PROCESS REFLECTIONS

Prerequisite to Digitalization of Production Line Management Systems

Previous process reflections have discussed time management including calculating cycle time efficiency, line stopping rules, and ***andon*** (行灯) systems. I noted that an ***andon*** may have two distinct signals with two unique responses which are used to indicate either an "out-of-control" production condition or a request for help by the workstation operator.

Furthermore, I described how the production team converges where this ***andon*** signal detection occurs to join the worker in rapidly investigating the issue and implementing an immediate corrective action. This coordinated ***kaizen*** (改善) approach returns the process to its standard work condition, hopefully within single-digit minutes. This reaction occurs by applying the principle of a "second set of eyes" or **jishuken** (自主権) to diagnose the trouble and immediately resolve it.

How does ***jishuken*** work? Each operator is monitored by a ***mizusumashi*** (漢字) or water spider. This person is an experienced line worker who is in training to become a supervisor and has responsibility for monitoring daily work activity. They can also intercede when an anomaly is detected. For more difficult issues, colleagues on the production line can join along with the supervisor to cooperate in the resolution of a troubling issue within the takt time of the production line plus the allocated distance for product travel within the workstation.

In addition, each operator constantly pursues a personal kaizen journey by pursuing ***jishu kanri*** (自主管理), a self-directed management system to become accomplished as a specialist in performing their work and inspecting the quality of work that is accomplished at the preceding workstation. This principle of source inspection and receiving inspection is embedded at each workstation in the sequence of production

This process reflection describes how a nihon-teki (日的) or Japanese style production system is designed and how it works to gain a quick reaction to improvement that does not delay finding and fixing problems.

Building a Sense of Urgency into Productive Systems

The supervisor's job is to train workers and whenever workers do not or cannot follow standard work then supervisors must urgently take immediate corrective action (***imadesho*** (今) meaning 'do it right now' or 'immediately'). Its purpose is take action to re-establish standard work. Therefore, whenever an **andon** signals any kind of process disruption, or other-than-normal- production, then it is a call to act immediately to do something.

Each workstation is designed so that work is performed in small, well-defined steps that are simple to accomplish and readily understood. This simplicity also means that workers are capable of understanding what can go wrong as their tasks are designed and structured in a logical way so each movement is crisp and straight-forward. Thus, avoiding chaos is a critical design rule for organizing productive work. This should not be a surprise to anyone who has studied Japanese production management systems and is familiar with how a 3-S activity is built into each day's work.

After management has determined the production plan for the day, it is communicated by the Supervisor who initiates the workers' acts of ***Seiri-Seiton*** (整理 – 整頓). This command tells workers to eliminate chaos at the start of the day by organizing work that needs to be done and making tools and equipment immediately available to perform this work. Work will progress by following the established ***kata*** (方) or established 'way of doing,' emphasizing the method or form and order of the standard daily work process. Work proceeds throughout the day and at the end of their shift the workers perform ***seisou*** (清掃) or clean up their workstation and return it to the original condition, so it is ready for the next day to start again. However, ***seisou*** is more than just tidying up the workstation.

In Japanese ***katazuke*** (片付け) is common sense housekeeping, or 'tidying up.' When setting up the ***seisou*** activity it may begin as a ***katazuke*** activity in the daily management process. However, the way to control production in the factory management system is much more involved than just surface cleanliness. It requires 'tidying the data' and 'kaizen activities' in collaborative teamwork as well as ordering the physical activities. ***Seisou*** is the first step in establishing Total Productive Maintenance (TPM) to manage and control plant equipment in productive systems. ***Seisou***, also can occur at deeper levels depending on the nature of the production system and may include ***jishu hozen*** (自主保全) or activities of self-directed (AKA autonomous) maintenance (preservation, conservation, or integrity) which is performed on a routine basis as standard operator work. These ***jishu hozen*** activities include ***seisou*** as well as inspection, lubrication, and tightening or tuning production apparatus. Thus, the prerequisite of the 3-S system in daily requires prior development of work standards as well as knowledge of the equipment requirements and means to avoid potential failure or degradation mechanisms. So, 3-S is not the starting point to develop control of daily production processes; developing the work standard and pursuing Single-Minute Exchange of Dies (SMED) for changeover help to get the production operation in a state of control where order may be achieved through 3-S. This process is supplemented by a focused improvement process called ***kobetsu kaizen*** (個別改善) which is part of ***seiketsu*** (清潔) or purification of production by a process of making immaculate or sanitary production equipment – this is a deeper cleaning that is required in the planned maintenance activity of TPM.

