OPTIMIZING COST EFFICIENCY: PRODUCT COST REDUCTION FOR PRODUCT X BALANCED ARMATURE RECEIVERS

Mariechu P. Sorallo

New Product Introduction and Research and Development, Medical Technology and Specialty Audio
Knowles Electronics (Philippines) Corporation, Cebu Light Industrial Park, Basak, Lapu-Lapu City, Cebu
Mariechu.Sorallo@knowles.com

ABSTRACT

Nowadays, manufacturing companies are continuously pursuing operational excellence strategies to gain a better position in a highly competitive manufacturing landscape. Manufacturing cost is one key element - that is, being able to reduce the cost of manufacturing a product while maintaining a high standard of quality will ensure higher profitability and better market position.

This project pioneered the series of cost improvement initiatives for Product X balanced armature (BA) receivers and explored on the different cost reduction strategies at Knowles Electronics (Philippines) Corporation. Using Lean and Six Sigma methodologies, two cement application processes and one visual inspection process were eliminated which resulted in significant product cost reduction.

1.0 INTRODUCTION

1.1 Background of the Study

The hearing health industry has significantly benefitted from the balanced armature (BA) technology which has elevated the development of receivers for more advanced hearing aid solutions. For instance, the Receiver-in-the-Canal (often called RIC) hearing aids are becoming more popular because of their high gain-to-size ratio[1]. A key component of this RIC hearing aid is the BA receiver which converts the amplified electrical signals back into sounds and transmits them directly into the ear[2]. A huge portion of the RIC hearing aids uses Product X Dual Receiver which is a combination of 2 single receivers conjoined together to maximize the sound output.

Product X receiver family has started to gain traction among hearing health customers because of its capability to produce the desired level of sensitivity despite its minimal size. In fact, in 2023, the production demand for these receivers has significantly increased. As shown in Fig. 1, it started with just 1 variant in 2021 but has increased to 4 different variants in a span of 2 years. In terms of volume, it has increased by as much as 306% in 2023, from 671k pcs in 2022 to as high as 2.06M pcs in 2023.

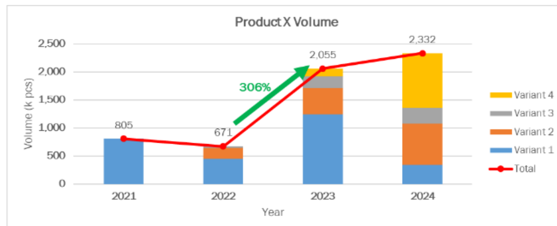


Fig. 1. Product X volume for 4 different variants over a period of 4 years.

1.2 Statement of the Problem

With the surging demand for Product X receivers, it is imperative to look closely into the cost components of manufacturing this product. There are three primary elements of the Product Cost: Bill of Materials (BOM), Direct Labor, and Manufacturing Overhead. BOM cost is the total cost of the raw materials that go into the finished product while direct labor cost is the cost paid for all employees involved in the assembly of the product. Overhead cost is the cost of the use of utilities including the indirect labor for the supporting roles. By convention, the overhead cost is a factor of the direct labor cost and is defined using the OH factor to the DL cost.

As can be seen in Fig. 2, the major drivers for the manufacturing cost of Product X are labor and overhead costs with an average of $1.63. In 2023, the total spending on labor and overhead costs was estimated at $4.07M. Thus, attention was given to reducing the direct and indirect labor components of its product cost to enable the competitive advantage of Knowles Electronics.

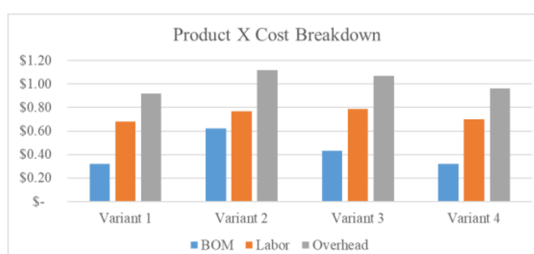


Fig. 2. Manufacturing Cost Components of Product X.

1.3 Objective of the Study

This project aims to reduce the direct labor and overhead cost components of Product X by at least \$0.05 per piece equivalent to a 3% reduction. This is expected to generate savings of at least \$77,000.

1.4 Scope and Limitations of the Study

Although the approach of analyses covers the whole manufacturing flow, only a selected number of processes are covered in this technical paper. This is because the whole project is planned in different stages according to the duration of the developmental activities and the available resources.

2.0 REVIEW OF RELATED WORK

Not applicable.

3.0 METHODOLOGY

3.1 PDCA – Plan Phase

3.1.1 Process Flow of Product X

Manufacturing Product X receivers involves sub-assembly processes in which the raw materials are pre-processed offline before it is fed to the mainline process. This includes assembly of the coil using thermo-bond technology, punching and annealing of some metal parts such as cups, yoke, reed, and assembly of the diaphragm.

There are two major process flows in the mainline assembly. Firstly, single receivers are assembled in the mainline assembly. See Fig. 3 for the product illustration including the major components and Fig 4 for the process flow.

