MEMS MV8P WIRE PROXIMITY PPM REDUCTION

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ABSTRACT

As one of the critical parts of the wire bonding process, loop formation will be discussed in this technical paper, focusing on how the optimization of loop formation reduces the wire proximity PPM for the MEMS MV8P device. Using problem-solving methodology, the team was able to identify and analyze the root causes of wire proximity rejects during the wire bonding process through DMAIC approach.

1.0 INTRODUCTION

The MEMS product is one of the company's high-volume production lines. The top device in this product line is the MV8P. The ramp-up of this device is very challenging. Department KPIs should be met by implementing all necessary controls in the line to achieve the target yield.

Figure 1 shows the MEMS MV8P PPM trend of wire proximity in the wire bonding process, averaging 350 PPM from WWK2418 to WWK2431. The target is to reduce the wire proximity PPM level to 174 PPM by the end of Q4 2024.

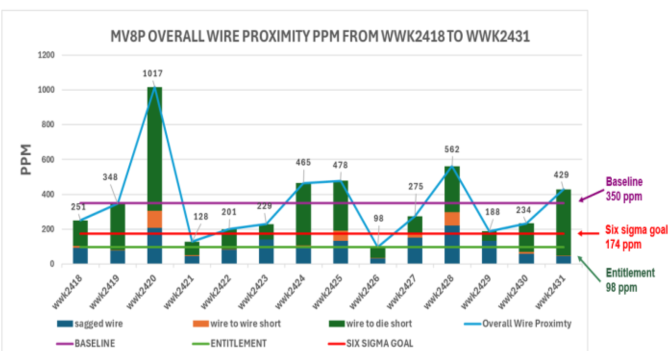


Fig. 1. MV8P Wire Proximity PPM trend WWK2418 to WWK2431.

2. 0 REVIEW OF RELATED WORK

"Not Applicable."

3.0 METHODOLOGY

3.1 Define

Overall, wire proximity is the top defect contributor in MEMS wire bond yield. All reject codes related to wire proximity, such as sagged wire, wire-to-wire short, and wire-to-die short, are combined to determine the wire proximity PPM as the primary metric as shown in Fig.2

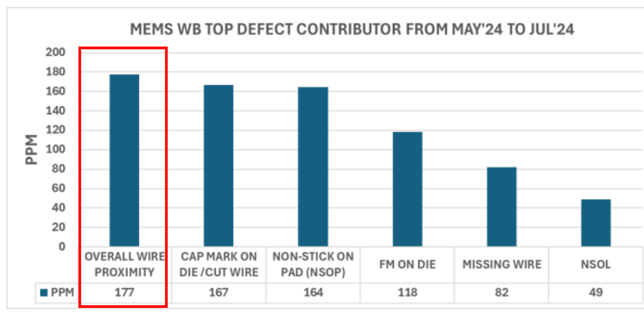


Fig. 2. MEMS Wire bond Top defect contributor from MAY'24 to JUL'24

Analyzing the yield detractor, the top device contributor for wire proximity rejects is the MV8P, as shown in Fig. 3.

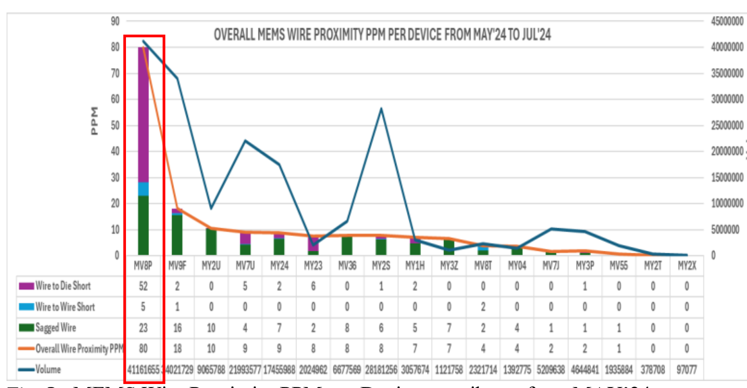


Fig. 3. MEMS Wire Proximity PPM per Device contributor from MAY'24 to JUL'24

Based on line data, the top contributor to MV8P wire proximity defects is wire-to-die short, followed by sagged wire and wire-to-wire short, as shown in Fig. 4.

