robots have not played a prominent role in the implementation of lean strategies. However, due to robots' repeatability, speed, accuracy and flexibility, the role of robots in lean implementations is constantly increasing. Automation equipment, which includes robots, is rapidly becoming a core component to lean manufacturing and the reduction of manufacturing costs.

Robotics has made it possible for manufacturers to vastly increase the scale of factory automation over the past three decades. With over 15,000 sold each year, industrial robots have become a mainstay of all sizes and types of manufacturing facilities. This increase in robotic automation has resulted in higher production rates, improved quality with decreased requirements for human intervention, while elevating the nature of work by removing people from dull, dirty & dangerous tasks. Adding robotic automation however, does not automatically make a manufacturing environment lean.

2. LEAN SYSTEMS AND ROBOTS

Automation systems with or without robots cannot be lean by themselves. Designing the manufacturing system to be lean is the challenge that is faced by engineers today. Some of the factors that need to be taken into account while designing a lean manufacturing system comprised of robots are:

- Flexibility required in the process
- Budget available for the entire system
- Human machine interface requirements
- Allowable scrap rate
- Life cycle of manufactured product to ensure acceptable ROI
- Line automation requirements (% Automation Vs Manual)
- Line production rate requirement
- Space availability for robotic operations
- Equipment reliability and downtime statistics
- Flexibility of process desired
- Product handling requirements
- Cycle time requirements by station or operation
- Human machine interface requirements
- Number of product variants
- Product handling requirements
- Maintenance requirements
- Conveyor and other transportation requirements
- Repair time of equipment

- Safety standards and ergonomics guidelines

Based on some or all of the above factors, robots could be an acceptable automation solution that adds value to the system. While small manufacturing systems can be easy to design with limited need for software based validation, larger systems involving multiple robots, tooling fixtures, humans, etc. need to be validated and optimized prior to system build to ensure that the robotic system behaves as predicted. One tool that is being used heavily in the robotic automation engineering business is robotic simulation software to validate robot reach, robot cycle times, robot motion paths and envelopes, robot positioning within the system. Using these simulation tools has helped make robotic systems lean in terms of design and manufacture.

Most importantly, the decision to use robots must be justified by an ROI (return on investment) analysis. Small and large manufacturers have proven today's robots can significantly improve the ROI in a manufacturing environment, especially when implementing robots in support of a lean initiative. The robots must be properly incorporated into the overall lean manufacturing environment to get the desired results.

3. APPLICATION OF ROBOTS IN LEAN SYSTEM

Material Handling and Machine Tending Applications
Prior to robots, material handling and machine tending were purely manual tasks. Operators would transport material from one fixture or machine to the next, wait on the equipment to finish its task, and then relocate the processed part(s) to another tool or process fixture. Several operators were usually required. These material handling and machine tending tasks are now almost always accomplished using robots, especially in operations requiring high speed and accuracy.
How do robots make the system lean?

- There is no wait time for operators. A material handling robot can be set up to multi-task, performing additional processing operations between operations.
- Robots have negligible downtime. Robots deliver a limited production loss compared to manual operations which tend to be error prone and inconsistent in terms of production rate, shifts, work breaks, etc.
- Robots are less expensive to operate, compared to human labor – especially when overtime is required. Robots' return on investment can be quickly realized when there is high demand for the manufactured product.
- Robots are capable of highly accurate, highly repeatable tasks, which results in lowered scrap parts once the robot tasks are optimized.
- Robots do not get fatigued and are not subject to heat, dust, humidity and other challenging work environments

4. MULTIPLE APPLICATIONS - ONE ROBOT

To incorporate robots into a lean manufacturing environment, engineers should look to process as many operations as possible within the given floor space. While standard off the shelf robots have one arm to which you can mount tooling, the advent of tool changers and dual equipment end-effectors design have helped make robotic operations more flexible and lean in terms of higher per cycle utilization. In the die cast industry, robots are commonly used for material handling parts as well as de-gating and finishing operations like deburring and grinding.

Robots in an automotive body shop are often used for material handling of parts as well as welding or sealant application. Robots that need to perform more than one function are built with tool changing equipment that can be used for robots to disengage/engage new end-effectors tooling. Servo motor driven external axes allow robots to be more flexible by acting as auxiliary axes of motion to ensure maximum robot utilization.

Advances in robotics have given engineers the flexibility they need to incorporate robotics into a lean manufacturing initiative. Robotics have furthered engineering's ability to optimize operations based on floor space, cycle time and feasibility constraints. Over time, multi-arm robots will become the norm, continuing the progression of manufacturing operations that are faster and leaner.