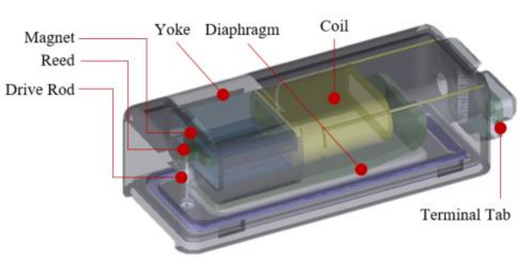


Fig. 3. Single Receiver Major Components

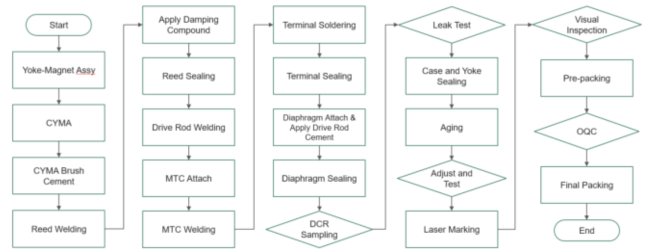


Fig. 4. Single Receiver Process Flow

Two single receivers are then conjoined together to form a conjoin receiver. In some variants of Product X, a tube is attached to the conjoin receiver. See Fig 5 for the product illustration and Fig. 6 for the conjoin receiver process flow.

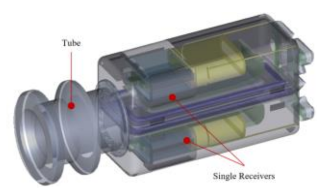


Fig. 5. Conjoin Receiver Major Components

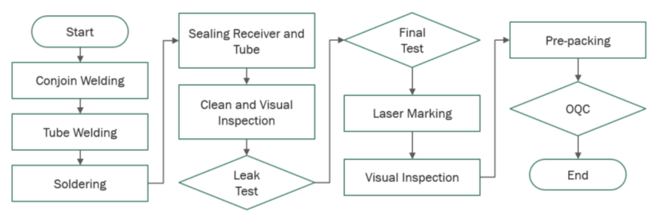


Fig. 6. Conjoin Receiver Process Flow

3.1.2 Value Stream Mapping

This project employed the Lean Six Sigma principle of Value Stream Mapping (VSM). A visual map of the end-to-end process of Product X was created including the information on the processing time, actual headcount, amount of Work-in-Process (WIP) inventory in each process, and the yield assumption per process. The cross-functional team (CFT) then did a Gemba walk in the line to validate all the information pre-defined in the VSM Map. Also, the team took into account the non-value adding process or process steps. Additionally, the CFT members documented the areas of improvement be it for productivity or yield improvement.

3.1.2.1 Value Stream Mapping – Single Receiver

Shown in Fig. 7 is the VSM for the current state of the Single Receiver mainline assembly.

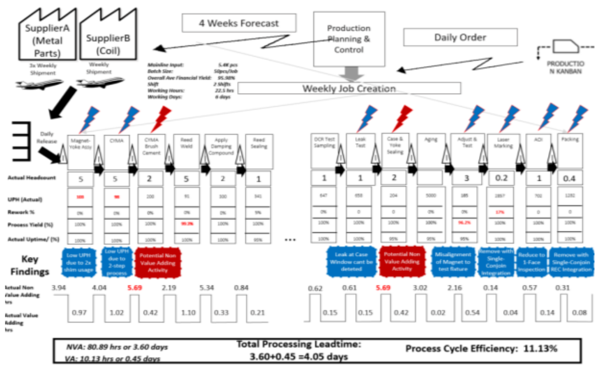


Fig. 7. VSM for the Before State of Single Receiver Assembly.

Significant findings from the Gemba Walk are listed in Table 1 below. As initially planned for Stage 1 of the Product Cost Efficiency Improvement Initiative, this study only covers the CYMA Brush Cement and Case and Yoke Sealing processes. For the CYMA Brush Cement, the team challenged that the cement application on the coil might be a non-value adding activity and could potentially be eliminated. The same is hypothesized for the cement brushing in the Case and Yoke Sealing process and that process step can be eliminated.

Table 1. Summary of VSM Findings & Proposed Actions for Single Receiver Assembly

Process	Current State	Proposal/Action
Magnet-Stack/Yoke Assembly	Low UPH due to 2x shim usage and material-inherent concern	i-CYMA (One-Step CYMA Process)
CSMA/CYMA	Low UPH due to 2-step process	
CYMA Brush Cement	Non-value adding activity	Eliminate this process
Leak Test	Leak test is not able to detect leak at case window	Optimize Test Setup such that all possible leaks are detected - inlet of air is at terminal side
Case and Stack/Yoke Sealing	Non-value adding for the brush cement	Eliminate the brushing of cement in yoke
FCAAT	Misalignment of Magnet and Test Fixture Pole-piece causing Fail Adjust Failures	Design and implement a new test fixture such that the magnet is aligned to the pole piece
Laser Marking	Single receiver have laser marking process	Eliminate laser marking and packing at single receiver level with Single-Conjoin REC Integration
Packing	Single receiver have packing process	
Visual Inspection - AOI	6 sides of receivers are inspected	Reduced Surface AOI

3.1.2.2 Value Stream Mapping – Conjoined Receiver

As illustrated in Fig. 8, the VSM Before State of the Conjoined Receiver showed two major findings. As part of the study limitation, only the Visual Inspection is being assessed as a potential non-value adding activity (see Table 2).