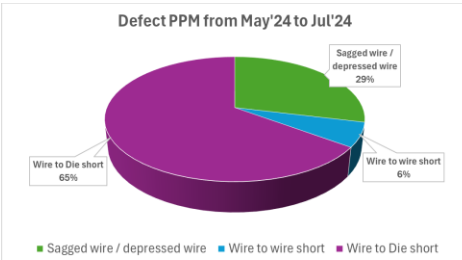


Fig. 4. MV8P Wire Proximity contribution from MAY'24 to JUL'24

3.1.1 What are the Types of Wire Proximity at Wirebond?

Sagged Wire is typically a vertical deflection of the Wire. This is rejected for wire gaps that come closer than 2 wire diameters to the substrate, unprotected die area, or die edge in the Z-axis.

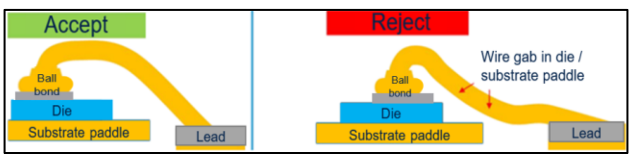


Fig. 5. Sagged Wire defect signature.

Wire-to-wire short is typically a lateral deflection of the wire. This is rejected if gaps come closer than 2 wire diameters to another wire.

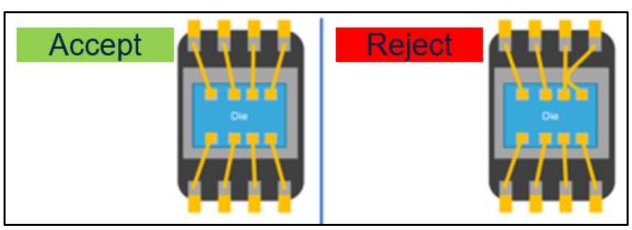


Fig. 6. Wire-to-wire short defect signature.

Wire-to-die short occurs when the wire has already touched the die surface, die edge.

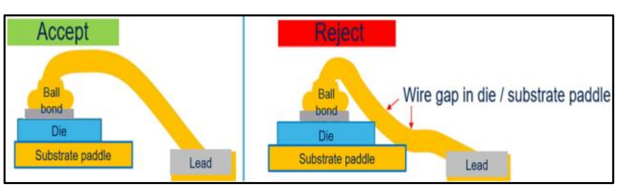


Fig. 7. Wire-to-die short defect signature.

3.2 Measure

Below Macro map shows the process of MEMS MV8P device from Assembly to Test and Finish where Wirebond is the focus of this project as shown in Fig.8

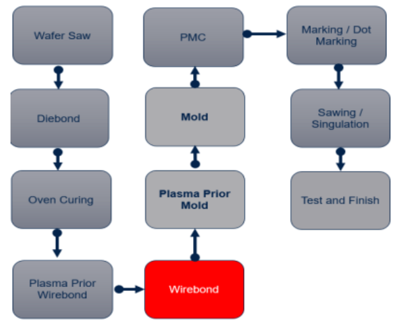


Fig. 8. MEMS MV8P Process Macro Map.

Based on the detailed process flow, the critical process steps are material preparation, program/recipe loading, parameter verification, machine setup using dummy units, and wire bonding, as shown in Fig 9.

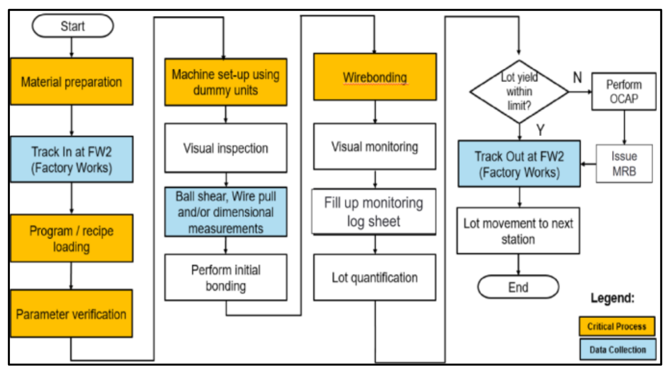


Fig. 9. Wirebond detailed process map.

3.2.1 What is Wirebond Process?

Wire bonding is a process of interconnecting internal chip circuitry using fine wires to the substrate or lead frame.

