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Autonomation: The Future of Manufacturing

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Abstract

This paper discusses the autonomation process in terms of conversion from manual processes to the use of complex systems that not only automate the manufacturing process but also automatically monitor and control it. In light of the high initial investment for autonomation, this paper presents the long-term benefits of the ability of automated lines to do a type of self-diagnosis when a problem arises and either make a correction or prescribe a correction to human technicians. As a method of reducing defects and waste in many ways, autonomation is portrayed here as an important and effective tool of lean production that has seen great developments for better decision-making and more applications. This paper not only discusses the details of autonomation, also known as *jidoka* in Japanese, but also looks at common elements and ways for effective implementation in manufacturing systems today.

1. Introduction

Just as in the life cycle of humans, after the adolescent stage, there is the strong urge to be independent and move out of the family house, the same has been seen in the industrial world. The production and manufacturing industry has grown to the point where machines and processes are autonomous, requiring less human intervention. Machines want to be able to think for themselves and make their own corrections when possible.

The industrial world has seen a rapid change in manufacturing and production over the past years from the mould systems which produce single pieces at a time to modern manufacturing lines that produces mass volumes per day. The last time the world witnessed a revolution in manufacturing systems was in 1913 when the world came to Detroit to see Henry Ford's line [1]. Today, manufacturing has advanced, and industry has reached a point where products can be manufactured in production sequences that usually involve less or no human intervention from start to finish in a process called automation. Most often, automation is confused with autonomation, while automation is a function of autonomation. The latter cannot exist without the former. The term "autonomation" is a combination of autonomy and automation. It implies the independence of automation or allowing a process to be able to make its own decisions, thereby giving it a human touch. The autonomation process is a conversion from manual processes to the use of complex and often expensive manufacturing systems, presenting long-term benefits with the application of lean principles. This has been improved over the years to enable these automated lines to do a type of self-diagnosis when a problem arises. This self-diagnosis as a quality control measure among automated lines is what is commonly referred to as autonomation.

Table 1. Difference between automation and autonomation

Category	Automation	Autonomation
People	Manual processes become easier but still needs human supervision	Supervisors can multi-task and productivity improves
Machines	Machines complete cycle until stop button is activated	Machine detection of errors and correction is autonomous
Quality	Defects can be produced in mass quantities due to machine alfunction	Machine crashes are prevented by auto-stop, hence defects are avoided
Error and Diagnosis	Errors are discovered later and root cause analysis is long term	Errors are discovered and corrected quicker

Autonomation is a term commonly associated with Toyota, where early applications of this process were experimented and documented.

Taiichi Ohno's example at Toyota was the auto-activated loom of Sakichi Toyoda. This auto-activated loom immediately and automatically stopped the loom if any discrepancy was caused with lateral or vertical threads. This tool was called one pillar of the Toyota Production System by Taiichi Ohno, while Shigeo Shingo calls it pre-automation.

The autonomation process today has been essentially incorporated into machine design, allowing the machine to malfunction or stop during an unusual process. Modern applications of autonomation does not limit it to just the stopping of machines when they malfunction. It is rather a complete and clever approach to automation. Real autonomation includes a complete automation strategy, with series of steps to automate fabrication and assembly operations, as well as an approach to managing the daily interactions between humans and machines on a manufacturing shop floor. This is in line with modern lean principles of manufacturing that aim towards reduction of waste or elimination of anything that is not considered as adding value to the production process for which a customer is willing to pay.

Autonomation aids in excludes overproduction and considers the issues to confirm that it never reappears. This prevents the production of defective products and improves quality, during process review and improvement of design.

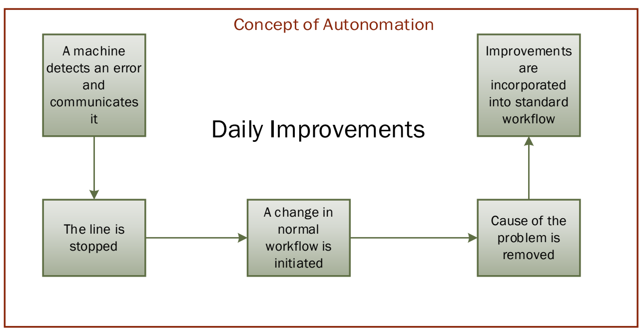

Fig. 1 Concept of autonomation

Common causes of defects are detected, investigated, and eliminated:

- Wrong operating techniques
- Unaccepted operation variation
- Raw material defects
- Machine or human error

From a production perspective, supervision has been integrated in the machine; human intervention only comes in when the problem cannot be self-rectified. This is integrated quality control, a necessary step in the design of the factory with a future as discussed in J. T. Black's book [1].

