Nexperia Philippines Inc.

IMPROVING CONTACT RELIABILITY THRU RELIABILITY CENTERED MAINTENANCE APPROACH: A COST-EFFICIENT WAY OF CONTACT FINGER CONSUMPTION

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IMPROVING CONTACT RELIABILITY THRU RCM APPROACH: A COST-EFFICIENT WAY OF CONTACT FINGER CONSUMPTION

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ABSTRACT

Final Test ASM FT2026 are Test and Mark handler that process singulated packages from input module to taping module. Devices undergo inline electrical parametric test, laser mark and are placed in carrier tapes. This test handler uses four (4) different test site modules with distinct test set up to segregate devices that fail parametric test. Contact fingers are commonly used in testing a wide range of packages that require low to high voltage supply applications. Test site modules use two (2) type of contacting method; it is either (1) clamping method consist of upper and lower contact finger or (2) plunging method that uses cantilever contact finger that get in contact the leads during testing of devices.

This paper presents the structured and detailed study of determining the factors that affect the reliability of contact finger without any impact on product quality and test capability. This also supports the company's cost saving initiative by reducing the cantilever contact finger consumption by 20%. Further analysis shows that tool parts measurement, mechanical handler set up and control are the key factors that result in premature contact finger replacement.

Through the analytical and in-depth approach of DMAIC, potential root causes were identified. Reliability Centered Maintenance (RCM) methodology was used to identify all the mechanical related issues and implement the proper maintenance task to improve contact finger reliability. Statistical Process Control (SPC) is put in-placed to monitor critical signal on handler as indication that there is deviation in the setup.

Implementation of all identified corrective actions, appropriate setup, proper maintenance task and controls significantly reduce the contact finger consumption.

1. 0 INTRODUCTION

Nexperia is a global semiconductor company – expert in high-volume production of diodes, bipolar transistors, ESD protection devices, MOSFETs, etc. To maintain competitiveness on business market in terms of cost per unit, the company plans to minimize operations cost spending through Repairs and Maintenance (RNM) cost reduction. Final test is the 3rd highest contributor in FY2021 RNM expenditure amounting to $765K which is 18% of overall maintenance consumption. Out of the $765K final test spending, 64% is from the contact finger consumption while the remaining 36% is for other remaining maintenance parts. The top package contributor in contact finger consumption is SOT1210 at 60% of total cost, as shown in Figure 1.

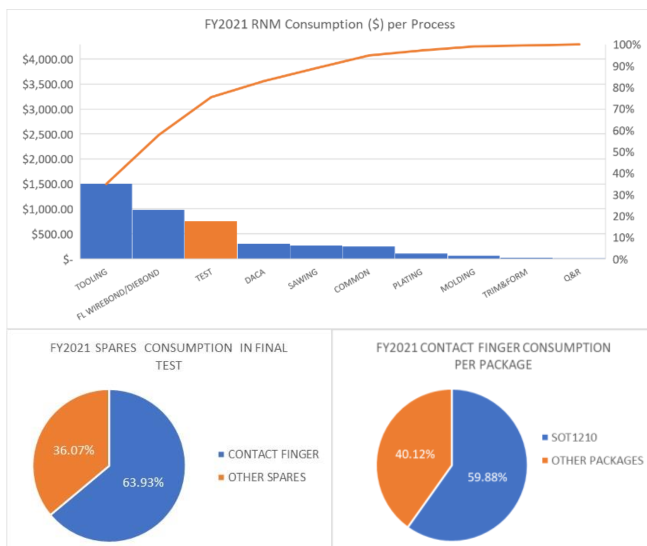


Figure 1. Pareto of overall RNM Consumption

SOT1210 packages are tested in ASM FT-2026 handlers (see Figure 2) which perform different tests such as parametric and functional testing. From FY2022 there is an average of 3.5% quarter to quarter increase of parametric device resistance (Kelvin) rejection resulting to high contact finger consumption averaging to 117 sets per quarter.

Frequent replacement of contact finger occurs when there is a high Kelvin rejection related to contact module issue.

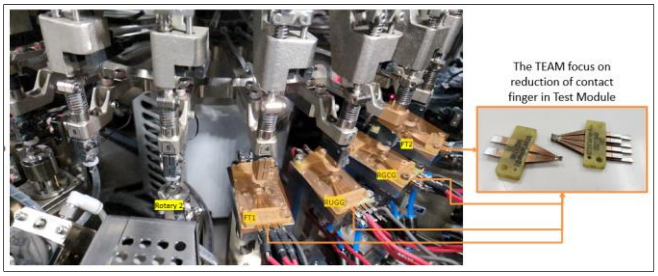


Figure 2. ASM FT-2026 Handler Test Modules and Contact Finger

2.0 METHODOLOGY

Comprising of selected experts from Process, Equipment and Test Engineer, Production Supervisor, Operator, Equipment and Preventive Maintenance Technician, a Six Sigma project is created to establish a systematical approach on resolving the high consumption of contact finger aligned with high Kelvin rejection.