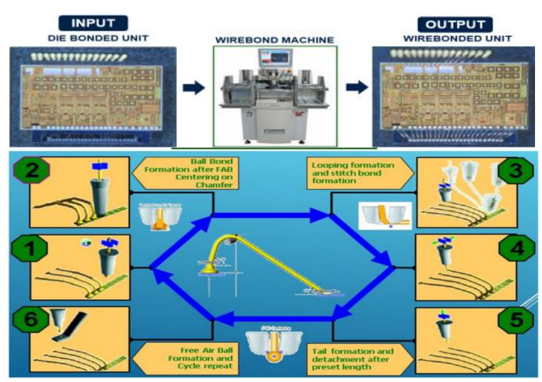


Fig. 10 Wire bonding process flow

3.2.2 Identification of Potential Rootcause

Shown below is the fishbone diagram of wire proximity at wirebond. The team identified 14 potential root causes, as shown in Figure 12.

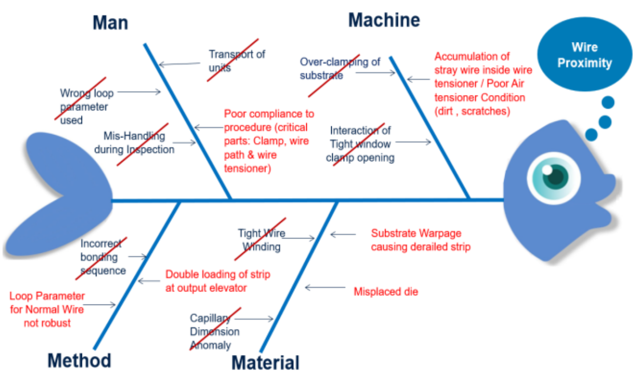


Fig. 12. Fishbone diagram.

Using Cause and Effect diagram there are 6 X potential root cause that need to be address as shown in Table 1.

Table 1. Cause and Effect diagram.

				Wire Proxinity	Loop Height									
			Is Y Continuous / Discrete?	Discrete	Continuous									
			Specification Limits (for Y)	0.00%	(70 um - 100 um)									
			Customer Priority	10	10									
S.No	Process Step	Input	Characteristic of Input (KPIV / X)	Rating	Rating	Total	Is X Continuous / Discrete?	Operating Range (for X)	Unit of Measure (UOM)	Count 3's	Count 9's	X Selected / Discarded?	X Selected / Discarded?
1	fishbone diagram	Poor compliance to procedure (critical parts: Clamp)	Wire Clamp cleaning procedure	3	3	60	Discrete	cleaning every change of gold wire / change capillary	N/A	2	0	Select the X	Select the X
2	fishbone diagram	Accumulation of stray wire inside Wire tensioner / Poor Air tensioner Condition (dirt , scratches)	Wire tensioner condition	3	3	60	Discrete	Cleaning of wire path assembly every 13 weeks preventive maintenance.	condition	2	0	Select the X	Select the X
3	fishbone diagram	Mis-placed die	Die placement	3	3	60	Discrete	X,Y die placement criteria	micron	2	0	Select the X	Select the X
4	fishbone diagram	Double loading of strip at output elevator	output elevator configuration	3	3	60	Discrete	none	N/A	2	0	Select the X	Select the X
5	fishbone diagram	Substrate Warpage Causing Derailed Strip	Substrate condition	3	3	60	Discrete	4.0 MM allowable warpage	MM	2	0	Select the X	Select the X
6	fishbone diagram	Loop Parameter for Normal Wire not robust	Robustness of Normal Wire Loop Formation	9	9	180	Discrete	(70 um - 100 um)	visual inspection / micron	0	2	Select the X	Select the X

3.2 .3 Quick Wins

There are 5 activities that help address 5 potential causes and contribute to the current wire proximity PPM performance, as, shown in Fig. 13 –17.

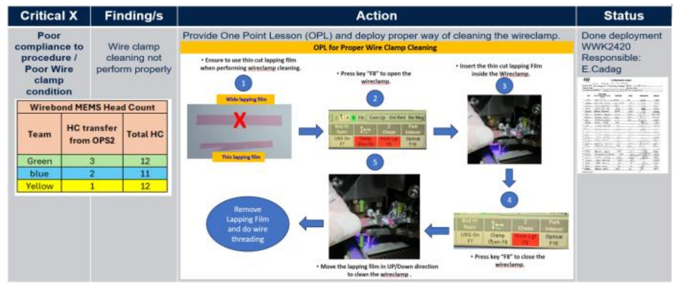


Fig. 13 Quick wins # 1.

