Implementation of an Automated OEE Scada System on a New Manufacturing Line

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Abstract – *A need for capturing performance for a manufacturing line was fulfilled by implementing an Overall Equipment Effectiveness (OEE) automated system in a manufacturing line. To successfully implement the system, it was important to understand the OEE metric and use the necessary Lean tools [such as PQPR (Product Quality Process Routings], Standard Work, and Daily Management) to characterize and optimize the implementation. An easy-to-use system was successfully implemented, delivering historical data collection, providing performance health indicators, and highlighting improvement opportunities for the manufacturing line. Additionally, integration into existing Daily Management practices was undertaken to ensure consistent monitoring cadence. The process taken to implement the system is captured in this research.*

Key Terms *— availability, daily management, Overall Equipment Effectiveness (OEE), performance, product quality process routing (PQPR), standard work, quality*

PROBLEM STATEMENT

A new manufacturing line is to be introduced in a manufacturing company. The manufacturing cell is composed of equipment designed to surpass current operational performance. This equipment also represents a new manufacturing method introduction that can present its challenge as Standard Work and line support are yet to be defined and optimized. The equipment development department, responsible for the development and commissioning of said equipment, has a need to measure and optimize the manufacturing line performance with the purpose of properly identifying continuous improvement opportunities. The Overall Equipment Effectiveness (OEE) metric can serve such purpose. The main goal is to identify and implement action plans focused on tackling equipment performance rates, top downtime reasons, and repeated quality non-conformances. Although these elements are captured in existing daily management practices in other lines, data accuracy and labor-intensive efforts to compile (manually) the required data are a big challenge. Using an automated OEE Supervisory Control and Data Acquisition (SCADA) system is intended to provide on-demand accurate OEE measures of the newly introduced manufacturing line.

Research Description

This research is being performed to provide a tool that can provide clear insight into prioritizing issues worth addressing based on data-driven analysis of a manufacturing line performance. The focus is on implementing a robust and reliable OEE data gathering system along with the standard work and sustainment measures to maintain its relevance. As with any change, engaging management, and the involved personnel on the value-added aspects of this implementation is a key to success.

Research Objectives

The objective of the research is to fully understand the requirements needed to automate the data gathering of the elements of a manufacturing line OEE metric. After completion of this research, it is expected to have a customized system able to capture the line's actual failure modes and doing so with ease to the operators involved in the interaction with the system. The goal of this research is to first understand the baseline OEE of the line. Secondly, to provide ranked improvement opportunities enabling correct prioritization. Thirdly, and most importantly, provide a means of immediate impact verification through the OEE metric after improvements have been made.

Research Contributions

The expected contribution of this research is to deliver a proven system of performance optimization for a manufacturing process. Automating the data gathering of the OEE will prove beneficial to the Operations and Supporting teams. By automating this process, efforts and focus can be redirected toward identifying proper solutions to opportunities rather than spending time on manual data collection and compilation. The PDCA (Plan Do Check Act) cycle, which is key to a continuous improvement culture, is enabled by the system. It provides the necessary tools to validate the effectiveness of the improvements made. Once proven successful, this method can be deployed to other manufacturing lines within the manufacturing site.

LITERATURE REVIEW

Overall Equipment Effectiveness (OEE) is a measuring instrument first introduced by Seiichi Nakajima as part of the Total Productive Maintenance (TPM) concept [1]. OEE quantifies how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run [2]. OEE is composed of the product of three indicators: Availability, Capacity of Performance, and Quality (1).

$$OEE = Availabity \times Performance \times Quality \quad (1)$$

These elements isolate the six big losses as per Nigasaki: equipment failure, setup and adjustment, minor stoppages, reduced speed, defects in the process, and reduced yields [3].

The ideal, absolute effective machine should be able to run continuously with maximum (design) speed without producing defective product [1].