In this project, the team have fully defined the true root causes using DMAIC approach of Six Sigma practice. Using the structured flow of six sigma the team was able to identify the major contributors that leads to high contact consumption with relation to kelvin test failure while defining the correct maintenance and control thru SPC using RCM methodology as foundation.

2.1 Define Phase

Part of the define phase is to generate problem statement to identify the focus of the team. Using problem definition tree, it is concluded that the top spending contact finger is SOT1210 packages across final test area. Cost analysis shows that SOT1210 contact finger has 400% more spending compared to the remaining packages.

SOT1210 packages use plunging method while other packages use clamping method in testing the product. Correlating the contact finger consumption in relation to contact resistance failure, it was found out that plunge type testing has significant high kelvin rejection across all SOT1210 handlers as shown in Figure 3.

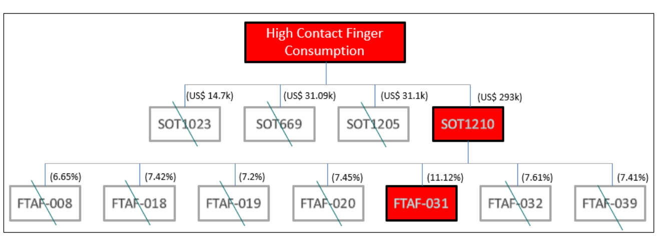


Figure 3. Problem Definition Tree

2.2 Measure Phase

Listed below are the tools used to study the baseline data as part of measurement phase analysis.

2.2.1 Measurement System Analysis for Power uParset Tester

Power uParset are type of DC tester used on all packages across Final test area capable of sorting electrically good and reject device under test. Gage Reliability and Repeatability (GR&R) Analysis is conducted to determine the consistency of Tester to provide electrical measurements with precision and accuracy. In figure 4, GR&R results show all SOT1210 testers are within acceptable criteria of below 30%.

Parameter	FTAF-018	FTAF-019	FTAF-020	FTAF-031	FTAF-032	FTAF-039	Tolerance
tIGSSP1	0.68%	0.97%	1.05%	0.73%	0.71%	6.81%	< 30%
tIGSSN1	1.07%	1.25%	1.54%	1.01%	0.48%	7.69%	< 30%
tIDSS1	0.47%	0.60%	2.80%	1.06%	0.36%	0.54%	< 30%
tIDSS30V	0.15%	0.18%	0.14%	0.13%	0.25%	0.15%	< 30%
tVGSTX1	0.91%	0.91%	0.81%	0.75%	6.04%	0.39%	< 30%
tVGSTX3	0.57%	0.57%	0.49%	0.42%	13.47%	0.34%	< 30%
tBVDSS	0.33%	0.41%	0.25%	0.22%	0.27%	0.45%	< 30%
tBVDSS_100uA	1.31%	1.55%	1.25%	1.29%	1.47%	-	< 30%
tVDSV	1.45%	1.51%	1.44%	1.05%	2.87%	0.11%	< 30%
tRDSon4	1.50%	1.68%	1.75%	1.27%	1.85%	0.52%	< 30%
tRDSon1	1.77%	2.03%	1.82%	1.08%	4.77%	0.90%	< 30%
tRDSon3	3.13%	6.32%	5.85%	1.66%	10.76%	0.76%	< 30%
tVSDS1	0.67%	1.01%	1.01%	0.64%	1.19%	0.57%	< 30%
tVSDS2	0.74%	0.79%	0.79%	0.70%	1.08%	0.43%	< 30%
tIDSS4	0.31%	0.55%	0.46%	0.36%	0.29%	0.65%	< 30%
tIGSSP2	0.79%	0.76%	0.85%	0.55%	0.63%	6.40%	< 30%
fIGSSP1	1.72%	1.39%	1.35%	2.40%	1.17%	8.90%	< 30%
fIGSSN1	1.68%	1.78%	1.69%	2.48%	1.48%	8.65%	< 30%
fIDSS1	0.75%	0.77%	0.55%	0.95%	0.64%	0.20%	< 30%
fVGSTX1	0.84%	0.63%	0.61%	0.67%	5.79%	0.36%	< 30%
fBVDSS	0.29%	0.34%	0.25%	0.25%	6.61%	0.49%	< 30%
fRDSon1	2.07%	1.95%	1.38%	1.67%	4.41%	0.23%	< 30%
fVSDS1	0.67%	1.09%	0.93%	1.00%	0.94%	0.45%	< 30%
fIDSS4	0.55%	0.38%	0.35%	0.46%	0.28%	0.08%	< 30%
fIGSSN2	2.47%	3.67%	3.03%	1.99%	1.61%	9.48%	< 30%
fIGSSP2	1.74%	2.80%	2.02%	2.16%	1.67%	9.89%	< 30%

Figure 4. GR&R Result in Handler's Power uParset Tester

2.2.2 Test Data Collection

SOT1210 packages average first pass test yield is less than 95% from Q1 to Q3 of 2022, as shown in Figure 5. Quarterly Volume is increasing but the Test Yield remains below 95% level. It denotes the Quarterly test yield is not driven by the total unit tested.