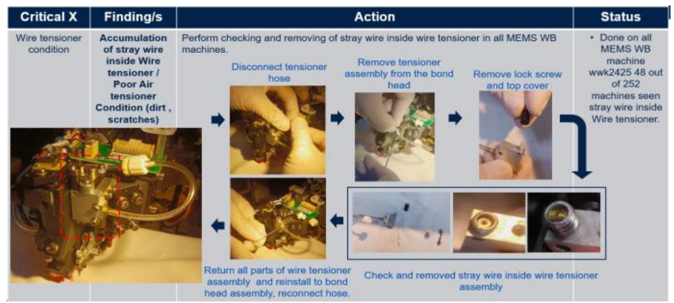


Fig. 14 Quick wins # 2.

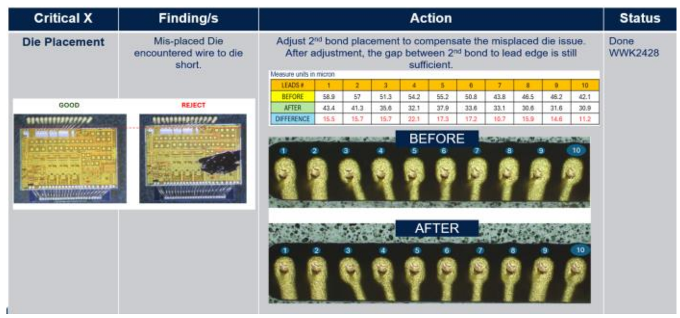


Fig. 15 Quick wins # 3.

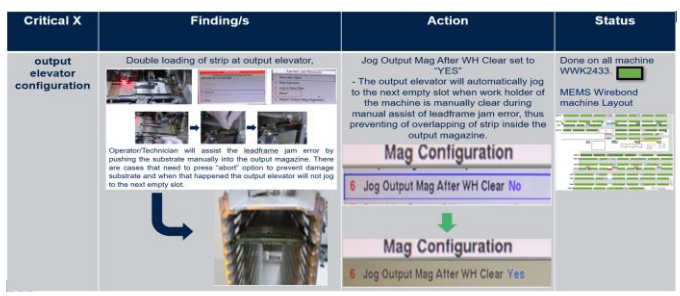


Fig. 16 Quick wins # 4.

Fig. 17 Quick wins # 5

Fig. 18 shows the wire proximity PPM trend after implementation of the 5 Quick wins activities.

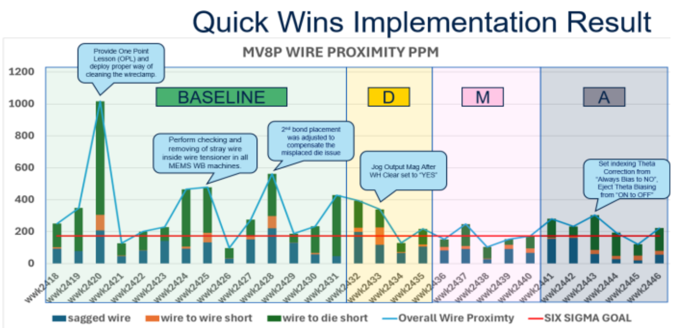


Fig. 18 Quick wins implementation result.

3.3 Analyze

Table 2 shows the validation plan for the remaining potential root cause.

Table 2. validation plan for potential root cause.

Y (or mini Y)	Unit of Measure	Y treated as	X	True nature of X	Range of X, if continuous	Levels of X, if discrete or converted into discrete	Hypothesis Statement		Statistical Test	Beta	Alpha	Sample Size
							Null Hypothesis	Alternative Hypothesis				
Loop Height	microns	Continuous	Reverse motion setting	Continuous	(2, 3, 3.8 mils)	Reverse Motion is 2 mils vs 3 mils vs 3.8 mils	Ho = P Loop height using reverse motion 2 mils = 3 mils = 3.8 mils	Ha = P Loop height using reverse motion 2 mils < 3 mils > 3.8 mils	ANOVA	0.10	0.05	8 units
Wire Proximity	occurrence	Discrete	Robustness of Normal Wire Loop Formation	Discrete	N/A	Reverse Motion is 3.8 mils vs Reverse Motion is 3 mils	Ho= P Wire Proximity Occurrence of Reverse Motion 3.8 mils = P Wire Proximity Occurrence of Reverse Motion 3 mils	Ha=P Wire Proximity Occurrence of Reverse Motion 3.8 mils < P Wire Proximity Occurrence of Reverse Motion 3 mils	2 Proportion Test	0.10	0.05	2,043 units

3.3.1 Statistical Testing of Reverse Motion Setting.

Fig. 20 shows the comparison of loop formation with three reverse motion settings. At 3 mils reverse motion, there is a small change in reverse payout, while at 2 mils reverse motion, there is a noticeable change in reverse payout and lower loop height compared to the current setting.