Koichi Kimura reported the following conversation: [1]

Shigeo Shingo: "***Seiri***, ***Seiton***, and ***Seisou*** are important to maintain the factory, isn't it true?"

Taiichi Ohno: "Yes, keeping the factory in the condition of ***Seiketsu*** is essential for factory management."

Shitsuke (躾), the final step in a 5-S process occurs when work is performed "without being told what to do" by a supervisor. This occurs because Toyota designs production systems using the principle of ***ji kotei kanketsu*** (JKK) (自工程完結) which assigns ownership of the production operations, so workers are given responsibility for performing and improving standard work. In order to manage self-directed work, there must be standard performance measures to indicate how the process is operating. These Key Performance Indicators (KPIs) must be established and agreed upon by management as part of the standard work procedures required for control. All flows must be synchronized in standard work: materials, production process, and work orders.

To assure process control capability there must be adequate quality in materials, quality of production process, and ability to maintain control using KPIs that respond to feedback.

Making a Diligent Effort at Workplace Control

The starting point in developing a factory control system is improving process reliability, production capability and capacity, and ***gemba-ryoku*** (現場努力) meaning to make a 'diligent effort' in the workplace. This approach does not follow a simple process of adding a new tool or applying a new method. It cannot be done by a single project or even a collection of projects; it requires a diligent effort as part of the organizational infrastructure to effect and control work at an improved level of capability and capacity with high quality.

Developing a well-managed productive system is more than implementing methods and tools like 5-S and ***kanban***, it requires inculcating the mindset for simplification, standardization, and waste reduction that fosters consistent quality. This approach requires increasing capability in productive systems, capacity in potential output, as well as quality of results produced. This effort needs to be more than a project, it needs to become systematic. To maintain any new system or to stabilize production as ***gemba-ryoku*** requires, is more difficult than executing a project as projects must only be managed over a short period of time. Workplace discipline requires dedicated effort over the long term which means that there must be some permanent structure to assure the continuing effort. To improve both organization-wide as well as ***gemba*** capacity, designing work around a committee structure is superior to a project structure which is only good for a short, limited time effort. ***Jishu kanri*** relies upon both JKK as well as support by a consensus committee system to assure that kaizen activities become structural and do not just rely on individual efforts. This subject will be addressed in a subsequent process reflection.

Intelligent Design of Productive Capacity

The development of a productive system that consistently delivers desired throughput of a high quality, operates within cost targets, while minimizing hazardous potential risks to those employed in the system, does not happen without design. The development of such a system of production is one of the fundamental foundations of the Toyota Production System (TPS) that is called ***Jidoka*** (自働化) or intelligent automation. ***Jidoka*** occurs through the engineering of the productive system. It requires thorough knowledge of all elements of production including the process of data collection and processing. In such a production process if an abnormal situation occurs, then embedded sensors are triggered so the machine detects the condition and stops to prevent escalation of the problem. This action automates the stoppage of a production line. In this case, ***jidoka*** should be considered a quality control process. ***Jidoka*** operations are designed using four principles – two principles relate to the machine design and two to human response:

1. *Detect Abnormal Condition*. This capability requires that the right sensors be designed for the system and that the desired limits of performance have been established with "trigger-point" settings identified for issuing operator warnings or machine stop orders.
2. *Stop the Production*. To perform this action requires that a diagnostic feedback loop be established which is linked to a process control actuator that enables the stop setting. In current production systems this may be enabled through a "weak Artificial Intelligence" algorithm using machine learning logic.
3. *Correct the Immediate Condition*. This activity is beyond the capability of a ***jidoka*** device and requires immediate response by workers who have knowledge of potential failure as well as the appropriate corrective actions that rectify this situation. These actions can not be investigated from a root cause but rather through comparison to the known set of potential failure conditions that has been designed into the equipment and its ***jidoka*** alerting system which triggers the ***andon***.
4. *Investigate the Root Cause and Install a Countermeasure*. This act requires collaborative action by all production operators, the line supervisor, and the maintenance team that supports the TPM process. In-depth understanding of the equipment and material at an engineering level of detail may be required to analyze production data and to possess an ability to make changes to the equipment. While most large corporations may have such capability as an internal expertise, this may be beyond the ability of the M-SME (micro-to-small-to-medium-enterprise). No matter how this final step is managed, this must be included within the design of the jidoka system so that rapid turnaround and a permanent correction may be installed as part of a more comprehensive system that is engineered as ***poka-yoke*** (ポカヨケ) devices in design of a mistake-proofing process.[2]