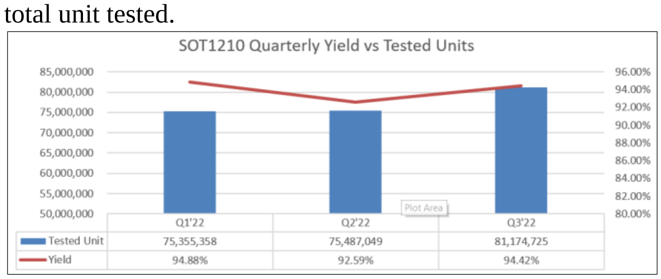


Figure 5. SOT1210 Volume vs Yield Trend

First Pass yield loss is averaging 6.4% for the past three quarters. Test kelvin failure contributes greater than 55% of the total First Pass rejects, as shown in Figure 6.

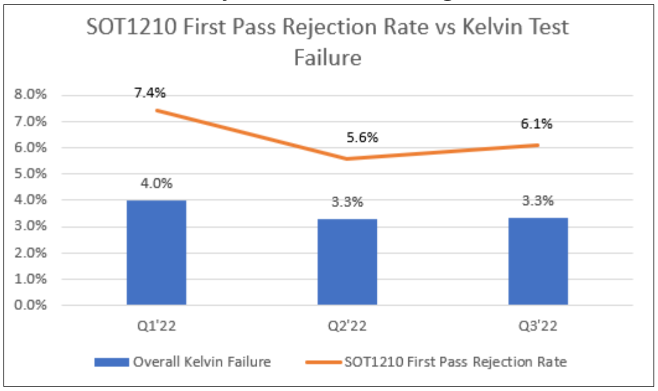
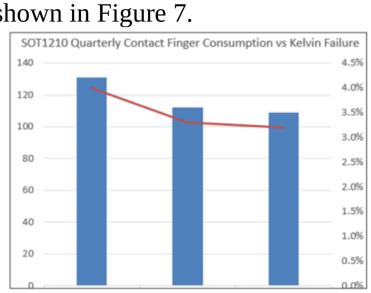


Figure 6. SOT1210 First Pass Reject and Kelvin Failure

Contact Finger withdrawal is proportional with the high percentage of kelvin test failure. The higher the test kelvin failure the more frequent contact finger replacement. SOT1210 Contact finger quarterly average consumption is 117 sets, as shown in Figure 7.



INPUTS	Q1	Q2	Q3
Contact Finger Consumption	131	112	109
Kelvin Failure	4.0%	3.3%	3.2%

Figure 7. Quarterly Contact Finger Consumption vs Kelvin Failure

3.3 Analyze Phase

This phase contains the analytical method in identifying the root cause/s:

3.3.1 Ishikawa Diagram / Cause & Effect Matrix

Ishikawa Diagram breaks down the information within five categories of Man, Machine, Method, Material and Mother Nature (Environment) to determine what are the factors associated with High Contact Finger Consumption as shown in Figure 8.

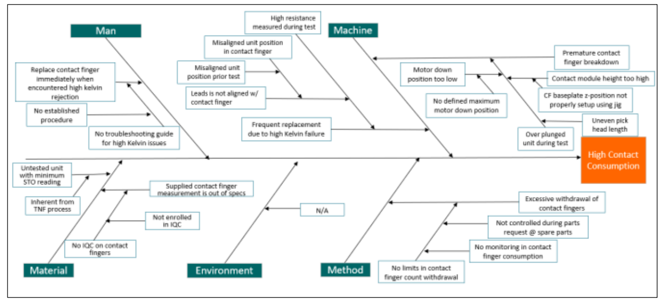


Figure 8. Ishikawa Diagram

Listed in the Cause-and-Effect Matrix are the rating and ranking of root causes based on process output. Identified the top 5 contributing factors as follows (see Figure 9):
(1) No IQC on contact finger,
(2) No limits in contact finger count withdrawal,
(3) Contact Module too high,
(4) Motor down position too low and
(5) Uneven pick head length