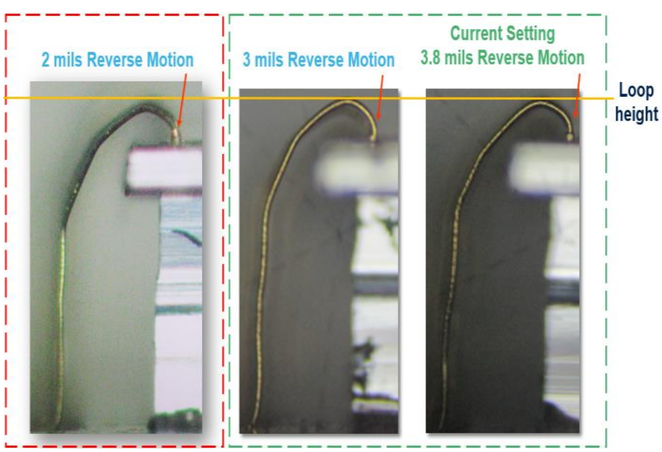


Fig. 20 comparison of loop formation with three reverse motion settings.

Fig. 21 Statistical testing of three reverse motion setting.

3.3.2 Practical Conclusion:

At 95% confidence level, loop height of 2 mils reverse motion is significantly lower than 3 mils and 3.8 mils reverse motion. Thus, reject Null Hypothesis, as shown in Fig 21.

3.3.3 Statistical Testing of Robustness of Loop Formation.

Fig. 22 Statistical testing of robustness of loop formation.

3.3.4 Practical Conclusion:

At 95% confidence level, there is a significant difference in wire proximity occurrence if the Reverse Motion is 3.8 mils and if the Reverse Motion is 3 mils. Thus, reject Null Hypothesis, as shown in Fig. 22.

3.3.5 Phase Conclusion.

- Loop height of 2 mils reverse motion is significantly lower than 3 mils and 3.8 mils reverse motion.
- Using 3 mils reverse motion is statistically better than using 3.8 mils reverse motion in terms of wire proximity occurrence.

3.4 Improved

Potential Problem Analysis was used to determine the risks prior to implementing the best solution to ensure that the best solutions will not incur new problems as shown in Table 3.

Table 3. Potential Problem Analysis.

Item	Problem	Validated KPIV / Cause	Preventive Action	Responsible	Potential Problem Analysis	Counter Measure	Status
1	Wire Proximity	Loop Parameter for Normal Wire not robust	Adjust reverse motion from 3.8 mils to 3 mils	E.Cadag	• Decrease UPH • Wire Sweep at Mold • Out of Specification and Out of Control in loop height • Wire Proximity Detected at Test and Finish	• UPH time study • Verification at mold after adjustment • Monitor SPC data trend after adjustment • Monitor Test Performance of 5x lead lots	Done WWK2446

3.4.1 Description of Preventive Action

The adjusted value was based on the KNS Iconn machine's recommended parameter setting. The value of reverse motion is based on 60% to 80% of the kink height value, as recommended. If the value of reverse motion is too close to the kink height value, it will cause the wire to be dragged in the reverse motion direction, resulting in wire proximity rejection, as shown in Fig 23.

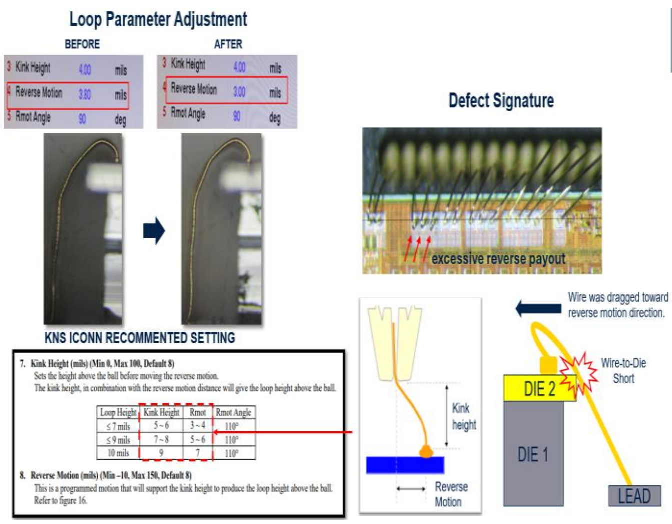


Fig. 23 Loop parameter Adjustment.

