REDUCTION OF MACHINE FAILURE THROUGH ERROR PROOFING METHODOLOGY

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ABSTRACT

The goal of this paper is to meet the Overall Equipment Efficiency (OEE) target by analyzing the Equipment Unscheduled Downtime (TEUD).

Using DMAIC approach, the team define, measure and analyze the TEUD detractors. The analysis led to reduced machine error and the modification of machine parts to improve machine performance resulting to 23.5% OEE improvement.

1. 0 INTRODUCTION

Instrip Film Frame Testing is one of the high-volume productions for our company, STMicroelectronics, Inc. OEE or Overall Equipment Efficiency is the focus but it's not consistently hitting with an average of 51.9% vs. 70% target. See Figure 1. Overall Equipment Efficiency trend.

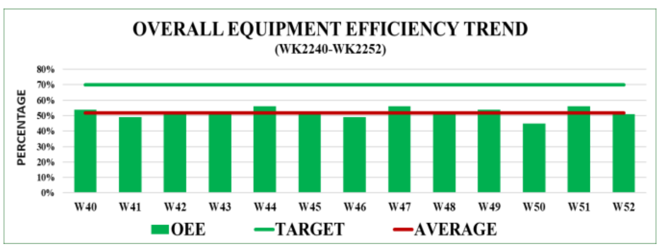


Figure 1. Overall Equipment Efficiency Trend

Further stratification shows that TEUD shaded in red is the top detractor with an average of 22.1% as seen in Figure 2.

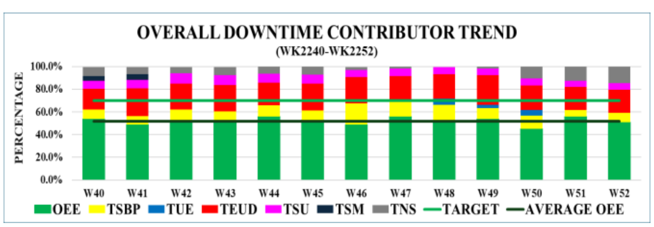


Figure 2. Overall Downtime Contributor Trend

Equipment Unscheduled Downtime trend top 2 downtime contributes a total of 86% namely, Auto-alignment Failure and Material Handler (MH) error shown in Figure 3.

One of the detractors in the TEUD occurrences that need to be focused on, implement corrective and preventive actions.

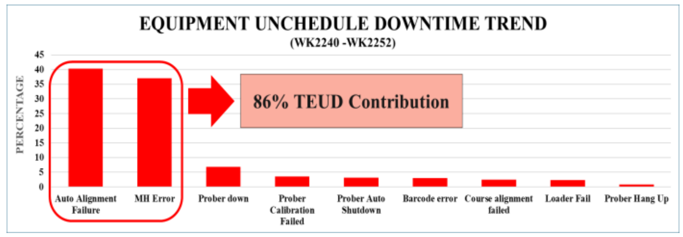


Figure 3. Equipment Unscheduled Downtime Trend

1.1 Auto-alignment Failure

This failure occurred when the film frame was not centered to the chuck during placement of gripper-arm.

From the cassette, gripper-arm will pick a film frame and it will transport to the chuck then perform auto-alignment process, as shown Fig 4. Film Frame loading to chuck/ Centering happened. Due to placement error, auto-alignment failure was encountered.

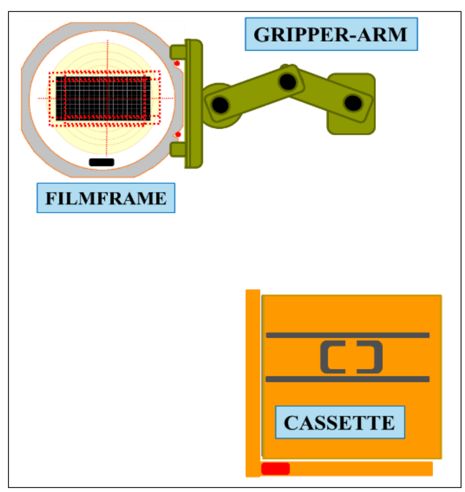


Fig 4. Film Frame Loading to Chuck/ Centering happened.

