DATA ANALYTICS THROUGH FAILURE CODE TRIGGER AND MULTI-LEVEL SCORECARD

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ABSTRACT

This paper tackles the use of data automation and analysis, using Vigilance Analytics (VA), in the manufacturing process of Balanced Armature (BA) drivers. Achieving optimum performance in BA drivers require meticulous attention to detail, and suitable data analysis tools are essential for managing the process effectively and meeting growth objectives. Manual handling of the exponential growth of data can lead to errors and delays, making data automation a practical solution that streamlines processes, enhances accuracy, and saves time.

With the current complex set-up and manufacturing flow for Knowles BA drivers, traditional approaches struggle with data inaccuracy and longer lead time of problem-solving, resulting in increased Yield excursions. This led the team to develop data analytics through Failure Code Trigger and Multi-Level Scorecard inside VA which would provide valuable insights from big data, enabling engineers to address yield problems more efficiently and effectively. This improved the existing data analytics framework. This approach promotes innovation and success in continually improving Financial Yield. The analytical tools are designed to be flexible and can be easily applied for future line expansions.

1.0 INTRODUCTION

The product of Knowles Electronics Philippines are Balanced Armature (BA) drivers which utilize the principle of electromagnetic induction that converts electrical signals into sound waves. The product functions using an electronic signal causing varying magnetic field in the coil to vibrate an armature (reed) that is balanced between two magnets. The motion of the balanced armature is transferred to a very stiff aluminum diaphragm through a tiny drive rod that connects both parts. This diaphragm then produces the sound waves which the user hears. See Figure 1 for the construction of Balanced Armature (BA) drivers.

The balanced armature is a crucial component in various audio and medical devices, necessitating precision engineering during its manufacturing process.

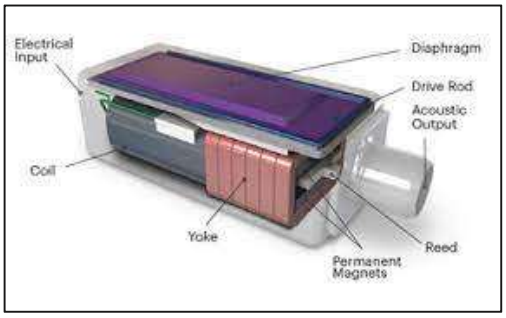


Figure 1. Balanced Armature Driver

Knowles BA manufacturing process is a complex set-up comprising of different business units and each business units are considered key factors in the production of excellent balanced armatures. Refer to Figure 2 for the Knowles BA manufacturing process flow.

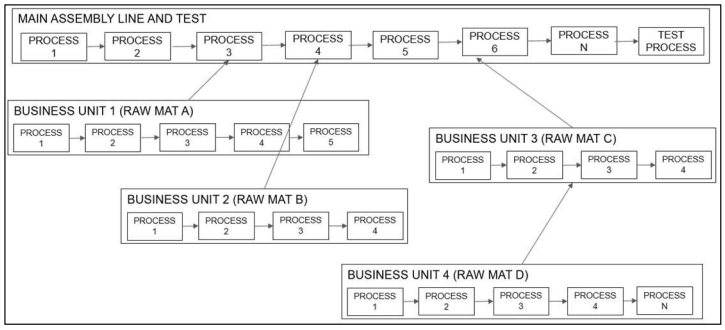


Figure 2. Knowles Balanced Armature Process Flow

Traditional approach of problem solving rely on manual data generation requiring more data processing time and the accuracy of analysis results are affected by data processing errors. This areas of concern lead to suboptimal production results and increased production costs. In response, a web

based tool that is capable to describe and diagnose a problem was crafted we call Vigilance Analytics designed to revolutionize balanced armature manufacturing.

This paper presents two of the recently developed tools inside Vigilance Analytics --- the Multi-Level Scorecard and the Test Failure Code Trigger (see Figure 3).

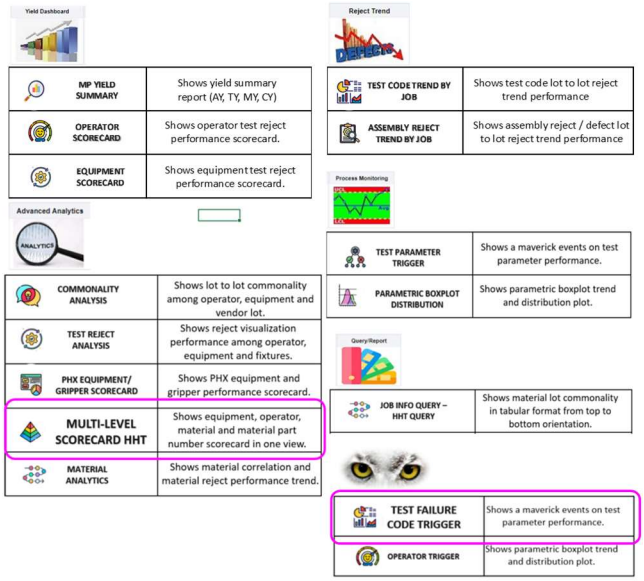


Figure 3. Vigilance Analytics Capability

The Multi-Level Scorecard feature analyzes problems by identifying the commonality in terms of Man, Machine, and Material across multiple processes involved in various business units.