3.4.2 Statistical Testing of Machine Variation after Adjustment.

Y (or mini Y)	Unit of Measure	Y treated as	X	True nature of X	Range of X, if continuous	Levels of X, if discrete or converted into discrete	Hypothesis Statement: Null Hypothesis	Hypothesis Statement: Alternative Hypothesis	Statistical Test	Beta	Alpha	Sample Size	p-value	Decision
Loop Height	microns	Continuous	Machine Variation	Continuous	(70 – 100) mincron	Loop height using 3 mils reverse motion of FWB1549 vs FWB1550 vs FWB1553 vs FWB1554 vs FWB1555 vs FWB1627	Ho = P Loop height using 3 mils reverse motion of FWB1549 = FWB1550 = FWB1554 = FWB1553 = FWB1555 = FWB1627	Ha = P Loop height using 3 mils reverse motion of FWB1549 ≠ FWB1550 ≠ FWB1554 ≠ FWB1553 ≠ FWB1555 ≠ FWB1627	ANOVA	0.10	0.05	6 units	.9745	Failed to reject Ho

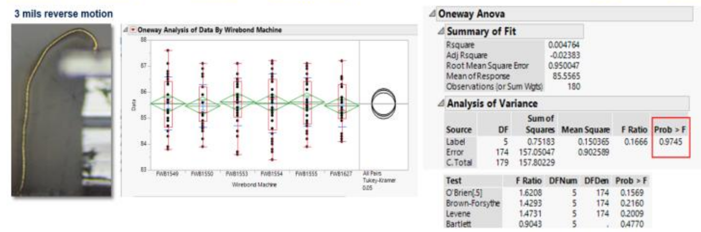


Fig. 24 Statistical Test for Machine Variation.

3.4.3 Practical conclusion:

At 95% confidence level, there is a no significant difference between 6x machine using 3 mils Reverse Motion. Thus, failed to reject Null Hypothesis, as shown in Fig. 24.

3.4.4 Validation of UHP after adjustment:

Table 4. shows Machine UPH after loop parameter adjustment is 448.79 still meeting the declared UPH of 441.

Table 4. Machine UPH:

❑ MV8P UPH Baseline from IE

PLE_C	IPT	MSS	BRH	SEQ	STP	STY	UPH	UTIL	CAP K/D	MTE	MTE_D	WCR	WCR_D	RNK	ADCS	RTG	CRI	LOT_SIZE BASE	LOT_S
MV8P14	77AA*MV8PBAE	29	MAIN	11	FWB	WB_AU	441	79	8.1	ICONN<3X3	WB-KS-ICONN	W0401	LGA MEMS/WB	24	DM00383689	ALGA2DA8T5	1	28980	LOT-A
MV8P14	77AA*MV8PBAE	29	MAIN	11	FWB	WB_AU	441	79	8.1	ICONN<3X3	WB-KS-ICONN	W0401	LGA MEMS/WB	24	DM00383689	ALGA2DA8T6	1	28980	LOT-A

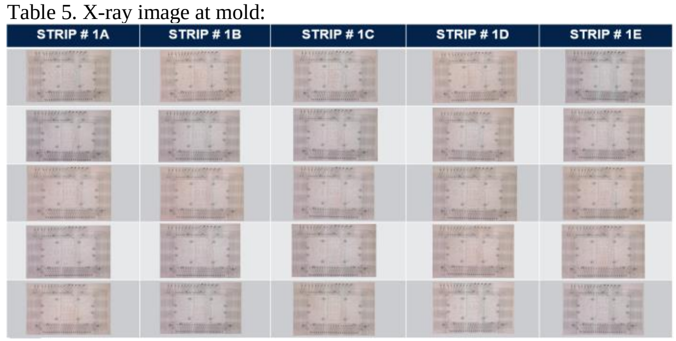
❑ Actual UPH Time Study After Adjustment

Station	PACKAGE:	DEVICE TYPE:	MACHINE TYPE	Wire Type	MACHINE ID	Strip Density	# of Wires	UPH	UTIL	EFF	CAP (k/d)	GAP
WIRE BOND	VFLGA2.5X3X86 14L P.5 L.475X.25	77CC*MV8PBAE	KNS ICONN	Au	FWB1497	1610	39	448.79	79%	97%	8.25	-0.13%

3.4.5 Validation of Loop Formation at MOLD after Adjustment:

Table 5. shows no wire sweep seen after random X-ray inspection at mold.