Run Continuously (Availability)

Availability or operating rate (2) is based on the ratio of the actual operation time, excluding downtimes, to the available time the equipment is planned to be running [3].

$$Availabity = \frac{operation\ \ time}{available\ \ time} \quad (2)$$

Losses due to availability are those periods in which the equipment was available for production, but no product was manufactured. These losses can be categorized as disturbances (equipment malfunction), idle time, and line limitations (e.g. resources not available) [1].

Design Speed (Performance)

Performance or operating speed rate (3) refers to the discrepancies between the ideal speed to which an equipment is designed to operate and the actual operating speed (3).

$$Performance = \frac{actual\ \ output}{ideal\ \ output} \quad (3)$$

While under the availability metric focus is on equipment uptime, performance metric is focused on identifying if the equipment is running at adequate speed during said uptime. The two types of losses related to performance are minor stoppages and reduced speed [1].

Without Producing Defective Product (Quality)

As explained before, OEE components seek to isolate the big losses pertinently. When looking into the performance metric, no distinction is made between good or defective product. The quality metric (4) focuses on the rate of good product versus total product produced.

$$Quality = \frac{faultless\ \ product}{actual\ \ output} \quad (4)$$

Quality losses are reflected in either defective products (scrap) or in products that are not faultless right away (rework) [1].

The OEE is primarily used as tool for the manufacturing sector to create awareness and responsibility. It is about helping the production team to get a better insight into existing losses. For this purpose, visual aids have proven to be effective. Every diagram should give a good overview and should facilitate information reception with colored lines. A well-structured, standardized OEE activity board, among others, with a Pareto analysis of the losses, the development of the OEE in the last month and the last 24 hours, and a plan of measures is, therefore, indispensable [1].

Data Collection

Manual Data collection has always been a challenge for OEE calculation. As expressed by Nagasaki, time workers spend recording data might be considered a waste and time not spent in operational procedure [3]. Data accuracy is also in question when relying on manual data gathering. For this reason, an automated OEE system which requires minimum interaction from the operators and provides on-demand calculations as needed will be deployed. For this purpose, a Vorne^{TM} XL system will be installed on the manufacturing line.

Vorne Industries, Inc. is a company dedicated to providing productivity enhancements for manufacturing companies since 1970 [4]. Vorne XL is a comprehensive production monitoring platform that includes:

- **XL Productivity Appliance^{TM}:** IoT (Internet of things) devices that each monitor one manufacturing process. XL devices work as networked devices in your internal network.
- **XL Enterprise:** A cloud-based application developed by Vorne that provides services that extend the XL platform. These services include alerts (real-time email alerts), reports (automatically delivered end-of-shift reports), and updates (software updates delivered to XL devices) (figure 1) [5]. Vorne^{TM} XL OEE monitoring system offers easy to install machine interaction sensors to collect machine status directly from the equipment. With the use of a barcode scanner, operator interactions are simple and fast to provide downtime reasons and yield information [6].

Figure 1
Vorne^{TM} XL Board [5]

METHODOLOGY

Process Characterization and Installation

The first step in this research is to understand and characterize the process. The OEE system will need to have accurate signals that represent the right status of the manufacturing cell (such as running, stopped, part count, etc.). A product quantity process routing (PQPR) analysis will be performed to outline routing variations and determine where would be the right machine to retrieve the signals from. Each of the product's routings will also be assessed to determine ideal rates for each of the product configurations. While equipment design speeds will be the primary source for ideal rates, cycle studies using Standard Work Combination Sheets will be performed to confirm ideal rates.

The other aspect to characterize, related to the Availability metric, is the downtime reasons associated with the process. It is important to have downtime reasons that are specific and relevant to the process so that the retrieved reports have meaningful information. For this purpose, existing process downtime reasons will be initially loaded into the system and refined along the implementation of the system.

The third aspect to consider is how non-conformances are to be categorized and input into the system. It will be sought to integrate the existing Non-Conforming Quality system with the Vorne system to eliminate duplicate efforts from the associates.