Automation in a ***jidoka*** system aims at preventing production of defective products, eliminating overproduction, and focusing worker attention on understanding problems and ensuring that they do not reoccur. This system was designed in a electro-mechanical era, before the advent of digital technologies (e.g., the Internet of Things (IoT), robotic process controls, and Artificial

Intelligence (AI)). Developing an advanced technology approach to design of a modern system for ***jidoka*** follows four steps:

1. *Designing the Data Collection System*: Automate data gathering from distributed sensors that are embedded in each process at control points where a feedback mechanism can be activated as a control signal to adjust process performance.
2. *Collecting Real-time Data*: Develop the real-time data gathering capability including its internal transmission to a local data historian for processing and analysis.
3. *Developing Predictive Analytics to Estimate Potential Problems*: Evaluate the stream of data to develop predictive estimates which foretell signs of impending machine troubles.
4. *Applying Adaptive Learning for Diagnostic Feedback and Control*: Establish control loops to transmit process adjustment signals to online robotic controllers that adjust process operating parameters to improve quality of performance based on the data and the AI diagnostic analysis.

Implementing a Production System with *Jidoka* and *Andon*

How is a ***jidoka*** realized and how will it be integrated with the ***andon*** signaling system in a digital Quality 4.0 application? The key objectives of any productive system is to deliver quality output in an efficient manner, at a desirable rate, cost-effectively. When examining assembly line work in light of these objectives, the impact of a line stop is evident. Stopping all workers in the line to correct an individual cause of a process problem is very costly from the perspective of financial impacts from productivity loss. Thus, the productive system should be designed so that one worker's problem does not create a significant working delay. Thus, the objective for a corrective action process must not only include the resumption of standard work, but it should also include the minimization of lost production time. As a result, the TPS manufacturing design accounts for the potential line stop abnormality through its ***jidoka*** and ***andon*** systems.

The components of an assembly line ***jidoka*** system consists of four elements. The first is the system that alternatively supports either a human or digital detection system that acts to initiate the diagnostic system which generates data for the feedback corrective action loop. This includes the ***andon*** *cord and* ***andon*** *signal*. The cord is the physical device that an operator will pull to activate the ***andon*** signal. This signal may also be activated by remote access after an out-of-control condition or unusual circumstance is detected by remote process monitor devices. ***Andon*** signals may include differing color lights to indicate unique conditions in the detected deviation (e.g., material flow, equipment, quality, or safety issue). The second part of this system is the *line leader management system*. The normal management system assigns to each of the workers responsibility for the quality of the work that they perform. Additionally, a real-time auditor (the water spider) monitors the work to assure they are following standard work procedures. The line supervisor is responsible for the quality of the flow of work including assignment of tasks, restructuring workloads, and balancing assembly throughput to assure a smooth, streamlined flow of work. The supervisor is also a trainer for the workers and facilitator of improvements that are either recommended or suggested by workers or those action plans imposed by engineering management. Included in this system is the activity of the worker who manages the third part of the system – the *self-check inspection system*. This is also known as "Zero QC," self-inspection responsibility is assigned to each worker to inspect the incoming quality of partially assembled products and to check the quality and standard-compliance of their own work. Operators are trained to understand the statistical controls that are appropriate for their work and know how to read, interpret, and respond to changes in the KPI indicators that tell about the current state of process performance. The last component of this design is the *fixed-position stop device*. It is not enough to merely develop an assembly procedure for a workstation, the entire related work activity must be designed to assure quality. To achieve this holistic approach to work, Toyota developed this concept of a "fixed-position stop device" as a critical ingredient in the reaction process to an adverse ***andon*** signal.