Table 5. X-ray image at mold:



3.4.5 Validation of Loop height after Adjustment:

No occurrence of Out of Specification and out of Control for MV8P after adjustment of Reverse Motion to 3 mils, as shown in the Statistical Process Control data trend Fig. 25

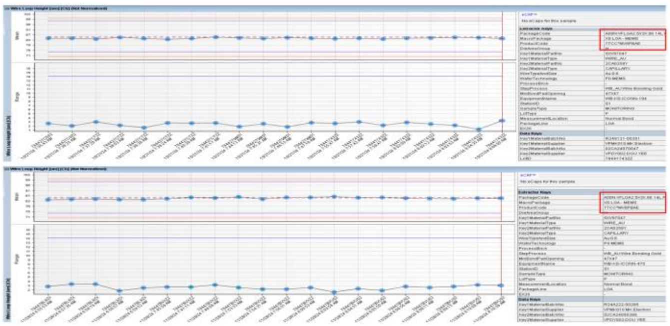


Fig. 25 Statistical Process Control data trend.

3.4.6 Monitoring the performance of lead lots during the Test and Finish phase:

No Wire Proximity reject was detected in the 5x lead lots based on their test performance, as shown in Table 6.

Table 6 lead lots performance at Test and Finish.

REVERSE MOTION IS 3 MILS LOT ID	LOT QTY	WIRE PROXIMITY REJECT AT WIREBOND PROCESS	WIRE PROXIMITY REJECT DETECTED AT TEST AND FINISH
784459YL02	27907	0	0
784459NPZX	39943	0	0
784459U701	28589	0	0
784459U9ZZ	40317	0	0
78445A3F02	28735	0	0
TOTAL	165491	0	0

4.0 RESULTS AND DISCUSSION

In WWK2504, the MV8P Wire Proximity is 30 PPM below the Six Sigma goal of 174 PPM. The PPM was reduced from an average of 350 PPM in WWK2418 – WWK2431 to an average of 187 PPM in WWK2447 – WWK2504, representing a 47% improvement, as shown in Fig 26.

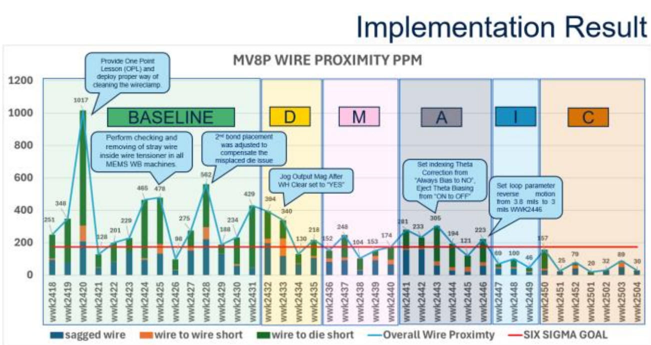


Fig. 26 Implementation result.

From being the top one defect contributor in Wirebond Process Yield the Overall Wire Proximity drop down to the top four defect contributor, as shown in Fig. 27.

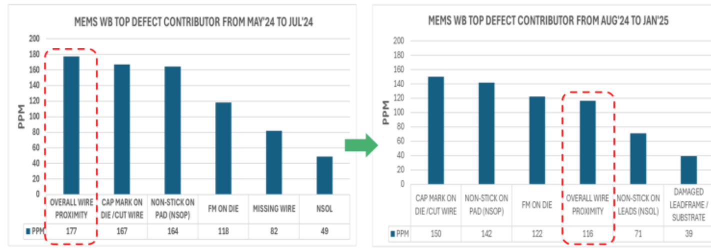


Fig. 27 Implementation result.

MV8P is still the top device contributor having the highest volume but with decreased in PPM from 80 PPM in May'24 – Jul'24 to 29 PPM Nov'24 to Jan'25 or 64% improved, as shown in Fig. 28.