2. The Toyota Story

The autonomation idea was resulting from the development of the programmed weaver by Sakichi Toyoda, originator of the Toyota company. The programmed weaver is a mechanism that twists string for fabric and weaves materials naturally.

Before mechanized gadgets were ordinary, back-strap weavers, weaving machines, high-twist weaving machines used to physically weave fabric. In 1896, Sakichi Toyoda designed Japan's first controlled toward oneself weaver, the "Toyoda Power Loom." Subsequently, he joined various progressive developments into his weaving machines, the weft-breakage programmed halting gadget (which naturally ceased the weaving machine when a string breakage was distinguished), the twist supply gadget, and the programmed shuttle changer. At that point in 1924, Sakichi developed the world's first programmed weaver, called the "Sort G Toyoda Automatic Loom (with non-stop shuttle-change movement)," which could change shuttles without halting operation [3].

This essential thought upset the business where beforehand, rather than an administrator needing to sit adjacent to every machine, sitting tight and hunting down an issue, one administrator could now multi-errand by viewing a few machines and simply making a move when an issue happened, along these lines expanding quality and gainfulness.

Autonomation is the method that Toyota utilizes for its machines and an essential variable for its example of overcoming adversity today, as opposed to putting resources into enormous stone monument machines that can do everything except for take quite a while to set up and require to run gigantic groups, they put resources into little machines that do particular undertakings that people find troublesome or dreary and use autonomation standards to guarantee that the administrator just needs to interfere with the cycle if something happens.

At Toyota, each specialist has the power and the obligation to stop a whole line when an issue emerges. The intention is to bring regard for the issue, paying little mind to how little, and center exertion on it. This outcome in a changeless arrangement. It has been regular law at auto plants that a mechanical production system should never stop. At the point when Taiichi Ohno first advised administrators to stop the generation lines when an issue came up, they were incredulous.

Ohno recounts the tale of two administrators: one who took after requests and ceased the line quickly when inconvenience created and an alternate who was hesitant to stop the line. At first, the line that halted habitually had lower creation yield. A while later, the circumstance switched. The line that seldom ceased still had the same issues. These issues stalled benefit enhancements and made revamp that brought down aggregate proficiency. The line that at first saw regular stoppages general effectiveness had enhanced significantly and in the end had less creation stops [2].

3 Principles and Characteristics

The purpose of autonomation is the quick response, identification and correction of mistakes that occur in a process. Instead of waiting until the end of a production line to inspect a finished product, autonomation may be employed at early stages of the process to reduce the amount of work that is performed on a defective product.
Autonomation by guideline is a quality control handle that applies these four essential standards:

- *Detect the abnormality:* This involves placing detective mechanisms along the production line at critical points to identify mistakes in production or defects. Mechanical devices such as lasers, photoelectric tube, magnetic coils, etc. are used to identify discrepancies in physical properties such as weight, texture, shape, torque etc.

- *Stop the production sequence*: stop signals are activated after detection of any abnormality and this halts conveyor belts, transfer chains, connecting links etc. The entire production process does not really stop, depending on the process and stage at which the error was detected. Usually it is a specific sequence within the production stage that halts. The entire production line stops, however, if the error is likely to cause a chain reaction involving the other processes.

- *Fix or correct the immediate condition:* Alarm systems with blinking lights are activated when errors are detected in places where human intervention is required. Automated systems with self-correction devices send relay signals to a processor system for problem identification and sends feedback signals for rectification action to the machine.

- *Explore the main driver and introduce a countermeasure*: A review system is a critical function of autonomation and this involves, investigating past error incidences to identify what caused it and how to avoid such problems from recurring. It is a periodic and continuous process.

The autonomation concept was developed due to many reasons, most commonly

- Overproduction of merchandises
- Unproductive time during manufacturing at the machine
- Waste of time in transporting defective material
- Waste of time for imperfect part re-processing
- Inventory waste

4 Autonomation Application Examples

A few gadgets are otherwise called poka yoke gadgets or oversight sealing; these are basic thoughts that keep the formation of deformities and are all that much piece of autonomation. Illustrations are instruments, for example, sensors that enrol when all holding cinches on an apparatus are completely shut as a sign that all parts are stacked effectively. Formed installations that will just acknowledge the right introduction of parts, sticks in apparatuses that mate with gaps in segments keeping a labourer from fitting the wrong segments are basic illustrations of poka yoke.