1.2 Material Handler Error

This error occurred when the gripper-arm failed to hold or transport the film frame to the next station. Gripper-arm is unable to perform its function causing machine error. Shown in Fig 5. Gripper-arm assembly parts.

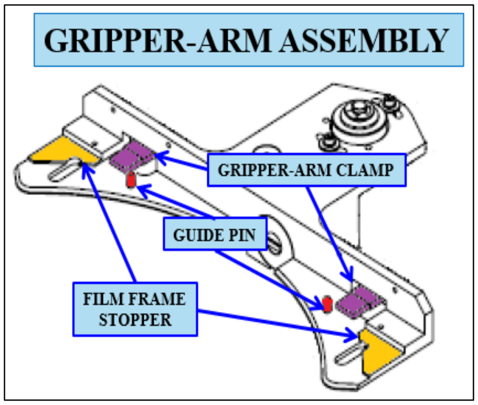


Figure 5: Gripper-arm Assembly Parts

Other factors that contributed to the top 2 downtimes were addressed and validated.

The team also focuses on the "Gripper-arm Belt Tension", see Figure 6. "Gripper-arm Belt Tension" and Figure 7. 'Film-Frame Design".

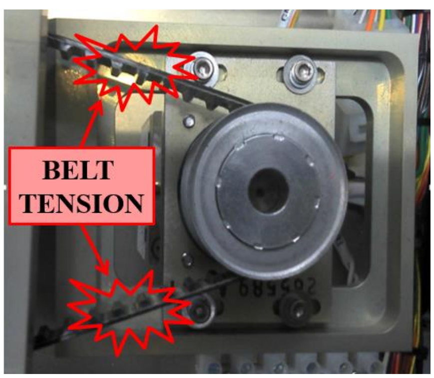


Fig. 6. Gripper-arm Belt Tension

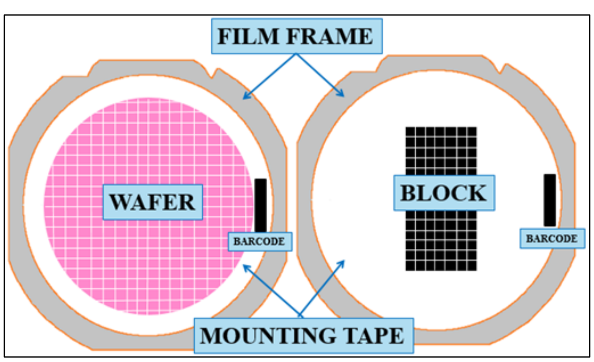


Figure 7. Film Frame Assembly

2. 0 REVIEW OF RELATED WORK

"Not Applicable"

3.0 METHODOLOGY

3.1 Define Phase

The Macro Map below (Figure 8) shows that the project scope focuses on Film Frame Testing.

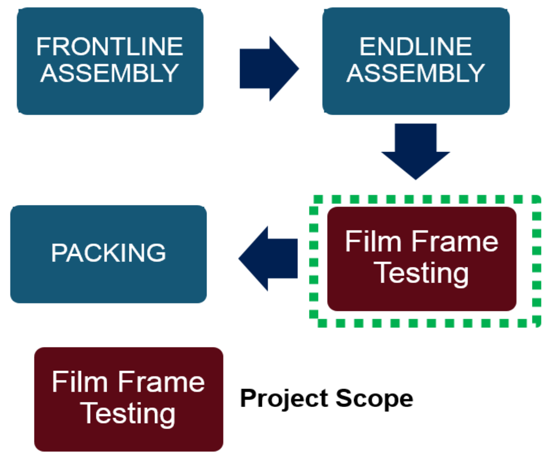


Figure 8. Macro Map

3.2 Measure Phase

UNDERSTANDING THE MACHINE PROCESS:

Shown Fig 9 below is the process flow of machine. It shows the process where error and failure were frequently encountered.