Once the established prerequisites have been performed, the system will be installed and commissioned (this includes training the associates involved in the manufacturing process).

Daily Management Integration

Alongside the system implementation, daily management practices (reports, metrics, data gathering) will be assessed to determine how the integration of the new system can merge with existing practices. The existing process consists of an SQDIP (Safety, Quality, Delivery, Inventory, and Productivity) daily management meeting at the manufacturing line, usually 5 to 10 minutes per line. Rather than adding additional metrics and extending meeting discussions, it is meant to consolidate and complement existing metrics in scope with automated reports from the system. A Standard Work Kaizen on Daily Management for the specific line will be carried out for this purpose.

RESULTS AND DISCUSSION

The first decision to be made was regarding where the display board was to be installed. It needed to be appealing and obvious, as it would be presenting real-time status of the line. It also needed to serve as an Andon (visual alert) signal obvious to supporting departments when a problem arises in the line. A location above the manufacturing cell facing the main walkway of the shop floor served the purpose (figure 2).

Figure 2
Installed board

As part of the process characterization, a PQPR was performed to understand product variation and optimize placing of the tracking signals to implement. It was important to identify common processes and bottlenecks to have an accurate tracking of part counts, cycle time and downtime occurrences. The system automatically accounts for downtime if no part count signals occur beyond the established (programmed) cycle time. It was also important to map the process to understand where non-conformances were generated to implement scrap reporting near the point of use.

Based on the PQPR analysis (table 1), it was concluded that the end capping process served a common process within all variations. Therefore, drawings from the end capping machine were analyzed to understand where the signals were to be taken from.

Table 1
PQPR analysis

ITEM	MATERIAL ISSUE	CORRUGATION	SIDE SEAL (A)	SIDE SEAL (B)	PACK GUILLOTINE	PACK CUT OFF	SERIALIZING	FORMING	END CAPPING (A)	WETTING	REVERSE BUBBLE	FORWARD FLOW	FLUSH POT
SCY51000DFLP	X	X	X	X	X	X	X	X	X	X	X		X
MCY4463DFLPH4ST SF	X	X	X	X	X	X	X	X	X	X	X		X
SCY51000DJLP	X	X	X	X	X	X	X	X	X	X	X		X
SCY51000DFLP-DIT	X	X	X	X	X	X	X	X	X	X	X		X
AB05DFLP	X	X	X	X	X	X	X	X	X	X	X		X
SCY51000DJLP-DIT	X	X	X		X	X	X	X	X	X	X	X	X
SCY51000UUA S/F	X	X	X		X	X	X	X	X	X	X		X
SCY51000DBW	X	X	X	X	X	X	X	X	X	X	X	X	X
SCY51000DV20	X	X	X		X	X	X	X	X	X	X	X	X

The end capping step proved to be the bottleneck process; therefore, a downtime tracking station (figure 3) was installed next to the end capping station. This station also served as a batch setup station to initialize different product configurations. This is needed to accurately determine performance as cycle time varies from product to product.

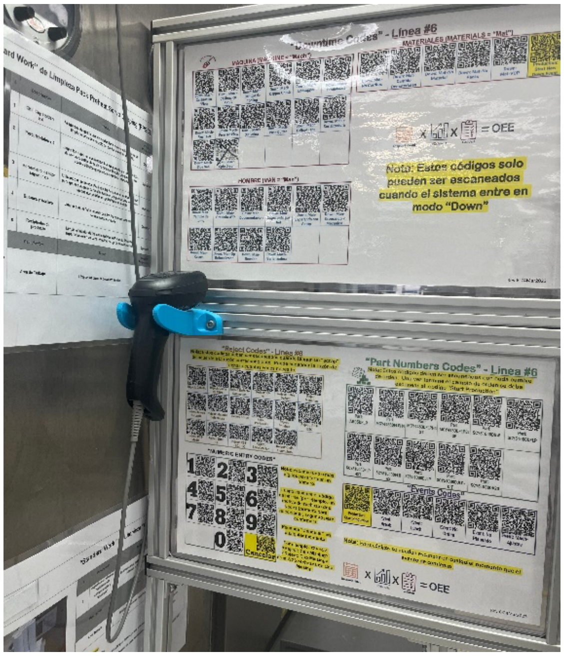


Figure 3
Tracking station

It was also found that the integrity testing process was predominantly the step where non-conformance was detected. A non-conformance station was placed by the integrity testing equipment.