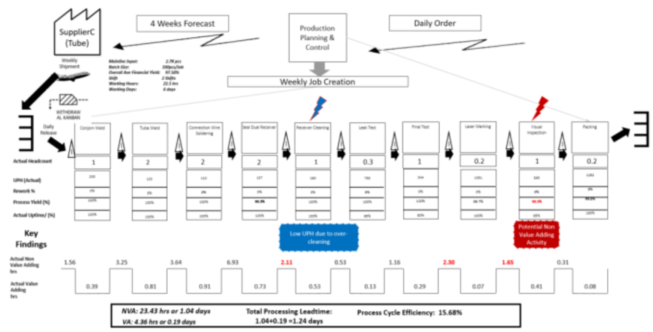


Fig. 8. VSM for the Before State of Conjoin Receiver Assembly.

Table 2. Summary of VSM Findings and Proposed Actions for Conjoin Receiver Assembly

Process	Current State	Proposal/Action	PIC
Receiver Cleaning	Low UPH due to over-cleaning	Reduce steps such that cleaning areas and criteria are aligned according to VAM requirements	Chu
Visual Inspection	Non-value adding activity	Eliminate this process	Chu

3.2 PDCA – Do Phase

Based on the results of the Value Stream Map, three processes were identified as potential non-value adding activities and are candidates for elimination. These are:

- Single Receiver CYMA Brush Cement Application
- Single Receiver Case and Yoke Sealing – Brush Cement Application
- Conjoin Receiver Visual Inspection

With this, a series of engineering validations were conducted. This includes technical justifications through revisiting the product requirements, performing statistical analysis, and then running production builds with the eliminated processes to simulate any impact on the next assemblies, electro-acoustic performance, and product reliability.

3.2.1 Technical Justification on Process Elimination

3.2.1.1 CYMA Brush Cement Elimination

CYMA (Coil Yoke Magnet Assembly) process is the sub-assembly of thermo-bond coil, yoke, and magnet joined together by an adhesive or commonly termed cement in Knowles. Subsequent to CYMA is the Brush Cement process. Brushing of cement is done by applying a dot of cement on the coil and then spreading it across the coil body with the aid of a brush (see Fig. 9). This is performed based on below product requirements:

- There must be a strong bond between the wound wires
- There must be a strong bond between the wound coil and the lead wires

Fig. 9. CYMA Brush Cement Process.

Product X receivers use thermo-bond coil which uses high temperature to trigger the self-bonding adhesive wire coating during winding (see Fig. 10). This self-bonding technology may potentially be able to meet the first requirement which is ensuring a strong bond between wound coils.

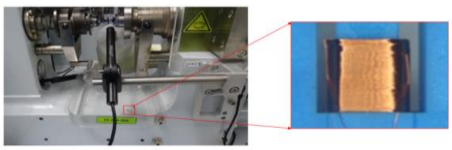


Fig. 10. Thermo-bond (TB) Coil Assembly.

On the second requirement of securing the bond between the wound coil and the lead wires, if the lead wires are able to withstand the pull test requirements then it can be justified that this cement brushing may not be necessary. With the validation plan as shown in Fig. 11, the project pushed through with the production trial build, eliminating the CYMA Brush Cement process. These trial units were then forwarded to the laboratory for reliability testing.

Product Requirements	Technical Justification	Validation
1. Strong bonding between wires	• Thermo-bond uses high temperature self-bonding technology	• Per Process Inspection to detect detached wire and cut wire
2. Strong bonding between wound coil and the lead-wires	• Minimum requirement on pull-strength ensures bonding between wound coil and lead wires	• Pull Test

Fig. 11. Validation plan for CYMA Brush Cement Elimination.

3.2.1.2 Case and Yoke Sealing - Brush Cement Elimination

At Secondary line, the yoke material undergoes annealing process. Part of the annealing process is the cement coating. The yoke is dipped in the cement solution 13-893 to prevent corrosion (see Fig. 12). At Mainline assembly, when this annealed yoke is fed to the line, it is brushed with cement 13-825-3145, still to prevent corrosion (see Fig. 13). These processes of cement coating at Secondary and Mainline assemblies is repeatedly done and is being considered for streamlining or process elimination.

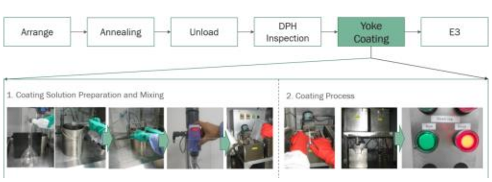


Fig. 12. Yoke coating process at Secondary Line.