Figure 2 demonstrates a basic loop feeder [5] that gives a nonstop source of steel pane to a robotized press stamping out segments, with no manifestation of autonomation sensor, an administrator would need to watch this to guarantee that the strain was right and that the steel has not run out. Basic sensors will caution the administrator if any issues happen and stop the press to avoid deformities being created or even harm to the press. This permits the administrator to multi-assignment and enhances benefit and value.

The stamping press nourishes segments through a little slide to load the following machine all the while, if that next machine stops for any reason, a sensor on the slide will demonstrate the fabricate up of additional parts on the slide and stop the stamping press promptly to avoid overproduction of parts that would flood the slide and conceivably cause jams and broad harm.

Different illustrations spread basic gadgets that measure the quantity of clasp that are fixed and the torques that are fixed; if the right torque is not arrived at or insufficient latches are fixed, the specialist can't move ahead onto the following methodology, along these lines highlighting the imperfection.

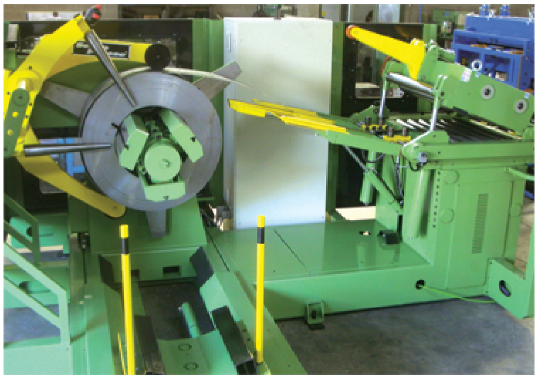

Fig.2 Coil feeder

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In the 1950s, 60s, and 70s, robotization depended on hand-off rationale and regularly obliged a human administrator to recognize blunders. This constrained the profits of computerization enormously. Indeed in the 1950s interlocks, for example, as far as possible switch delineated in Figure 3, were accessible. What varied at Toyota was the degree of their utilization. In the same way as other of Taiichi Ohno's systems, this is a basic thought that he sought after reliably for a considerable length of time until it turned into a vital upper hand and is being utilized broadly as a part of today's worldwide business.

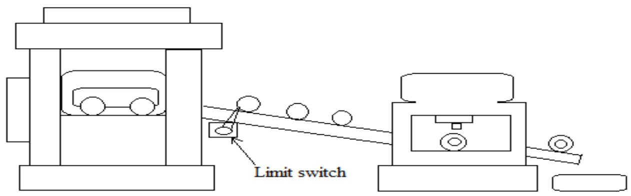

Fig. 3 Autonomation interlocks: a limit switch stops the process flow when the transfer conveyor has a specified number of pieces

5 Different Categories of Enterprise and Their Practical Use of Autonomation

The introduction and implementation of lean production principles, including autonomation, over the last 20 years has had a notable impact on many manufacturing enterprises. The practice shows that lean production methods and instruments are not equally applicable to large and small companies. After the implementation in large enterprises belonging to the automotive sector, the concept of lean thinking was introduced successfully in medium-sized enterprises.

Most of the instruments of lean production have their origin in large companies and are very suitable for this type of organization [4]. Certain methods of *jidoka* are only recommendable for large organizations, because the complexity and the effort for implementation are only realizable for firms with enough resources in sense of qualified personnel, time, and capital.

A manufacturer must therefore identify which category of enterprise best describes his company and analyze how suitable it is to implement autonomation. Small enterprises can start by automating their manual processes and then utilize basic forms of *poka yoke* as described earlier on and large firms can move on to more complicated applications of *jidoka*.

Most of the micro enterprises use *poka yoke* without knowing it, and this can be combined with automation of their manual processes to give autonomation. They, however, face challenges in the conversion, and this is explained below.

Table 2 contains feasibility studies conducted on lean methods, including autonomation, and their practical application in the various enterprise sizes.

Table 2. Cluster of lean production methods and their suitability for different enterprise size classes

Type	Lean Production Methods	Micro	Small	Medium	Large
MACHINERY AND EQUIPMENT	Basic automation	1	3	4	2
	Total Equipment Effectiveness	0	1	3	4
	Preventive Maintenance	1	2	4	4
	Setup Time Reduction	1	3	4	4
	Total Productive Maintenance	0	1	3	4
MATERIAL FLOW AND LAYOUT	Cellular Manufacturing	0	3	4	3
	First in first out (FIFO)	4	4	4	4
	One-piece-flow	0	1	3	4
	Simulation software	0	0	2	4
	Supply chain optimization	0	3	4	4
	Value Stream Mapping	0	3	4	4
	Work Station design	1	3	4	4
ORGANIZATION AND STAFF	5S	1	4	4	4
	Autonomous work groups	0	3	4	4
	Benchmarking	4	4	4	4
	Ideas Management	4	4	3	3
	Job Rotation	1	3	3	4
	Lean Administration	0	1	2	4
	Kaizen	2	4	4	4
	Standardization	2	3	4	4
O L	Just in Sequence	0	1	2	4