				PROCESS OUTPUT						TOTAL
				Cost	Downtime	Kelvin failure	Yield	Capacity	Standoff	
				10	9	8	7	6	5	Importance Rating
ITEM	CATEGORY	PROCESS STEP	PROCESS INPUT	CORRELATION OF INPUT TO OUTPUT						Total
16	MATERIAL	IQC	No IQC on contact finger	9	9	9	4	4		295
15	METHOD	Equipment Maintenance	No limits in contact finger count withdrawal	9	9	9	4	4		295
2	MACHINE	Test Module	Contact module height too high	4	9	4	9	4	9	285
6	MACHINE	Test Module	Motor down position too low	4	9	4	9	4	9	285
23	MACHINE	Equipment Maintenance	Uneven pick head length	9	9	9		4		267
3	MACHINE	Test Module	CF base plate z-position not properly setup using jig (too high)	4	4	9	1	4		179
7	MACHINE	Test Module	Frequent replacement due to high Kelvin failure	9	1	4	4	1		165
1	MACHINE	Test Module	Premature contact finger breakdown	4	4	4	4	4		160
20	MAN	Equipment Maintenance	Replaced contact finger immediately when encountered high Kelvin rejection	4	4	4	4	4		160
21	METHOD	Procedure	No trouble shooting guide for high Kelvin issues	1	9	4	1	4		154
8	MACHINE	Test Module	Misaligned unit position in contact finger	4	4	4		4		132
11	MACHINE	Test Module	High resistatnce measured during Test	1	4	4	4	4		130
4	MACHINE	Test Module	Overplunged during test	1	4	4	1	4	4	129
17	MATERIAL	Supplier	Supplied contact finger measurement is out of specs	4	1	4	4	1		115
19	MATERIAL	Untested Units	Untested units with minimum STO reading	1	1	4	4	1	4	105
9	MACHINE	Rotary 1	Misaligned unit position prior test	1	1	4	4	4		103
10	MACHINE	Test Module	Leads is not aligned w/ contact finger	1	1	4	4	1		85
22	METHOD	Procedure	No established procedure	1	4	1	1	4		85
5	MACHINE	Test Module	No define maximum motor down position	1	1	1		9		81
12	METHOD	Spare Parts Group	Excessive withdrawal of contact finnger	1	1	1		9		81
13	METHOD	Spare Parts Group	Not controlled during parts request in spare parts	4	1	1		1		63
14	METHOD	Spare Parts Group	No monitoring in contact finger consumption	1	1	1		1		33
18	MATERIAL	IQC	not enrolled in IQA	1	1	1		1		33

Figure 9. Cause and Effect Matrix

3.3.2 Pick head and Test Module Mechanism: RCM Methodology Approach

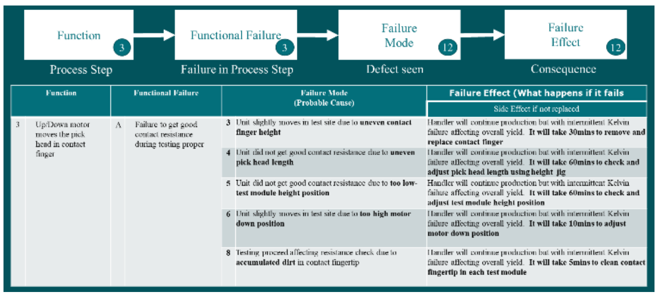
The team selected RCM (Reliability Centered Maintenance) approach on studying the mechanical part of Test equipment that will help reduce contact finger replacement. Reliability Centered Maintenance (RCM) is a methodology for determining the level of maintenance that's needed for a company to operate effectively in terms of overall cost, production availability, spare parts stockholding, and other factors. Focus on preserving system functions, rather than preserving equipment. RCM is used to define the appropriate maintenance task/s to be applied with reference to failure type of the Part in consideration. This is to improve the Part reliability and reduce the consequence/s as a result of the Part Failure event.

RCM Major Steps defined are the following:
(1) Determine the Assets Operating Context
The Test Module Sub-assembly is designated for testing of units. The RCM approach determines the parts that have

significant impact on kelvin test failure during electrical testing.
The sub-assembly parts that have impact in this project are Up/Down motor, Pick head, Pick head collet, contact finger and Contact module height as identified in machine operating context.

(2) RCM information worksheet shows the critical failure mode in this project, see figure 10

(1) Uneven Contact finger height
(2) Uneven pick head length
(3) Too high-test module height
(4) Too low motor plunge position
(5) Accumulated dirt on contact fingertip.



Function		Functional Failure		Failure Mode (Probable Cause)		Failure Effect (What happens if it fails) Side Effect if not replaced
3	Up/Down motor moves the pick head in contact finger	A	Failure to get good contact resistance during testing proper	3	Unit slightly moves in test site due to **uneven contact finger height**	Handler will continue production but with intermittent Kelvin failure affecting overall yield. **It will take 30mins to remove and replace contact finger**
				4	Unit did not get good contact resistance due to **uneven pick head length**	Handler will continue production but with intermittent Kelvin failure affecting overall yield. **It will take 60mins to check and adjust pick head length using height jig**
				5	Unit did not get good contact resistance due to **too low-test module height position**	Handler will continue production but with intermittent Kelvin failure affecting overall yield. **It will take 60mins to check and adjust test module height position**
				6	Unit slightly moves in test site due to **too high motor down position**	Handler will continue production but with intermittent Kelvin failure affecting overall yield. **It will take 10mins to adjust motor down position**
				8	Testing proceed affecting resistance check due to **accumulated dirt** in contact fingertip	Handler will continue production but with intermittent Kelvin failure affecting overall yield. **It will take 5mins to clean contact fingertip in each test module**

Figure 10. RCM Information Worksheet

3.3.2.1 Contact Finger Critical Measurement
Figure 11 shows the design and critical measurement of contact finger that has significant effect for good set-up of test module.