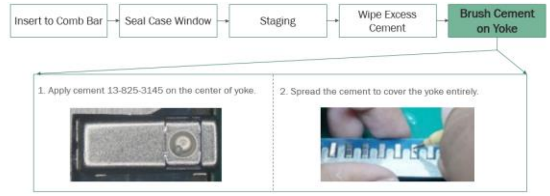


Fig. 13. Yoke Coating Process at Mainline Assembly.

3.2.1.3 Conjoin Receiver Visual Inspection Elimination

Prior to packing product X at Conjoin receiver assembly, it undergoes a visual inspection process. A visual inspection process is necessary to filter unwanted cosmetic defects. Once done inspection, conjoin receivers are packed and stored at Kanban system. These units are then forwarded to Value-Added Manufacturing (VAM) assembly lines for further processing. At VAM assembly, the receivers are fully encased in housings and connected with cable.

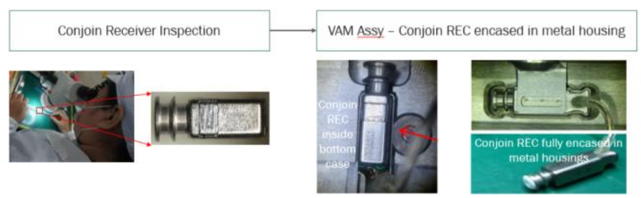


Fig. 14. Flow with Final Inspection at Conjoin Receiver, however, encased in VAM assembly.

From the illustration shown in Fig. 14 above, it can be observed that any visual defect found at receiver level inspection can no longer be seen in the Finished Good (FG) at VAM level since it will be covered with the housings. Thus, it can be deduced that the visual inspection at conjoin receiver level is no longer necessary.

3.2.2. Process Qualifications

3.2.2.1 Brush Cement Processes Elimination

The initiative to remove brush cement after CYMA was assessed in the succeeding processes to ensure that this will not create a process or yield concern. Since this Brush Cement process aids in creating a strong bond between the wound coil and the lead wires and the wound coils itself, the processes next to it were checked on the possible occurrence of detached wire.

As for the Brush Cement removal at the Case and Yoke Sealing process, no negative impact on the succeeding processes is expected since this is just a second cement application within the process. This is expected to reduce the sealing void because the first layer of cement applied when the gap between the yoke and cup window will no longer be disturbed with the 2nd cement application for the cement brushing on the yoke surface.

3.2.2.2 Conjoin Visual Inspection Elimination

Production build was triggered to simulate any impact of the visual inspection elimination at the conjoin receiver level to the VAM assembly. Of the 4 variants of Product X, only Variant 2 has a potential risk since the metallic VAM housings are joined together through a welding process. So excess cement or any impurity not removed during receiver assembly may produce bad weld at VAM assembly. The rest of the variants are using plastic housings which are joined and sealed by cement sealing.

3.2.3 Electro-acoustic Performance Assessment

When eliminating processes, such as the case of the removal of Brush Cement applications after CYMA and at Yoke and Case Sealing, it is imperative to evaluate its impact on the overall electro-acoustic (EA) response. Thus, builds for the Trial Group (eliminated Brush Cement) and Control Group (normal processing) were done, using the same set of production operators and machines and built at the same time. This is to determine that the EA response after removing the Brush Cement processes is comparable to the current response without the process eliminations. This is a crucial checkpoint as any variation on the EA response will potentially impact the system-level testing at the customer side.

3.2.3. Product Reliability Testing for Brush Cement Elimination

Conjoin receiver-level reliability testing was arranged for the Trial and Control groups. In particular, four reliability tests were conducted, namely, Highly Accelerated Life Test (HALT), E3, Vaporized Aggressive Acidic Sweat, and IEC tests. This is to ensure that the eliminated brush cement processes will not have any adverse effect on the product after subjecting to the above-mentioned environmental tests.

4.0 RESULTS AND DISCUSSION

4.1 PDCA – Check Phase

4.1.1 Brush Cement Elimination Process Qualification Results

4.1.1.1 Validation Results on Strength within Wound Coil

All units from trial and control group were inspected every after process from CYMA to Seal Terminal to detect any traces of detached wire or cut wire. From the 300 pcs trial samples build, no detach wire was found, see Fig. 15 for the performance per process for the trial build.