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	Just in Time	2	4	4	4
	Kanban	0	3	3	4
	Line balancing and Muda reduction	0	1	2	4
	Milkrun	0	1	2	4
	PPS Simulation software	0	0	2	4
	Economic lot size	0	2	4	4
	Visual Management	2	4	4	4
QUALITY	FMEA	0	0	2	4
	Poka Yoke	1	3	4	4
	Quality Circles	0	2	4	4
	Quality Function Deployment	0	0	2	4
	Six- Sigma	0	0	2	4
	Statistical Process Control (SPC)	0	1	4	4
	Supplier Development	0	1	3	4
	Total Quality Management	0	1	3	4
	Autonomation	0	4	2	4

Scale: unsuitable (0), less suitable (1), suitable (2), well suitable (3), very suitable (4)

6 Advantages of Autonomation

- *Increased quality:* More refined products are produced because quality inspection is removed from the final product stage to various points of production. The problem review and continuous improvement program ensures that less defectives are produced in the future.

- *Lower costs:* Problem correction at various stages of production reduces the amount of work that needs to be done on a defective product, thereby saving more money as compared to waiting until the final product is out before any correction is done at a complex stage. Autonomation eliminates the cost involved with full automation, which usually fails; the majority of the benefits can be obtained using simple, low-cost machines with the operator being responsible for several.

- *Improved customer service:* Both internal and external customers are satisfied since autonomation gives the internal customer more time to supervise rather than be correcting problems that are now done by the machine, or he is only alerted to an issue when needed rather than watching out for it. The external customer also purchases a product with superior quality and value for the money. It makes sense to customers even if they have to pay more for superior quality products.

- *Improved productivity:* The company using autonomation is able to increase production per shift since more work can be done in less time when the machines are correcting themselves. The workers are therefore used efficiently as they attend to the necessary issues when needed.

- *Reduced lead-time:* Autonomation eliminates wait time that was previously used to watch out for defectives and correct the final defective product, since this is done by the machines at various stages now. This allows more work to be done in less time. Products are therefore ready-made when the final product has no defectives to be worked on, and this is the ultimate aim of just-in-time production.

- *Reduction in equipment failure rate:* Since defectives are stopped instantly for correction, a machine only works within the scope it was designed to. Damages and losses from working on defective parts are eliminated and there is longer machine and tool life.

7 Challenges Regarding Implementation of Autonomation

- *High cost of implementation:* Autonomation is a cost intensive and continuous process that requires financial input to realise short and long-term benefits. A lot of companies agree and support autonomation but financing sometimes becomes a bottleneck

- *Misunderstanding of autonomation leads to misapplication:* A company must really understand that the principles of autonomation involves continuous improvement and means investing in automation to enhance human capability, rather than replacing it. Actual autonomation is centred on human-machine interactions.
- *Difficulty of small enterprises hiring qualified staff:* The lack in qualification and intellectual capital is a generally difficulty for small enterprises. Many firms suffer under the rising complexity that requires qualified persons in product development and manufacturing. For firms that are trying to introduce productivity improvement programs the presence of a

specialist or an industrial engineer seems to be critical. Because of the limited budget and the only moderate attractiveness for highly experienced engineers, many small firms hire young industrial engineers coming from the university or collaborate with external consultants.

When autonomation is discussed, there is a lot of uncertainty as to its rightful application. These are some of the reasons:

- The Japanese dialect, from which the steps were taken, appears to be less exact than English, and the few implications of jidoka don't interpret well.
- For chronicled reasons, the autonomation idea of yesterday appears to be less applicable today and more like customary great sense and practice.
- The line-stoppage version of *jidoka* is a bold decision that few managers are taking and those that are not still believe to be practicing it somehow.
- The original meaning of *jidoka* in its native Kanji, when translated to English is "automation."

8. Conclusions

The autonomation process, presents long-term benefits that make it worth the investment. It reduces the physical and mental load on workers. Autonomation is a critical part of lean assembling procedure for high-creation, low-assortment operations, especially where item life cycles are measured in years or decades. In high-mixture, low-volume circumstances, the time and exertion needed is not suggested as demonstrated in the venture table. This process of giving production system self-control is ongoing and should be adapted where possible to stay ahead in today's competitive global market.

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