- Dowel hole (I and H): 2.00 ±0.20mm
- Contact finger height (O): 3.40 ±0.050 mm
- Tungsten tip length (R and S): 18.30 ±0.050 mm

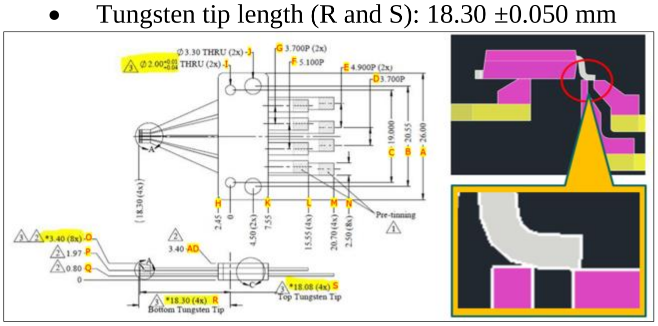


Figure 11. Design Measurement of contact finger

Delivered contact finger were subjected for IQC check and statistical shows that some contact fingers received are beyond critical measurement particularly in contact finger height and Tungsten tip length resulting to kelvin failure, as shown in Figure 12.

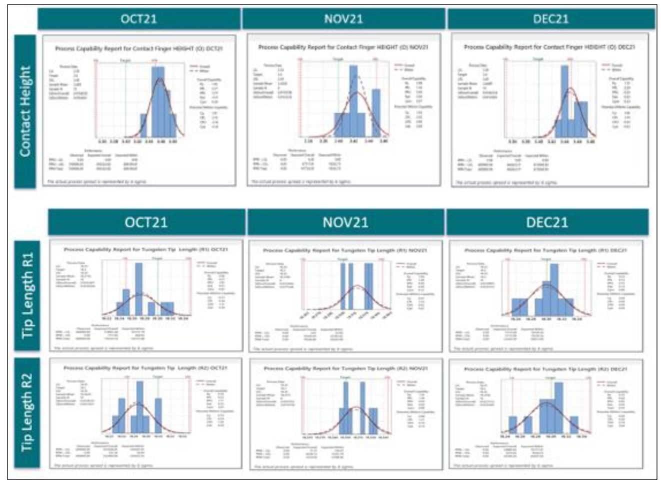


Figure 12. Capability Analysis of IQC Report for Delivered Contact Finger

3.3.2.2 Pick Head Length and Validation

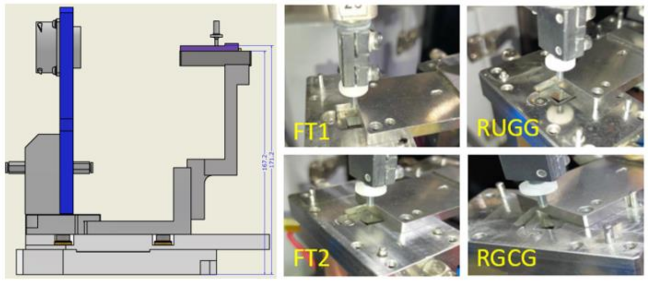
The ASM FT2026 Handler uses 26 pick head that should have the length of 60.50 ±0.020 mm. One of the pick head is below the minimum length resulting to under plunged during testing (see Figure 13).

Pickhead	Measurement	Tolerance (20 microns)	Pickhead	Measurement	Tolerance (20 microns)
9	60.50	0	20	60.50	0.00
8	60.52	-0.02	19	60.50	0.00
7	60.51	-0.01	18	60.50	0.00
6	60.25	0.25	17	60.50	0.00
5	60.50	0.00	16	60.50	0.00
4	60.49	0.01	15	60.50	0.00
3	60.49	0.01	14	60.50	0.00
2	60.49	0.01	13	60.50	0.00
1	60.52	-0.02	12	60.50	0.00
24	60.52	-0.02	11	60.50	0.00
23	60.50	0.00	10	60.50	0.00
22	60.50	0.00	26	60.50	0.00
21	60.50	0.00	25	60.50	0.00

Figure 13. Pick head Height Measurement

3.3.2.3 Contact Module Height and Motor Down Position Validation

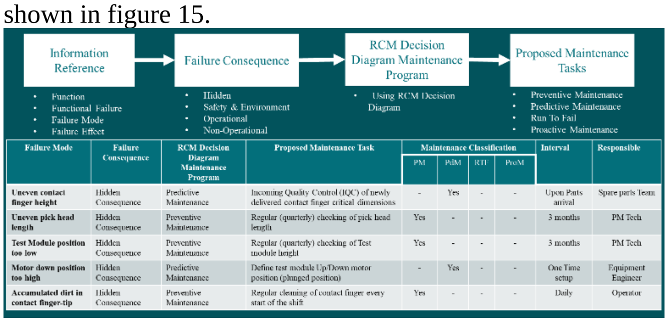
The desired idle contact module height is 173.0 mm while Motor down position is 171.3 mm using jig.
Actual contact module height for four (4) test module is lower than 0.16 mm to 0.32mm. while motor down position is over plunged by 0.25 to 0.30 mm, as shown in Figure 14.