	Trial Lot					Control Lot				
PROCESS NAME	INPUT	OUTPUT	Actual FPY	REJECT NAME	LOSS QTY	INPUT	OUTPUT	Actual FPY	REJECT NAME	LOSS QTY
Magnet Yoke Assembly	300	300	100.0%		0	300	300	100.0%		0
CYMA	300	300	100.0%		0	300	300	100.0%		0
CYMA Brush Cement						300	300	100.0%		0
Reed Weld	300	300	100.0%		0	300	300	100.0%		0
Apply Dampening Compound	300	300	100.0%		0	300	300	100.0%		0
Reed Sealing	300	300	100.0%		0	300	300	100.0%		0
Drive Rod Weld	300	300	100.0%		0	300	300	100.0%		0
Motor To Case Attach	300	300	100.0%		0	[illegible]	[illegible]	[illegible]		[illegible]
MTC Welding	300	300	100.0%		0	[illegible]	[illegible]	[illegible]		[illegible]
Terminal Soldering	300	300	100.0%		0	[illegible]	[illegible]	[illegible]		[illegible]
Diaphragm Attach	300	300	100.0%		0	[illegible]	[illegible]	[illegible]		[illegible]
Diaphragm Sealing and Apply Drive Rod Cement	300	300	100.0%		0	[illegible]	[illegible]	[illegible]		[illegible]
Seal Terminal	300	300	100.0%		0	300	300	100.0%		0
DCR Test Sampling	300	300	100.0%		0	300	300	100.0%		0
Leak Test	300	300	100.0%		0	300	300	100.0%		0
Case and Yoke Sealing	300	300	100.0%		0	300	300	100.0%		0
Aging	300	300	100.0%		0	300	300	100.0%		0
Adjust and test	300	287	95.7%	DISTORTION - 4 FA - 9	13	300	288	96.0%	DISTORTION - 2 FA - 10	12
Laser Mark	287	287	100.0%		0	288	288	100.0%		0
Visual Inspection	287	287	100.0%		0	288	288	100.0%		0
	Overall Yield		95.7%			Overall Yield		96.0%		

No occurrence of detached wire or cut wire

Fig. 15. Per process inspection on trial and control groups

4.1.1.2 Validation Results on the Strength between Wound Coil and Lead Wires

Using the normal data distribution, the overall process capability performance for Coil-level Pull Strength Test has an actual capability, Ppk of 4.09 which is above the target of 1.33 (see Fig.16). This suggests that there is enough bonding strength between the wound coil and the lead wires. Refer to Appendix A for the actual pull strength test measurements.

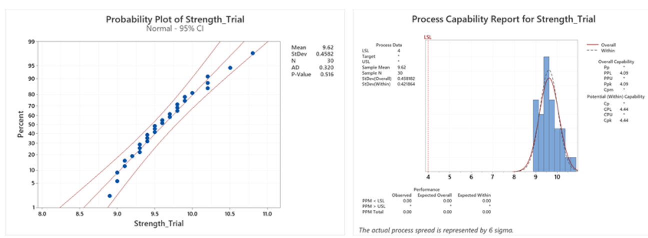
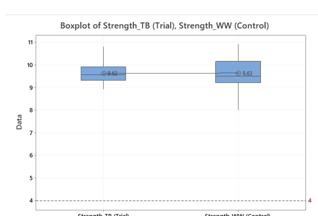


Fig. 16. Process Capability for the Coil-level Pull Strength Test.

Furthermore, the measured pull strength from the thermos-bond (TB) coil was compared with the old wet-wound (WW) coil assembly. From the Two-Sample T-Test results, with a p-value of 0.947 which is greater than the set alpha of 0.05, it is concluded that we can accept the null hypothesis and that there is no statistical difference in the pull strength of TB and WW (see Fig. 17). For a more comprehensive statistical analysis, refer to Appendix B.



Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Strength_TB (Trial)	30	9.620	0.458	0.084
Strength_WW (Control)	30	9.630	0.684	0.12

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.07	50	0.947

Fig. 17. Two Sample T-Test between Trial (TB coil) and Control (WW coil).

4.1.2 Process Qualification at VAM Assembly for the Elimination of Conjoin Visual Inspection

A small-scale trial run of 300 pcs whereby visual inspection at conjoin receiver level was eliminated did not yield any bad weld defect at the Top and Case Welding at VAM assembly.

4.1.3 Electro-acoustic Performance Assessment Results on Brush Cement Elimination

Electro-acoustic response of the Control and Trial Group are comparable for both Single Receiver (see Fig. 18) and Conjoin Receiver (see Fig. 19).

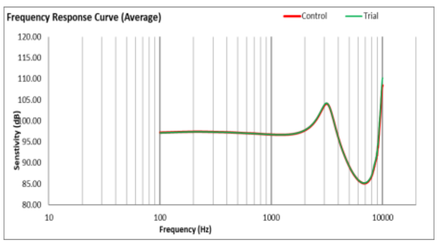


Fig. 18. Single Receiver Electro-acoustic Response

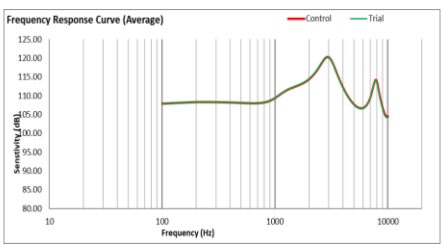


Fig. 19. Conjoin Receiver Electro-acoustic Response

4.1.4 Product Reliability Test Results on Brush Cement Elimination

Both Trial (Removed Brush Cement after CYMA and at Case and Yoke Sealing) and Control (With Brush Cement at CYMA and at Case and Yoke Sealing) group samples submitted to the reliability laboratory passed all four environmental tests (see Fig. 20).