The Test Failure Code Trigger feature aims to logically identify drifts in failure rate trends which would then trigger abnormality handling.

This paper will outline the development of these tools in terms of data collection, preprocessing, analysis techniques, and reporting mechanisms.

2.0 REVIEW OF RELATED WORK

The following concepts in data automation and analytics were explored in this study:

2.1 Extract, Transform, Load (ETL)

ETL is the main concept used for data processing and automation. Data from various sources are collected, transformed, and loaded into a data storage system. It is a fundamental process in data integration and business intelligence workflows.

2.2 Data Modeling

Data Modeling simplified the process of understanding the whole data and software system and how it flows through diagrams or blueprint of data elements represented using text and symbols.

2.3 General Concept Use

This general concept of analytics, according to Robert D. Peng and Elizabeth Matsui,, employs the notion of *What we did is not a specific "formula" for Data Analysis but to apply the method and run the test.* The concept is applicable on a variety of situations.

2.4 Multiplication Rule[2]

The multiplication rule is a way to find the probability of two events happening at the same time. The specific multiplication rule, P(A and B) = P(A) * P(B) was used specific for this Vigilance Analytics tool.

This technique allows to calculate the probability of the joint occurrence of two or more independent events

3.0 METHODOLOGY

3.1 Data Collection and Preprocessing

The manufacturing production line utilizes CAMSTAR as its Manufacturing Execution System (MES) tool, effectively monitoring data related to Man, Machine, Material, and process time at the lot level. This data is stored within the CAMSTAR Database. On the other hand, the testing system uses a custom-made testing software with data stored in the Test Database. To enable seamless communication between these two distinct software systems, the team has developed CAMSTAR Utilities, an Application Programming Interface (API) tool that facilitates data exchange.

Figure 4 presents the Data Model of the existing Vigilance Analytics system, offering an overview of the data collection sources and the system as a whole. It also illustrates the implementation of multiple ETL processes, which handle data extraction from various sources and transfer it to the VA Database located on the Big Data server. This ensures smooth integration and effective data management for the analytics platform.

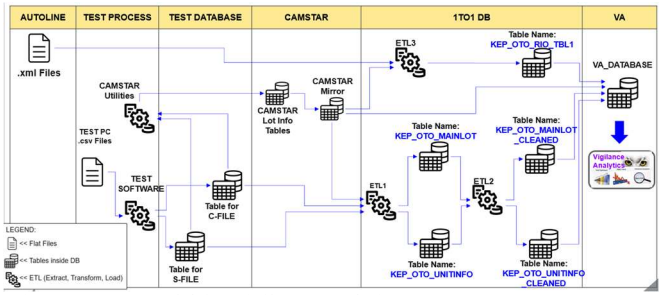


Figure 4: Data Model for Vigilance Analytics (VA)

For Vigilance Analytics, the Extract-Transform-Load (ETL) technique is employed.

3.2 Data Analysis and Analytical Flow

3.2.1 Multi-level Scorecard

The intricate manufacturing design necessitates collaboration among multiple business units, each responsible for producing specific raw materials required for balanced armature production. The main assembly line integrates these diverse raw materials from different units (refer to Figure 5). Handling the enormous amount of data and the process complexity demands substantial server bandwidth for result generation.

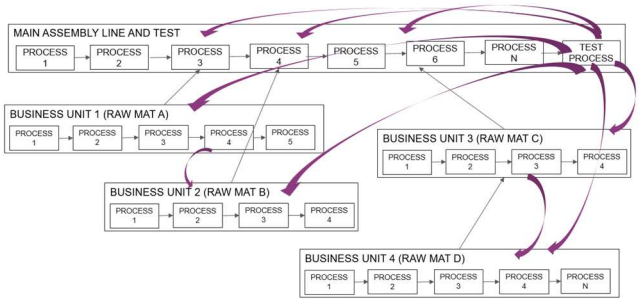


Figure 5. Process Flow

To overcome these challenges and obtain necessary information effectively, the Multi-level Scorecard is employed. Leveraging the STATION, TARGET OPERATION, and Business Unit (BU) LEVEL enables the algorithm to efficiently acquire the required data moving from one process to another across the different business units, leading to quicker data gathering and visualization processes (refer to Figure 6).