Before	FT1	RUGG	RGCG	FT2
Test Module Height	171.1	168.8	171.3	169.7
Motor Down Position	3740	3360	3200	3150

Figure 14. Current Measurement of Machine Set-up of Test Module Height and Motor Down Position

(3) RCM Tasks Decision Diagram Worksheet
Required Maintenance Task, frequency and person who will perform the activity were specified in each failure mode as shown in figure 15.



Failure Mode	Failure Consequence	RCM Decision Diagram Maintenance Program	Proposed Maintenance Task	Maintenance Classification				Interval	Responsible
				PM	PdM	RTF	ProM		
Uneven contact finger height	Hidden Consequence	Predictive Maintenance	Incoming Quality Control (IQC) of newly delivered contact finger critical dimensions	-	Yes	-	-	Upon Parts arrival	Spare parts Team
Uneven pick head length	Hidden Consequence	Preventive Maintenance	Regular (quarterly) checking of pick head length	Yes	-	-	-	3 months	PM Tech
Test Module position too low	Hidden Consequence	Preventive Maintenance	Regular (quarterly) checking of Test module height	Yes	-	-	-	3 months	PM Tech
Motor down position too high	Hidden Consequence	Predictive Maintenance	Define test module Up/Down motor position (plunged position)	-	Yes	-	-	One Time setup	Equipment Engineer
Accumulated dirt in contact finger-tip	Hidden Consequence	Preventive Maintenance	Regular cleaning of contact finger every start of the shift	Yes	-	-	-	Daily	Operator

Figure 15. RCM Decision Diagram Worksheet

(4) Implement the defined Maintenance Task and Interval

3.4 Improve Phase

3.4.1 Maximum Limit of Contact Finger Withdrawal
Maximum withdrawal was limited to 4 pcs per transaction which is the maximum contact finger used in every handler. Data shows that there is no excessive withdrawal occurred after the implementation, as shown in Figure 16.

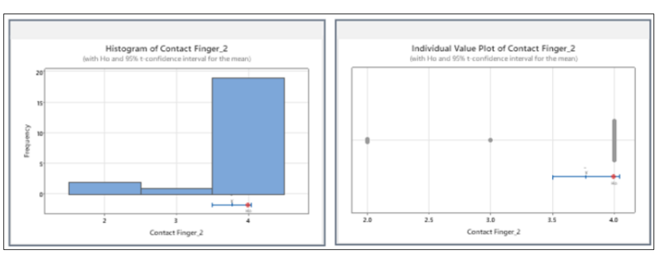


Figure 16. Histogram and Boxplot of Withdrawal of Contact Finger with Maximum Limit

3.4.2 IQC Contact Finger Measurement
The statistical contact measurement results exhibit out-of-specs contact finger measurement are still being received, but such are returned to supplier and are not used in production (See Figure 17).

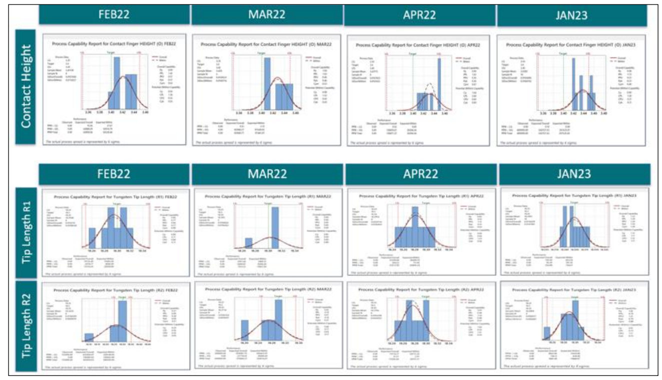


Figure 17. Capability Analysis of IQC Report of Newly Delivered Contact Finger

3.4.3 Design of Experiment
The define standard test module height and parameter for Motor down position become the factors in conducted DOE, determining the occurrence of kelvin test failure. (The table in) Figure 18 show the minimum and maximum settings for the define handler parameters. The experiment changes the motor down position setting by adding 60 step count and increment of 50 microns in height of Test Module Height to simulate the impact of these changes to kelvin test reading.

FACTOR	NAME	TYPE	LOW SETTING	HIGH SETTING
A	MOTOR DOWN POSITION	NUMERIC	2660	3320
B	TEST MODULE HEIGHT	NUMERIC	167	167.55

Figure 18. Design of Experiment for Motor Down Position and Test Module Height Minimum and Maximum value

Using response optimizer analysis, the optimized parameters are driven from the response of kelvin test failure and Standoff (STO) from motor down position and contact module height values. The upper gray scale refers to kelvin test failure occurrence with corresponding measurement for Test module height and Motor down position. While the gray scale at the bottom is the limit for the factors to avoid inducing Standoff in unit leads. Upon reaching the maximum side of Factor A and B, the set-up induced lead standoff reject (See Figure 19).