R-P-22426 Qual for the removal of Brush Cement and Yoke Sealing Process -							
Test Items	Lot No.	Qty	Result				
			3days	1W	2W	4W	6W
HALT	Control_Submission	30	PASS	PASS	PASS	PASS	PASS
	Trial_Submission	30	PASS	PASS	PASS	PASS	PASS
E3	Control_D29138402-1	30	PASS	PASS	PASS	PASS	PASS
	Trial_D29138401-1	30	PASS	PASS	PASS	PASS	PASS
Aggressive Acidic Sweat, Vaporized	Control_D29138402-1	20	PASS				
	Trial_D29138401-1	20	PASS				
IEC	Control_D29138402-1	20	PASS				
	Trial_D29138401-1	20	PASS				

Fig. 20. Reliability Test Results of Control and Trial Groups on Brush Cement Elimination.

4.1.5 Value Stream Mapping – After State

At Single Receiver assembly in which Brush Cement after CYMA and at Case and Yoke Sealing processes were removed, total processing lead-time was reduced by 0.5 days and process cycle efficiency improved by 0.15% (see Fig. 21).

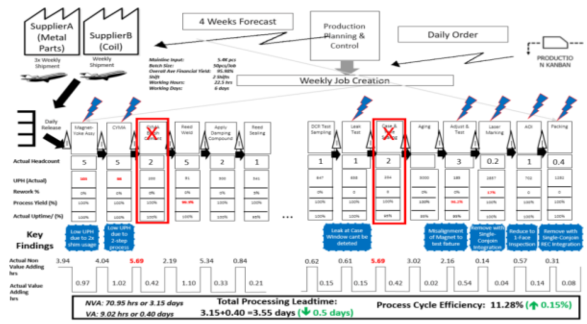


Fig. 21. After State VSM for Single Receiver

For Conjoin Receiver assembly whereby Final Inspection was eliminated, the total processing lead-time was improved by 0.10 days (see Fig. 22).

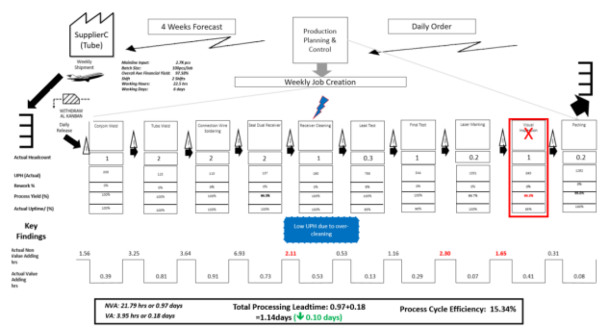


Fig. 22. After State VSM for Conjoin Receiver

4.1.6 Implementation Approval

The Management Team approved the implementation of the three process elimination initiatives below, namely:

- Single Receiver Brush Cement after CYMA
- Single Receiver Brush Cement at Case and Yoke Sealing
- Conjoin Receiver Visual Inspection

4.1.7 Product Cost Comparison and Cost Savings

Two of the four variants piloted the implementation of the Brush Cement Elimination and Visual Inspection elimination. A month after, 2 variants leveraged the implementation. With all 4 variants implementing the three process elimination initiatives, and with product cost savings ranging from $ 0.101 to $ 0.139, overall calendar savings for 2023 are estimated at $172,316 (see Fig. 23 below).

Product X Variant	Cost Component	Before Cost	After Cost	Cost Savings per Unit	2023 Calendar Volume (kpcs)	2023 Calendar Savings(k USD)
Variant 1	BOM	$ 0.320	$ 0.320	$ -	804.93	$ 81.3
	Labor	$ 0.680	$ 0.650	$ 0.030		
	Overhead	$ 0.920	$ 0.849	$ 0.071		
	Total Cost	$ 1.920	$ 1.819	$ 0.101		
Variant 2	BOM	$ 0.624	$ 0.624	$ -	311.13	$ 43.3
	Labor	$ 0.770	$ 0.732	$ 0.038		
	Overhead	$ 1.115	$ 1.015	$ 0.101		
	Total Cost	$ 2.510	$ 2.371	$ 0.139		
Variant 3	BOM	$ 0.431	$ 0.431	$ -	382.51	$ 41.7
	Labor	$ 0.789	$ 0.750	$ 0.039		
	Overhead	$ 1.069	$ 0.999	$ 0.070		
	Total Cost	$ 2.289	$ 2.180	$ 0.109		
Variant 4	BOM	$ 0.320	$ 0.320	$ -	43.43	$ 6.0
	Labor	$ 0.700	$ 0.645	$ 0.055		
	Overhead	$ 0.960	$ 0.876	$ 0.084		
	Total Cost	$ 1.980	$ 1.841	$ 0.139		
				Overall Savings		$ 172.3

Fig. 23. Validated Cost Savings Summary.