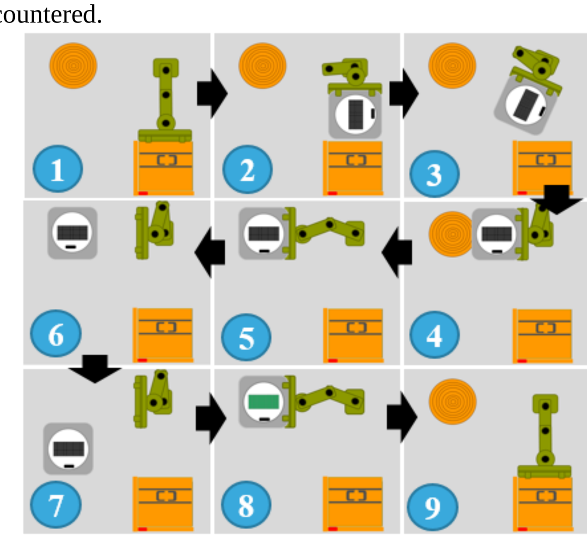


Figure 9. Machine Process Flow

> Steps 1 to 6	- Film Frame Loading Process
> Step 7	- Film Frame Auto-alignment
> Steps 8 to 9	- Film Frame Unloading Process

Using the Input / Output (I/O) Worksheet, we were able to identify Key Process Input Variables (KPIV's) in the above machine process flow, as shown in Table 1.

Table 1: Identifying Input Variables

		Process Inputs (KPIV's)				
Process Step	VA/ NVA	Type of Input	Input	Characteritic of Input (KPIV / X	C / N	Specification
Gripper-arm Loading of Film Frame from Cassette to Chuck top	VA	Equipment/ Infrastructure	Gripper-arm Rho Motor	Belt Tension	Controlable	No Error
	VA	Equipment/ Infrastructure	Gripper-arm Theta Motor	Belt Tension	Controlable	No Error
Auto-Alignment	VA	Raw Materials/ Infrastructure	Film Frame Ring	Film Frame Notch	Controlable	No Error
	VA	Raw Materials/ Infrastructure	Wafer/ Block	Sawing Variation	Controlable	Identical Film Frame Notch
	VA	Raw Materials/ Infrastructure	Wafer/ Block	Strip Lay-out	Controlable	2nd Reference Target
Gripper-arm Unloading of Film Frame from Chuck tor to Cassette	VA	Equipment/ Infrastructure	Gripper-arm Rho Motor	Belt Tension	Controlable	No Error
	VA	Equipment/ Infrastructure	Gripper-arm Theta Motor	Belt Tension	Controlable	No Error
	VA	Raw Materials/ Infrastructure	Film Frame Ring	Film Frame Planarity	Controlable	3.0mm Planarity
	VA	Raw Materials/ Infrastructure	Film Frame Notch	Design	Not Controlable Noise	No Error

Then we use the Cause & Effect Matrix, wherein from 9 KPIV's, they were trimmed down to 6 based on the rating of the relation between the I/O variables, shown in Table 2.

Table 2: Cause & Effect Matrix

			1			
		Is Y Continuous/ Discrete?	TEUD Downtime			
		Specification limit (for Y)	% Downtime			
		Costumer Priority	10			
Process Step	Input	Characteritic of Input (KPIV / X		Total	Count 9's	X Selected / Discarded?
Gripper-arm Loading of Film Frame from Cassette to Chuck top	Gripper-arm Rho Motor	Belt Tension	9	90	1	Select the X
	Gripper-arm Theta Motor	Belt Tension	9	90	1	Select the X
Auto-Alignment	Film Frame Ring	Film Frame Notch	9	90	1	Select the X
	Wafer/ Block	Sawing Variation	9	90	1	Select the X
	Wafer/ Block	Strip Lay-out	1	10	0	Discard the X
Gripper-arm Unloading of Film Frame from Chuck tor to Cassette	Gripper-arm Rho Motor	Belt Tension	9	90	1	Select the X
	Gripper-arm Theta Motor	Belt Tension	9	90	1	Select the X
	Film Frame Ring	Film Frame Planarity	1	10	0	Discard the X

Out of 6x KPIV's found to be common therefore 2x KPIV's were rejected in X's panel reduction table and 2x KPIV's will proceed to validation, shown in Table 3.