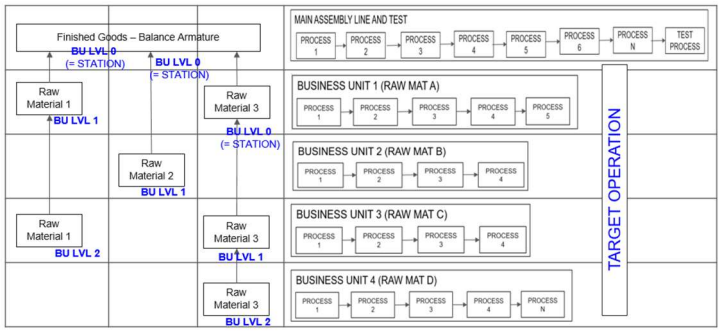


Figure 6. Multi-Level Scorecard Concept

3.2.2 Failure Code Triggers

Vigilance Analytics adopts the utilization of the Multiplication Rule Probability (MRP) concept, also commonly known as the "product rule."

$$MRP = m * \%FOR * Vol$$

In this case, the product of the reject trend slope (m), cumulative rejection rate (%FOR), and volume (Vol) based on a specified time period were utilized.

Based on the MRP, early detection of irregularities or potential issues can be performed. The engineers and line owners would then intervene when variations are detected. Vigilance Analytics would generate a daily maverick trigger through email, notifying stakeholders of any abnormal situations that demand attention.

4.0 RESULTS AND DISCUSSION

4.1 Test Failure Code Trigger Actual Use Scenario

The Test Failure Code Trigger visualization tool provides a comprehensive summary, including elements such as Product Name and Failure Code, indicating abnormal reject rate conditions. An email notification will be sent to predefined recipients, with notifications scheduled on a per shift interval (refer Figure 7).

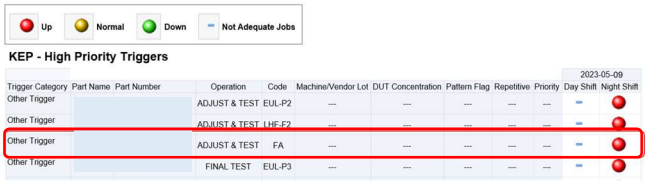


Figure 7. Visualization Tool for Test Code Triggers

The triggered product item was validated using other Vigilance Analytics descriptive tools and was confirmed valid.

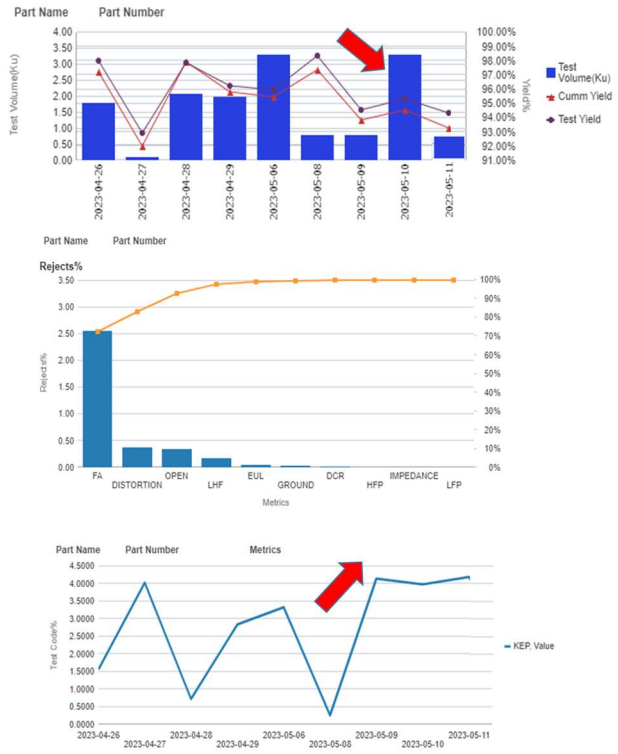


Figure 8. Trigger Validation using VA

4.1 Multi-level Scorecard Actual Use Scenario

The Multi-level Scorecard offers a visualization tool that includes information on Man, Machine, and Material. This tool assists Engineers and Line Owners in identifying key factors contributing to high reject occurrences more effectively. Data trend and statistics was shown and identified MATERIAL has the highest contributing factor (see Figure 9).