4.2 PDCA – Act Phase

To ensure process implementation and sustainability, necessary documents such as PFMEA, Process Flow Charts, Work Instructions, and Control Plan were revised and registered. Also, manufacturing systems setup in Oracle and CAMSTAR were updated. Refer to the summary in Fig. 24 and evidences of the document revisions are captured in Appendix C.

Item	Responsible	Completion Target	Status
PFMEA	Chu	09 Jun 2023	Closed (ECR Approved)
Process Flow Chart	Chu	09 Jun 2023	Closed (ECR Approved)
Work Instruction	Chu	09 Jun 2023	Closed (ECR Approved)
Control Plan	Reagan	09 Jun 2023	Closed (ECR Approved)
Oracle Update	Chu	30 Jun 2023	Closed
CAMSTAR Setup	Chu	16 Jun 2023	Closed

Fig. 24. Documents Registration and Manufacturing Systems Updating

5.0 CONCLUSION

Value Stream Mapping proved to be a very valuable tool in identifying the potential non-value adding (NVA) processes. These initial hypotheses of having NVA activities were justified technically based on the minimum product requirements while ensuring that electro-acoustic performance is not altered and that the reliability of the product is maintained. As a result, Brush Cement after CYMA and at Case and Yoke Sealing were eliminated in the Single Receiver assembly. At the Conjoin Receiver assembly, the Final Inspection was also eliminated. This resulted in a product cost savings of at least $0.10/unit and a calendar savings of $84,981 for the 2 variants of Product X. These improvement initiatives were then leveraged to the other 2 variants with an estimated total calendar savings of $172,316 for 2023.

6.0 RECOMMENDATIONS

The study recommends for the accelerated assessment and resolutions of the other eight productivity and yield concerns identified during the Value Stream Mapping activity.

The proponent of the study also recommends for a similar improvement activity in either high-cost or high-volume products to advance the company's competitive advantage in terms of product pricing and gross margin.

7.0 ACKNOWLEDGMENT

The author would like to thank the CFT of Product X Receivers who were involved in the execution of the project. Also, Operational Excellence team and the Senior Management Team of Knowles Electronics Philippines were instrumental in ensuring that appropriate resources were provided for, making this project successful.

8.0 REFERENCES

1. Starkey Laboratories, Eden Prairie, Minnesota (2021) Receiver-In-Canal (RIC) https://www.starkey.com/hearing -aids/styles/receiver-in-canal

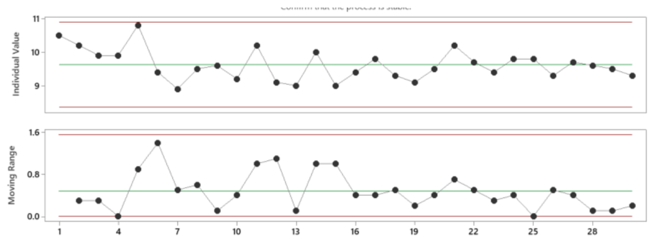
2. Knowles Electronics, LLC, Itasca, IL, USA. (2023). What is Balanced Armature? https://www.knowles.com/applications/ear-solutions/premium-sound/what-is-balanced-armature

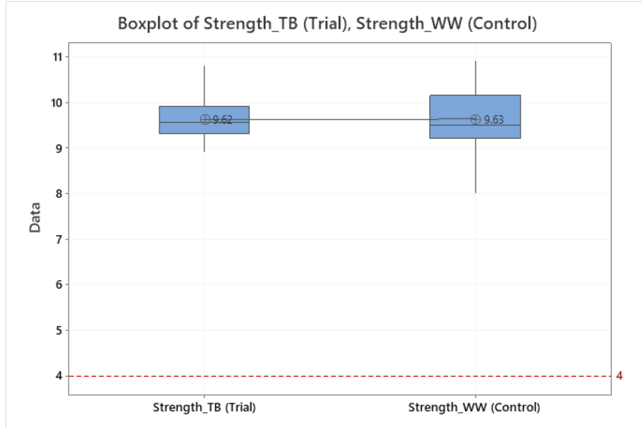
9.0 ABOUT THE AUTHOR

Mariechu P. Soralllo holds an engineering degree from Mindanao State University – Iligan Institute of Technology (MSU-IIT) and is a licensed Electronics Engineer. She is also a certified Six Sigma Green Belt practitioner and is currently pursuing training and certification for Six Sigma Black Belt. In her current role as Senior Advanced Manufacturing Engineer, she is responsible for managing projects involving process development in the context of new product and new technology development. Prior to joining Knowles Electronics Philippines, she had 8 years of experience at Cebu Microelectronics Inc., her last position being a Manufacturing Assistant Manager for Optical Transceivers.