Toyota industrial engineers design each workstation with both material buffers to manage the flow of parts and production buffers to manage the flow of products. The production flow includes a system of "Fixed-Position Stop Devices" that enable corrective action to be done in real-time without impacting production through a full line stoppage. Upon detection of a work delay or quality problem, the worker pulls the ***andon*** cord and calls help (or the system initiates the ***andon*** signal in the event of a system detection). At this time, the production conveyer does not stop immediately. It permits the work in progress (WIP) to proceed a certain distance on the line until the conveyor stops reaches a fixed position. During the time while the conveyor is moving to that position, most cases of the alert are resolved with the support of the line leader. If this condition is a one-off situation and it cannot be resolved, the line leader may have an option to keep the production line flowing and to remove that one product from the production line. At the end of the shift corrective action will be completed and that product will be corrected afterwards. This option is not available in all production lines and other rules may be built into the line to keep up throughput flow as long as product quality is not compromised.

Actions taken in this time by a line leader include coordination of QRQC (Quick Reaction Quality Control) and QRKA (Quick Reaction Kaizen Activity) to fix the situation ***imadesho***. Thus, self-check inspection and next process confirmation inspection are core components of Daily Management and operate within the SDCA (Standardize-Do-Check-Act) cycle. The line leader is seeking “fresh information” that indicates the out-of-control condition – typically this is data or information that was not in the standard data collection system and then the line leader needs to make an informed “nearest assumption” as to the cause. The “nearest assumption” is based on the baseline data, new perceptions, and experiential judgment to determine what is the most likely condition from the limited set of failure modes that could occur at that point in the production process.

Quality Circles are formed using the in-tact production teams working together in cells. The teams use the QRQC process to detect the “nearest condition’ that matches symptoms of the problem that has occurred and apply the QRKA process to identify the “nearest assumption” that rectifies this cause. However, if the system is switched from a manual human-centric way of responding to an engineered system using IoT-embedded sensors and adaptive machine learning, then the corrective action process can be totally automated for all failure conditions which are capable of mapping. But it is not reasonable to install all possible devices to detect all of the potential signals that might impact a particular production process. So, even though the time is coming in which IoT combined with embedded sensors and AI methods are operating, there will still be a need for QRQC and QRKA to be embedded in the concept of jidoka as it is applied to the human aspects of productive processes.

One of the design rules that is built into TPS is to maintain takt time and flow rates so their coordination in a synchronized flow of materials with the work order schedule is harmonized with the combined activities of production worker-machine are not operated at a pace that is too high to enable recovery from out-of-control conditions. Essential elements of production to achieve this outcome are maintaining low variety of production items, managing the flow one item at a time, designing the changeover time for rapid production using SMED, and then coupling this with human activities for source inspection, next process re-inspection, and finally using the “nearest condition-nearest assumption” methods of QRQC and QRKA to enable the countermeasures for disruption while applying kaizen activities to improve Lead Time efficiency.

References:

1. Email on the subject of 5-S from Koichi Kimura, Factory Management Institute, 20 June 2020 (see further: 5S Concept – FMI (factorymanagementinstitute.com)).

2. ***Poka-yoke*** is derived from ***poka o yokeru*** (ポカを除ける), a term that is used in both ***shogi*** (将棋) (a Japanese board game that is related to chess and generally referred to as "the general's game") and ***igo*** (囲碁) (the abstract strategy board game of Go which is an ancient oriental game that originated in China and is called "the encircling game") that refers to avoiding an "unthinkably bad move."

3. Koichi Kimura (2018), *Total Preventive Maintenance (TPM)*, volumes 1-3 (Tokyo: Factory Management Institute).

Reflective Questions:

1. Taiichi commented that "the lowly work standards" are the foundation of the TPS. How do the work standards operate with the engineering design of a production line? What is the role of the operator in each of these dimensions?

2. Examine this system to compare the roles of engineers, workers, line leads, and supervisors to the equivalent roles in your organization. How are they different? Compare and contrast these differences. What is able to be learned from this study?

Lesson to be Learned:

Developing automated or "digitized" production systems requires engineering a whole system of material flows, production throughput, order management, data and information flows, and the human activities that enable the system. Engineering the system requires building profound knowledge of all aspects of its design and operation.

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