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5. ROBOTS AND VISION APPLICATIONS

Vision systems are being used in combination with robots to help inspect parts for feature existence and feature sizes. Vision technology and robots are a natural pairing and the combination has resulted in making robotic operations leaner than ever before. Vision systems are commonly used to allow robots to vary their motion targets based on vision generated guidance information.

Operations such as racking/ unracking of parts, part picking from bins, visual inspection of parts, which were normally handled by human operators, are now being performed by robots with higher consistency, accuracy, repeatability and speed due to vision systems used in conjunction with the robots. Finishing operations such as routering, grinding, sealing are now being applied more accurately with fewer imperfections and scrap parts thereby contributing solidly to Lean Manufacturing. In the inspection arena, robots are utilized heavily in Flexible Measurement Systems (FMS). Robots mounted with vision cameras to collect feature information for multiple inspection locations have resulted in a drastic reduction in the number of vision cameras and fixtures required to inspect parts. In the past, the same inspection would have been performed with several fixed vision cameras.

6. COOPERATIVE APPLICATIONS AND COORDINATED MOTION

Fixture tooling that is custom designed is part of almost all product manufacturing plants. In some cases where the assembly process allows for a slightly lower level of structural accuracy, robots can be used in place of hard tooling fixtures. Robots with docking end-effectors or "geo end-effectors" allow for reduced tooling content and greater flexibility while maintaining a significantly high degree of accuracy and strength. Many assembly operations like roof assembly in automotive assembly are being done with a robot firmly gripping the roof on the automobile while other robots perform welding operations to assemble the roof to the main auto body. Robots are also used for part transfer between assembly stations instead of transfer equipment like lift and carry systems or shuttles thereby adding to the flexibility of the system. The latest trend in robotics that is gaining acceptance as a lean process is coordinated motion. In this system, two or more robots are controlled by a single controller which allows for easy communication between robots to simultaneously perform coordinated operations on a single large part.

7. ROBOTS AND CYCLE TIME

Most manufacturing lines are processed at a high gross production rate while they run at a lower net production rate. While larger corporations can afford this expensive production rate safety factor, smaller manufacturing companies need lines that run almost at max capacity to control equipment costs. Preprocessing of robotic operations prior to system integration can go a long way towards controlling equipment costs. Cycle time analysis of robotic operations using simulation tools is critical to ensure that the system is lean.

Some of the common cycle time issues impacting lean manufacturing are:

- Lack of part inventory for robots causing delays in production
- Unsafe work conditions causing slow human operation in situations where robots and humans work in a cooperative environment
- Poor equipment design resulting in wasted repair efforts
- Bottlenecked stations causing part blocking or starvation at other stations
- Individual robots over cycle causing entire station to be over-cycle
- Wait times on other equipment causing robots to go over-cycle
- Poor processing resulting in work overload on robots, operators or machines
- Poor human machine interface causing delays in manufacturing
- Poor software and controls engineering resulting in inefficient I/O and communication between equipment

8. WORKPLACE SAFETY AND ROBOTS

One of the primary drivers to automate a process using robots is the safety factor. Most manufacturing operations have a degree of human injury risk. Some simple part transfer operations may be safe for humans to perform while others like unloading parts from a press/die or foundry operations with molten metal are definitely not fit for manual operations. In these cases, robots are invaluable in lowering risk to humans.

An unsafe workplace leads to fear-driven human inefficiency, lowered production rates, higher insurance and workmen's compensation costs, and high employee turnover. Conversely, a safe workplace boosts morale, increases employee retention and lowers costs, which ultimately improves the bottom line. And again, robots can significantly elevate the nature of work by removing people from dull, dirty & dangerous tasks.

Unsafe working environments can lead to waste in terms of effort and time. For instance, if a robot cell is not guarded properly, operators may take longer to service the station because of fear of injury. Ensuring that robotic operations are analyzed carefully for safety and the proper steps are taken to make the work cell safe is very important to make the system lean.

9. CONCLUSION

The above cases are just a few examples of how robots, if used correctly, can contribute to lean manufacturing. Robots help achieve higher production quality at a reduced operating cost compared to manual manufacturing. They help produce more parts with fewer defects using less equipment while maintaining their flexibility for future changes. Their capability is only increasing with time. Major robot manufacturers are regularly upgrading their robots with increased payload capacity, greater accuracy, increased reach and range of motion, speed and acceleration, faster communication with external equipment, better safety features, lower operational cost. The most significant impact to lean manufacturing related to robots lies in their ease of use. Programming robots to perform manufacturing operations has evolved into a easy to use PC based process that can be easily understood and applied by engineers as well as skilled trades at the plant floor, thereby helping make model updates, maintenance and robot process upkeep lean.

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