10.0 APPENDICES

Appendix A – Pull Strength Measurement Results on Thermobond Coil





Appendix B – Two Sample T-Test on TB and WW Coil

Method

μ_1: population mean of Strength_TB (Trial)
μ_2: population mean of Strength_WW (Control)
Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Strength_TB (Trial)	30	9.620	0.458	0.084
Strength_WW (Control)	30	9.630	0.684	0.12

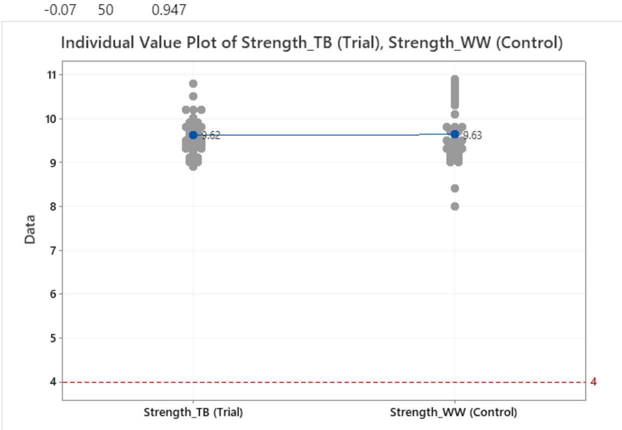
Estimation for Difference

Difference	95% CI for Difference
-0.010	(-0.312, 0.292)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-0.07	50	0.947



Appendix C – Documentation Evidences

Control Plan:

Change Sheet			
Date of Issue	Version	Changed By	Type and Reason of Change
23.Apr.2024	18	R. Pusta	
02.Apr.2024	17	R. Orcullo	
26.Feb.2024	16	R. Orcullo	
18.Sep.2023	15	R. Orcullo	
23.Aug.2023	14	R. Orcullo	
08.Jun.2023	13	R. Orcullo	Removed CYMA brush cement (Qualification Report No. R-P-22426) Removed steps pertaining to brush cement on yoke for Case and Yoke Sealing process (Qualification Report No. R-P-22426) **(ECR No.: P10007313)**

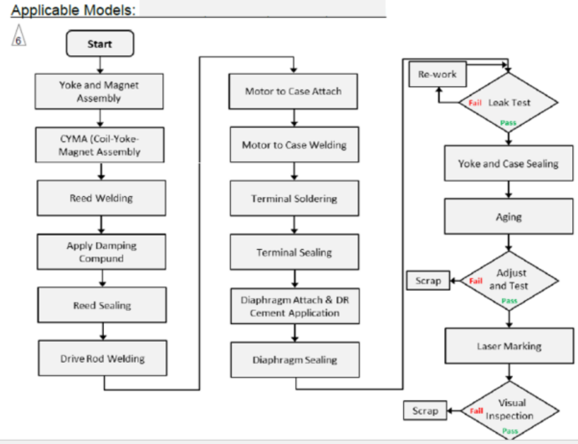
Single Receiver Process Flow Chart

REVISION HISTORY

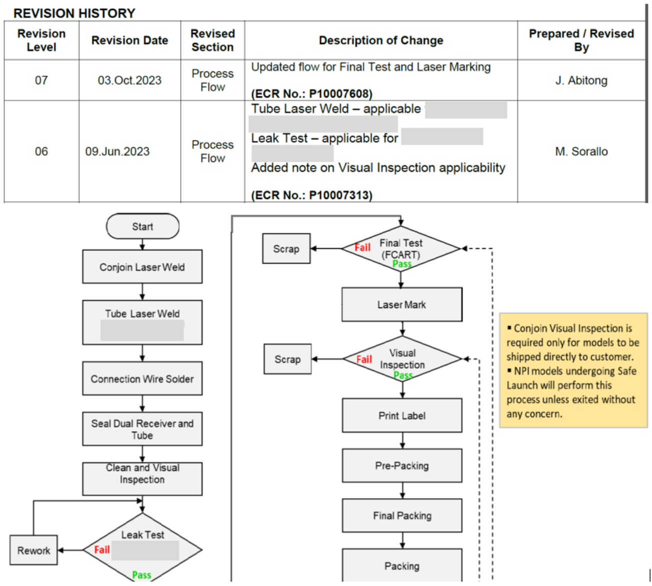
Revision Level	Revision Date	Revised Section	Description of Change	Prepared / Revised By
06	02.Apr.2024	Page 3&4		
05	07.Nov.2023	Page 1		
04	03.Oct.2023	Page 2		
03	08.Jun.2023	Page 2	Updated to only perform CYMA Brush Cement for Created separate flow for **(ECR No.: P10007313)**	M. Sorallo

Mainline: Single Receiver

Applicable Models:



Conjoin Receiver Process Flow Chart



REVISION HISTORY

Revision Level	Revision Date	Revised Section	Description of Change	Prepared / Revised By
07	03.Oct.2023	Process Flow	Updated flow for Final Test and Laser Marking **(ECR No.: P10007608)**	J. Abitong
06	09.Jun.2023	Process Flow	Tube Laser Weld – applicable Leak Test – applicable for Added note on Visual Inspection applicability **(ECR No.: P10007313)**	M. Sorallo