Once all installation was completed, it was time to program all product variants, downtime reasons and reject reasons into the system. A workshop was carried out involving line operators to capture the requirements (figure 4).

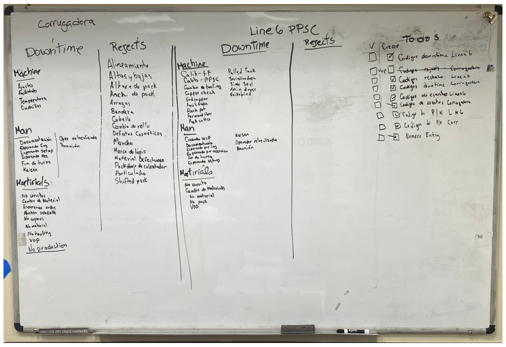
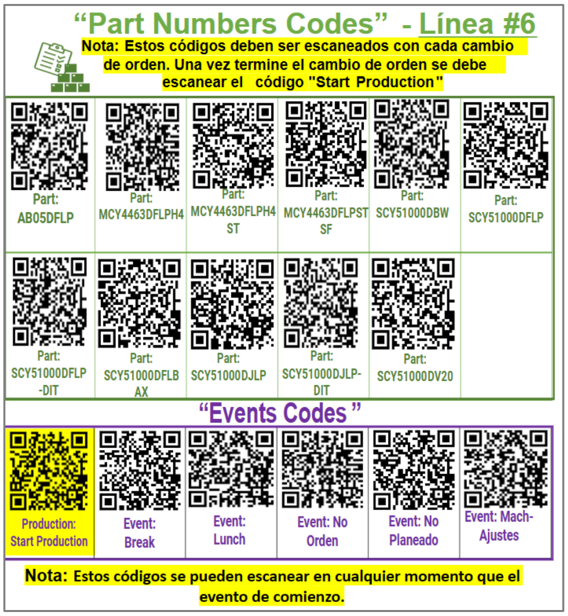


Figure 4
Brainstorming workshop

Part numbers were created along with cycle information (ideal cycle time allowances for recording downtime, etc.). A part number selection print (figure 5) was done with barcodes for the operator to scan from. Special events needing to be entered (such as lunch break, no orders, etc.) were also added to the printout.



"Part Numbers Codes" - Línea #6

Nota: Estos códigos deben ser escaneados con cada cambio de orden. Una vez termine el cambio de orden se debe escanear el código "Start Production"

Part: AB05DFLP	Part: MCY4463DFLPH4	Part: MCY4463DFLPH4ST	Part: MCY4463DFLPSTSF	Part: SCY51000DBW	Part: SCY51000DFLP
Part: SCY51000DFLP-DIT	Part: SCY51000DFLBAX	Part: SCY51000DJLP	Part: SCY51000DJLP-DIT	Part: SCY51000DV20	

"Events Codes"

Production: Start Production	Event: Break	Event: Lunch	Event: No Orden	Event: No Planeado	Event: Mach-Ajustes

Nota: Estos códigos se pueden escanear en cualquier momento que el evento de comienzo.

Figure 5
Part number codes printout

Similar printout was performed for downtime and reject codes (figures 6 and 7).