EQUIPMENT

Material Part Number	Input Val		2023-06-23	2023-06-24	2023-06-25	2023-06-26	2023-06-27	2023-06-28	2023-06-29	2023-07-01	2023-07-02
	V-PLASMA-001 LINESFI	Test In Qty	50	150	548	1,148	1,548	1,245	1,072	1,590	599
		%T-Reject	0.00%	0.00%	1.09%	0.00%	1.26%	0.08%	0.93%	0.18%	0.82%
	V-PLASMA-003 LINESFI	Test In Qty	50	200	748	1,059	890	545	998	1,290	435
		%T-Reject	0.00%	0.00%	0.83%	1.09%	0.26%	0.08%	0.93%	0.82%	0.00%

MATERIAL

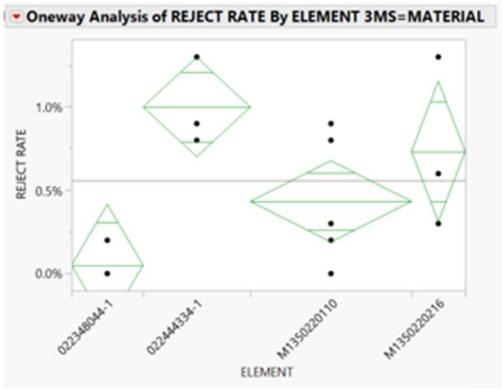
Material Part Number	Input Val		2023-06-23	2023-06-24	2023-06-25	2023-06-26	2023-06-27	2023-06-28	2023-06-29	2023-07-01	2023-07-02
	022348044-1	Test In Qty	100	350	1,296	559					
		%T-Reject	0.00%	0.00%	0.23%	0.00%					
	022444334-1	Test In Qty				1,648	2,438	1,790	2,070	2,880	1,034
		%T-Reject				0.90%	1.26%	0.80%	0.93%	0.82%	1.30%
	M1350220110	Test In Qty	100	350	1,296	2,207	1,200	1,790	1,548	2,880	200
		%T-Reject	0.00%	0.00%	0.23%	0.90%	0.00%	0.80%	0.29%	0.82%	0.94%
	M1350220216	Test In Qty					1,238		522		834
		%T-Reject					1.26%		0.65%		0.34%

OPERATOR

Material Part Number	Input Val		2023-06-23	2023-06-24	2023-06-25	2023-06-26	2023-06-27	2023-06-28	2023-06-29	2023-07-01	2023-07-02
	K-01487	Test In Qty	50	350	1,296	2,207	1,148	1,245	872	1,590	
		%T-Reject	0.00%	0.00%	0.23%	0.90%	0.76%	0.80%	1.15%	0.82%	
	K-01554	Test In Qty	50								
		%T-Reject	0.00%								
	K-01725	Test In Qty					400		200		1,034
		%T-Reject					0.50%		0.00%		1.30%

Figure 9. Multi-Level Scorecard inside VA

Validation using statistical tools had been done to validate observations on the data. See Figure 10. The goal of the statistical method is to check and validate the result derived from the visualization tool. The Analysis of Variance yielded a p-value of 0.0031, providing 95% confidence that one material lot exhibits significant performance differences compared to the other material lots.



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
ELEMENT	3	0.00024365	0.000081	6.7163	0.0031*
Error	18	0.00021767	0.000012		
C. Total	21	0.00046132			

Figure 10. Statistical Validation

After the immediate and corrective action done, the performance had significantly improved. This used case had saved 700 USD preventing more excursion of reject occurrence.

5.0 CONCLUSION

The development and deployment of Vigilance Analytics – Multi-level Scorecard and Failure Code Trigger was proven to be effective as data analytical tools in the manufacturing of BA drivers. The algorithms through Failure Code Trigger and multiple level diagnostic capability through Multi-Level Scorecard inside Vigilance Analytics provided a powerful and efficient means of analyzing complex manufacturing data so as engineers and line owners can swiftly identify significant contributors to high reject occurrences. This early detection of process variations empowers the entire manufacturing community to take proactive measures, ensuring faster resolution of issues and minimized production downtime.

6.0 RECOMMENDATIONS

The Vigilance Analytics tools developed are recommended to be proliferated to other manufacturing sites which employ similar complex manufacturing design.

7.0 ACKNOWLEDGMENT

Appreciation to those who have contributed to the successful completion of this technical paper specifically to the Knowles Electronics Management, IT, Engineering, OBIEE, MES, and Global Vigilance Analytics support groups.

8.0 REFERENCES

1. Peng, R. and Matsui, E., (2022, July 05) The Art of Data Science: A Guide for Anyone Who Works with Data". *Atsal.* https://fliphtml5.com/pnbjj/qqse/basic/

2. Glen, S. "Multiplication Rule Probability: Definition, Examples". *StatisticsHowTo.com: Elementary Statistics for the rest of us!* https://www.statisticshowto.com/multiplication-rule-probability/

9.0 ABOUT THE AUTHORS

Raffy Cosep, a graduate of Cebu Institute of Technology – University, brings extensive experience as a Quality Engineer, having worked in this role for eight years. Presently, he has been serving as an Analytics and Yield Engineer at KNOWLES ELECTRONICS PHILIPPINES CORPORATION for three years.

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10.0 APPENDIX

Not Applicable.