Table 3: X's Panel Reduction

			CnE Score		Common KPIV/ X	
Process Step	Input	Characteritic of Input (KPIV / X	Total	Decision	Common	Decision
Gripper-arm Loading of Film Frame from Cassette to Chuck top	Gripper-arm Rho Motor	Belt Tension	90	Select the X	Yes	Select the X
	Gripper-arm Theta Motor	Belt Tension	90	Select the X		Select the X
Auto-Alignment	Film Frame Ring	Film Frame Notch	90	Select the X		Select the X
Gripper-arm Unloading of Film Frame from Chuck tor to Cassette	Gripper-arm Rho Motor	Belt Tension	90	Select the X	Yes	Discard the X
	Gripper-arm Theta Motor	Belt Tension	90	Select the X	Yes	Discard the X
	Film Frame Notch	Design	90	Select the X	Yes	Discard the X

3.3 Validation Phase of the 2 Potential X's

We proceeded in validating the 2 remaining X's.

3.3.1 Belt Tension Validation

First is the "Belt Tension". Using the tension meter, we gathered 2 different tension reading ranges. 1st is ranging from 500-1000N and 2nd is from 1500- 2000N. See Table 4. Actual Belt Tension per Machine.

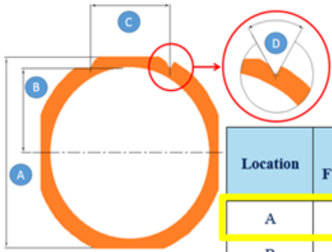
Table 4: Actual Belt Tension Reading per Machine

Machine Number	Action Belt Tension using Tension Meter
Machine #1	1750N
Machine #2	1573N
Machine #3	689N
Machine #4	752N
Machine #5	658N
Machine #6	1684N
Machine #7	1648N
Machine #8	784N
Machine #9	1712N
Machine #10	897N

2.3.2 Film Frame Validation

Second potential X is the "Film Frame Design". We discovered that we used different kinds or designs of film frame based on suppliers made. Teams gathered the 10x film frame based on suppliers made and measure the critical dimension and notches. See Table 5. Average Actual Dimension of Film Frame.

Table 5: Average Actual Dimension of Film Frame



Location	Film Frame #1	Film Frame #2	Film Frame #3	Film Frame #4
A	275.7	275.5	275.5	275.5
B	121.5	123.2	122.8	123
C	124.02	125.5	126.1	125.8
D	58 °	55 °	62 °	58 °

With that gathered dimension, teams agreed to modify the gripper-arm to cater for different types of film frame. We also notice that the film frame "Guide Pin" was already worn-out causing auto-alignment failure due to placement stability problem. The gripper-arm guide pin was removed and installed 1.5mm metal plate as "Stopper Plate" to cater all film frames with same dimension on "Location A" and formulate 2 proportion test for "Guide Pin" and "Stopper Plate". See Figure 10.

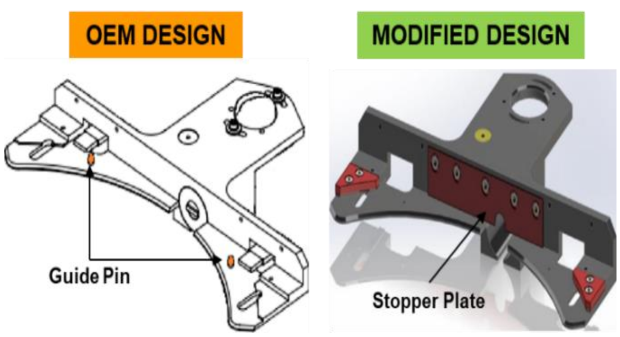


Figure 10: Modified Gripper-arm

3.4 Analyze Phase

Table 6 shows the validation plan to analyze if there is a significant difference. It also shows the final validation plan table with sample sizes at Table 7.