“Downtime Codes” - Línea #6

MAQUINA (MACHINE = “Mach”)

	Down: Mach-Calibracion FFlow	Down: Mach-Calibracion PPSC	Down: Mach-Cambio de Tooling	Down: Mach-Capper Check	Down: Mach-Endcapper
Down: Mach-Facilidades	Down: Mach-Flush Pot	Down: Mach-Forward Flow	Down: Mach-Guillotina	Down: Mach-Pack Cutter	Down: Mach-Pallsol Tank
Down: Mach-Serializadora	Down: Mach-Side Seal	Down: Mach-Spin Dryer			

HOMBRE (MAN = “Man”)

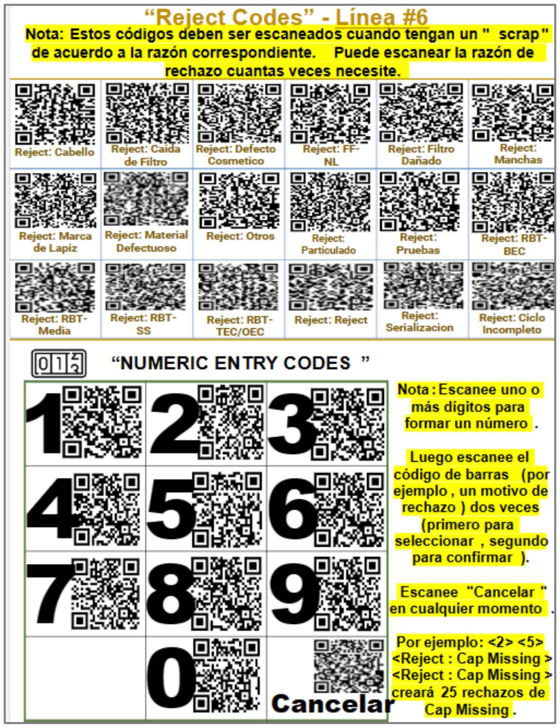
Down: Man-Cambio de turno	Down: Man-Creando WIP	Down: Man-Documentacion	Down: Man-Esperando por Ing	Down: Man-Esperando por Setup	Down: Man-Esperando x Mecanico
Down: Man-Kaizen	Down: Man-Op Relocalizado	Down: Man-Reunion	Down: Mach-Serializadora		

MATERIALES (MATERIALS = “Mat”)

Down: Mat-No Carritos	Down: Mat-Cambio Demateriales	Down: Mat-No Material	Down: Mat-No Packs	Down: Mat-VOP	Production: Start New Down Event

Figure 6

Downtime codes printout



“Reject Codes” - Línea #6

Nota: Estos códigos deben ser escaneados cuando tengan un " scrap" de acuerdo a la razón correspondiente. Puede escanear la razón de rechazo cuantas veces necesite.

Reject: Cabello	Reject: Caida de Filtro	Reject: Defecto Cosmetico	Reject: FF-NL	Reject: Filtro Dañado	Reject: Manchas
Reject: Marca de Lapiz	Reject: Material Defectuoso	Reject: Otros	Reject: Particulado	Reject: Pruebas	Reject: RBT-BEC
Reject: RBT-Media	Reject: RBT-SS	Reject: RBT-TEC/OEC	Reject: Reject	Reject: Serializacion	Reject: Ciclo Incompleto

“NUMERIC ENTRY CODES ”

1	2	3
4	5	6
7	8	9
	0	Cancelar

Nota : Escanee uno o más dígitos para formar un número .

Luego escanee el código de barras (por ejemplo , un motivo de rechazo) dos veces (primero para seleccionar , segundo para confirmar).

Escanee "Cancelar " en cualquier momento .

Por ejemplo: <2> <5> <Reject : Cap Missing > <Reject : Cap Missing > creará 25 rechazos de Cap Missing .

Figure 7

Reject codes printout

Operators were then trained in the correct use of the system and the needed interactions. As originally stated, the intention was to substitute manual tracking, so no additional tasks were introduced in the process. Instead of manual entries of scrap, output, and downtime into the Hourly Scorecard, the required interactions automated the data collection required.