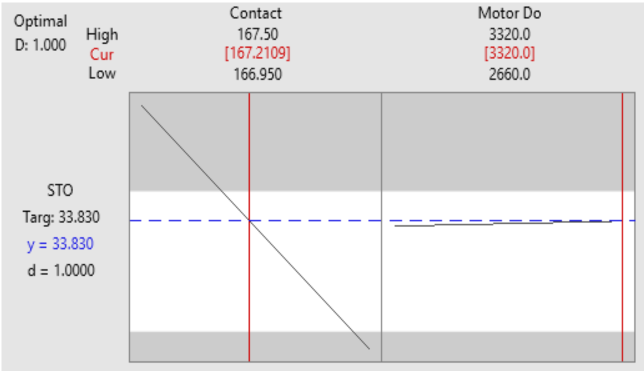


Figure 19. Design of Experiment Response Optimizer for parameter of Motor down position and Test module height vs Kelvin Test Failure

Figure 20 signifies the min/max motor down position of 2960 at fixed contact module height of 167.2109 in which the team define the standard tolerance for motor down position of ± 250. Figure 21 indicates the response of STO when the adjustment is applied in contact module height with fixed motor down position.

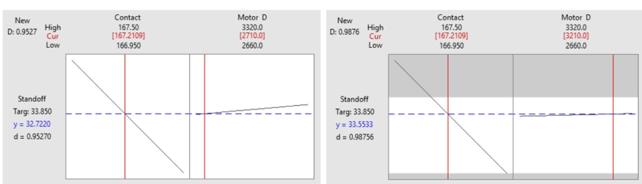


Figure 20. FT2 Fixed Contact Module Height vs Lead STO measurement.

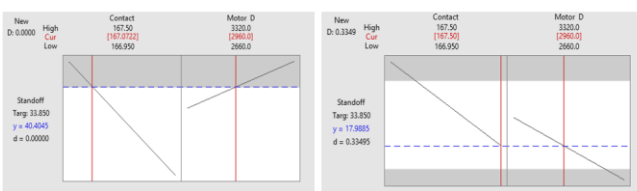


Figure 21. FT2 Fixed Motor down position vs Lead STO measurement

The interaction plot shows the outlier plot encircled denotes the response of having kelvin test failure if the motor down position is at 166.95 and motor down position at 2660. While the plot inside the box is the best set up of the motor position and contact module height without any significant change on package lead standoff with good kelvin reading (see Figure 22).

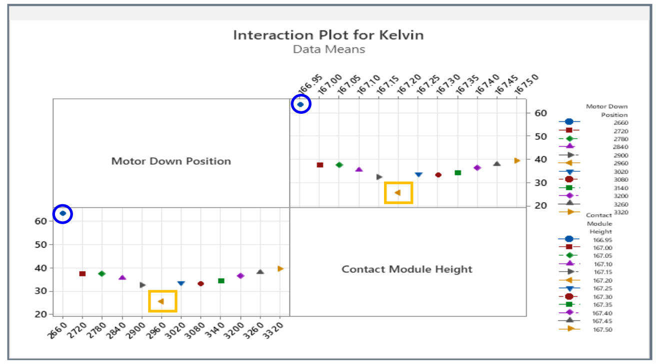


Figure 22. Interaction Plot of Kelvin Failure vs Motor down position and Test Module Height

4.0 RESULTS AND DISCUSSION

After the project completion, the results were collected and analyzed. The average quarterly consumption for the SOT1210 contact finger was reduced from 117 sets to 81 sets in the last 3 quarters, equivalent to 31% of total contact finger usage.

4.1 Contact Finger Consumption

Total of 117 contact finger sets were being consumed in the initial part of the project and was reduce to 81 sets after corrective actions implementation, shown in Figure 23.

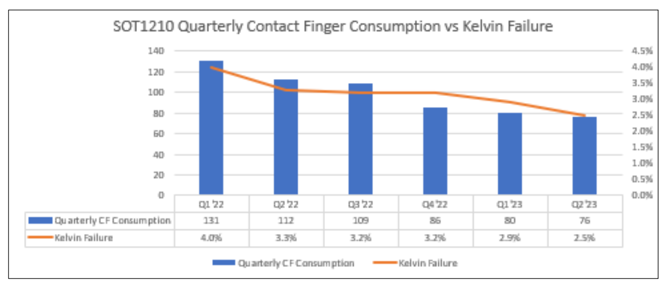


Figure 23. Quarterly Contact Finger Consumption

4.2 Contact Finger Cost Savings

This project significantly reduced the contact finger consumption that translates into cost savings amounting to 170K USD as shown in Figure 24.

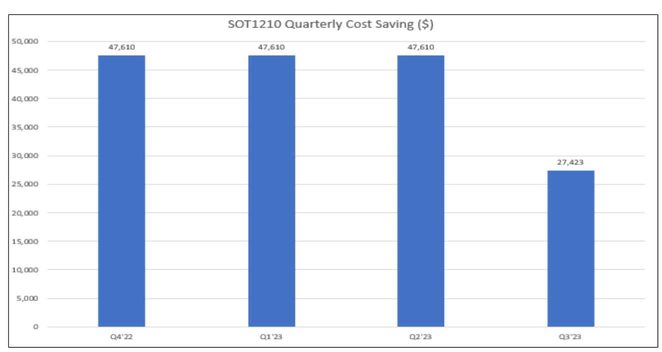


Figure 24. Quarterly Contact Finger Cost Savings

4.3 Kelvin Test Reading Monitoring
Shown in Figure 26, that kelvin reading significantly changed and becomes more stable after implementation of actions.