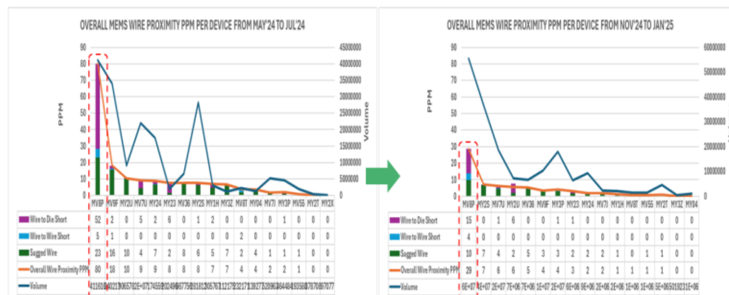


Fig. 28 Implementation result.

The IE Certified Annualized actual and forecasted cost savings for this project, from December 2024 to November 2025, were calculated to be 4.22 KUSD for the MEMS MV8P device.

Table 7. Annualized Cost Savings

Project: MEMS COMBINE WIRE PROXIMITY
IE Owner: EDROZO,ANGELO CARLO

Monthly Forecast Savings	Dec'24 (Actual)	Jan'25 (Actual)	Feb'25 (Forecasted)	Mar'25	Apr'25	May'25	Jun'25	Jul'25	Aug'25	Sep'25	Oct'25	Nov'25	Total
Input Volume (K)	12,835	11,551	11,979	36,814	24,055	25,385	29,175	28,033	27,910	31,960	27,592	26,281	293,569
Defect rate (%)													
Baseline	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	0.0297%	
Actual	0.0083%	0.0046%	0.0186%	0.0186%	0.0186%	0.0186%	0.0186%	0.0186%	0.0186%	0.0186%	0.0186%	0.0186%	
Improvement	0.0214%	0.0252%	0.0111%	0.0111%	0.0111%	0.0111%	0.0111%	0.0111%	0.0111%	0.0111%	0.0111%	0.0111%	
Scrap qty reduced (K)	2.75	2.91	1.33	4.08	2.66	2.81	3.23	3.10	3.09	3.54	3.06	2.91	
Device Cost ($)	0.1170	0.1196	0.1196	0.1196	0.1199	0.1199	0.1199	0.1182	0.1182	0.1182	0.1193	0.1193	
Savings (K$)													
Monthly	0.32	0.35	0.16	0.49	0.32	0.34	0.39	0.37	0.37	0.42	0.36	0.35	4.22
Cumulative	0.32	0.67	0.83	1.32	1.63	1.97	2.36	2.73	3.09	3.51	3.87	4.22	

RESPONSIBILITY MATRIX	IE
Actual + Forecasted Cost Savings (K$)	4.22
Project Owner	EMMANUELLE CADAG

IE CERTIFIED

4.1 Team Learning:

By following the machine-recommended parameter settings and capabilities, the team was able to reduce the occurrence of wire proximity rejects.

4.2 Control:

The team listed the needed documentation, such as program saving to e-star and RMS, which were successfully updated and saved, as shown in Table 8.

Table 8. Documentation.

Item	Action Item	Due Date	Responsible	Doc # / Rev	Remarks
1	Update Looping parameter of MV8P Save via uploading on e-Star / RMS (on KNS ICONN Bonders)	WWK2451	Emman Cadag	E-STAR / RMS	DONE Implemented 

5.0 CONCLUSION

In WWK2504 the MV8P Wire Proximity is 30 PPM below six sigma goal of 174 PPM, PPM was reduced from average of 350 PPM in WWK2418 – WWK2431 to average of 187 PPM WWK2447 – WWK2504 or 47% improvement. This improvement also reduces the value-added activity of the operator in visual inspection for the defect it produces.

6.0 RECOMMENDATIONS

Set Reverse Motion value of Normal Wire based on 60% to 80% of the kink height value. It is recommended to fan-out these learnings to other MEMS devices that has normal wire.

7.0 ACKNOWLEDGMENT

The team would like to thank all the Trainor's and Black Belts who conducted our Green Belt training for their shared knowledge and expertise.

Special thanks to Sir Conrado Villanueva, Ma'am Marianne Mayol, Ma'am Rhoda Yu and to our project sponsors for the awesome support guiding the team to finish this DMAIC Project.

8.0 REFERENCES

1. KNS Iconn Wirebond Process Parameter Manual

9.0 ABOUT THE AUTHORS

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