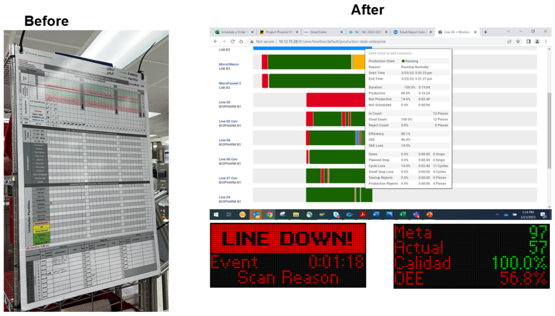


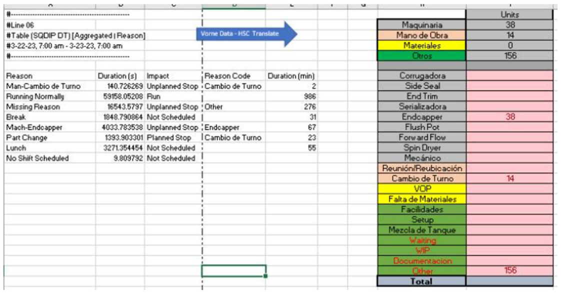
Figure 9

Hourly scorecard before and after

The last step regarded incorporating the data into the Daily Management practices. A Microsoft Excel automated script (table 2) was created to match the existing format.

Table 2

Excel Ssript



#---
#Line 06
#Table (SQDIP DT) [Aggregated | Reason]
#3-22-23, 7:00 am - 3-23-23, 7:00 am
#---

Vorne Data - HSC Translate

Reason	Duration (s)	Impact	Reason Code	Duration (min)
Man-Cambio de Turno	140.726269	Unplanned Stop	Cambio de Turno	2
Running Normally	59158.05208	Run		986
Missing Reason	16543.5797	Unplanned Stop	Other	276
Break	1848.790864	Not Scheduled		31
Mach-Endcapper	4033.783538	Unplanned Stop	Endcapper	67
Part Change	1393.903301	Planned Stop	Cambio de Turno	23
Lunch	3271.354454	Not Scheduled		55
No Shift Scheduled	9.809792	Not Scheduled		

	Units
Maquinaria	38
Mano de Obra	14
Materiales	0
Otros	156
Corrugadora	
Side Seal	
End Trim	
Serializadora	
Endcapper	38
Flush Pot	
Forward Flow	
Spin Dryer	
Mecánico	
Reunión/Reubicación	
Cambio de Turno	14
VOP	
Falta de Materiales	
Facilidades	
Setup	
Mezcla de Tanque	
Waiting	
WIP	
Documentacion	
Other	156
Total	

CONCLUSION

The OEE system implementation was performed successfully. During the piloting phase, manual entries (such as output, scrap, and downtime reasons) were compared to the automated generated data and were found to be equivalent. Operators’ interactions were reduced from an average of 5 minutes per hour to 3.5 minutes per hour, a 30% reduction. SQDIP daily management meeting preparation was also reduced as manual data entry from the Hourly Scorecards into the SQDIP form was no longer required. After a few weeks passed and the system used provided more accurate data, a baseline average OEE calculation of 68% (72% Availability, 98% Performance, and 96% Quality) for the new line was established. Although this OEE is far from ideal, the key deliverable from the implementation was to provide accurate OEE data and it was successfully achieved.

The next step for this implementation is to establish a process to translate captured deficiencies into improvement initiatives using the PDCA tool. It is meant for the Operations team to lead this effort as the OEE metric owner. Downtime reasons, Scrap and Rework failure modes are to be Pareto (automated report) to establish prioritization on issues to target. A project funnel for each of the contributing teams is to be defined from the opportunities. As the initiatives are active, the PDCA methodology will be used to track the status and, later, the improvement achieved. As improvements are proven, the bar goes higher.

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