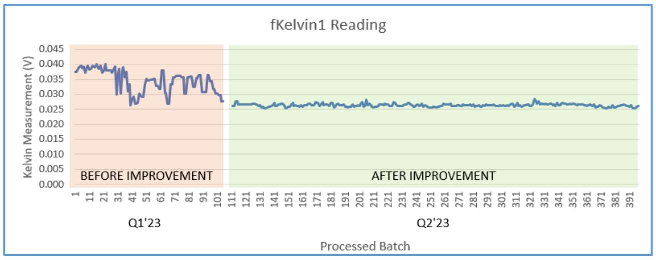
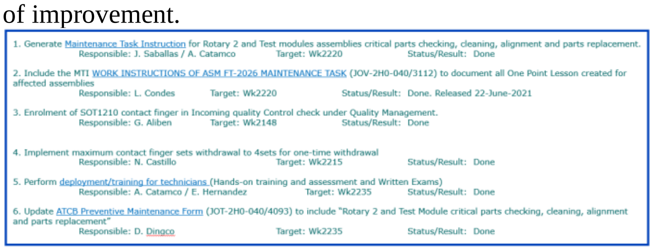


Figure 26. Kelvin (Contact) Test Measurement

4.4 Control Phase

4.4.1 Controls Documentation
Shown in Figure 25 the identified controls for the continuity of improvement.



1. Generate Maintenance Task Instruction for Rotary 2 and Test modules assemblies critical parts checking, cleaning, alignment and parts replacement.
Responsible: J. Saballas / A. Catamco Target: Wk2220 Status/Result: Done

2. Include the MTI WORK INSTRUCTIONS OF ASM FT-2026 MAINTENANCE TASK (JOV-2H0-040/3112) to document all One Point Lesson created for affected assemblies
Responsible: L. Condes Target: Wk2220 Status/Result: Done. Released 22-June-2021

3. Enrolment of SOT1210 contact finger in Incoming quality Control check under Quality Management.
Responsible: G. Aliben Target: Wk2148 Status/Result: Done

4. Implement maximum contact finger sets withdrawal to 4sets for one-time withdrawal
Responsible: N. Castillo Target: Wk2215 Status/Result: Done

5. Perform deployment/training for technicians (Hands-on training and assessment and Written Exams)
Responsible: A. Catamco / E. Hernandez Target: Wk2235 Status/Result: Done

6. Update ATCB Preventive Maintenance Form (JOT-2H0-040/4093) to include "Rotary 2 and Test Module critical parts checking, cleaning, alignment and parts replacement"
Responsible: D. Dingco Target: Wk2235 Status/Result: Done

Figure 25. Documentation of Identified Controls

4.4.2 SPC Implementation
Statistical Process Control is applied in monitoring parameters that will lead to special event in kelvin failure as shown in Figure 27.

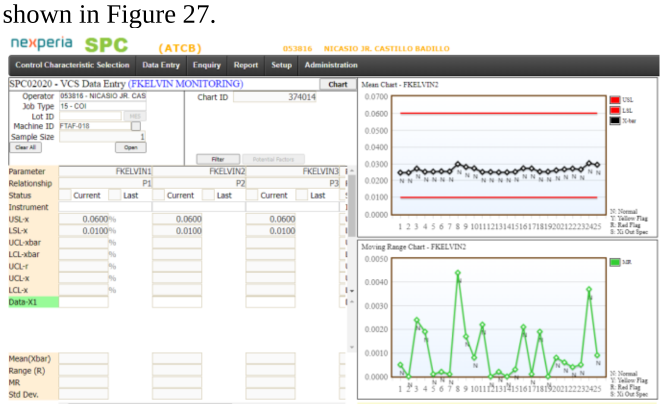


Figure 27. SPC Chart – Test Kelvin Failure

5.0 CONCLUSION

Using the systematical and analytical approach of Six Sigma, the robust solution and controls on the identified root cause. Problem is prevented to re-occur by applying right maintenance task using RCM methodology. The team has analyzed the failure of each part/module and formulated the corresponding solution. Contact finger quality check prior usage will not allow production to use out of specification tool. Standardizing the test module height and pick up head length will ensure that there will be no variability on handler set up. These actions resulted to 31% reduction of contact finger consumption equivalent to 170K USD savings.

6.0 RECOMMENDATIONS

The authors highly recommend the use of analytical approach of Six Sigma for the in-depth analysis of all potential root causes combined with Reliability Centered Maintenance ("RCM") methodology in solving machine related problems and placing proper maintenance task and controls.

7.0 ACKNOWLEDGMENT

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