Table 6: Validation Plan Table

Y (or mini Y)	Unit of Measure	Y treated as	X	True nature of X	Levels of X, if discrete or converted into discrete	Hypothesis Statement		Statistical Test
						Null Hypothesis	Alternative Hypothesis	
Auto-Alignment Failure	Occurrence	Continuous	Rho & Theta motor Belt Tension	Continuous	High 20000-30000 Low 10000-15000	P500N-P1000N = P1500N-P2000N	P500N-P1000N < P1500N-P2000N	2 Proportion Test
	Occurrence	Continuous	Gripper-arm frame (Stopper)	Continuous	Low Guide Pin High Stopper Plate	Guide Pin = Stopper Plate	Guide Pin > Stopper Plate	2 Proportion Test

Table 7: Final Validation Plan Table with Sample Size

Y (or mini Y)	X	Hypothesis Statement		Statistical Test	Beta	Alpha	Delta	Sample Size
		Null Hypothesis	Alternative Hypothesis					
Auto-Alignment Failure	Rho & Theta motor Belt Tension	P500N-P1000N = P1500N-P2000N	P500N-P1000N < P1500N-P2000N	2 Proportion Test	0.1	0.05	1.31	100
	Gripper-arm frame (Stopper)	Guide Pin = Stopper Plate	Guide Pin > Stopper Plate	2 Proportion Test	0.1	0.05	1.31	100

3.4.1 Belt Tension Statistical Test

Shown on Figure 11, using 2 Proportion Test in gripper-arm Belt Tension during Auto-Alignment. The result shows at 95% confidence level between 500-1000N and 1500-2000N has a Significant Difference in terms of Acceptable result.

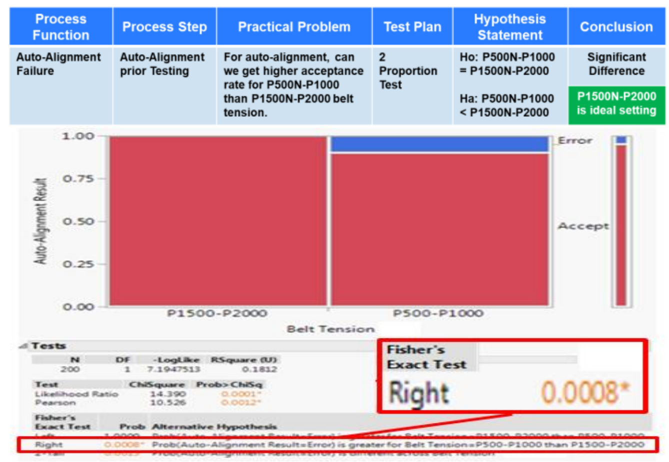


Figure 11. Belt Tension – 2 Proportion Test Result

3.4.2 Gripper-arm Stopper

For the gripper-arm stopper, using 2 Proportion Test for "Guide Pin" and "Stopper Plate" during Auto-Alignment at better than 95% confidence level, Significant Difference in terms of Acceptable result during auto-alignment. See Figure 12.

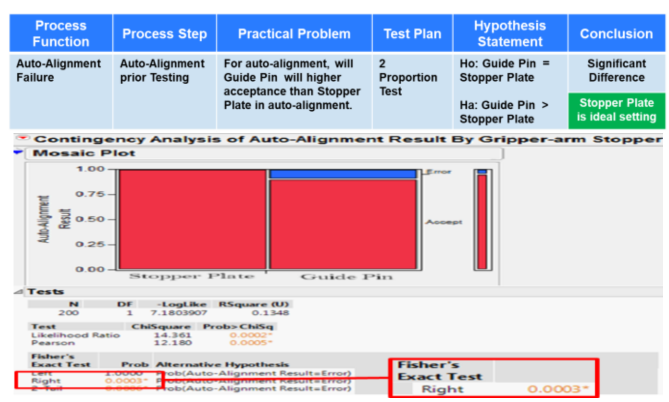


Figure 12. Gripper-arm Stopper Height – 2 Proportion Test

3.5 Improve Phase

To proceed Improve Phase, Corrective and Preventive actions were summarized using potential problem analysis as shown in Table 9.

Table 9: Corrective and Preventive Action

Selected Action	Potential Problem	Potential Cause	Counter Preventive Action	EP	Responsible	Status
Implement belt tension between 1500N-2000N in all machine	Machine downtime due to lose belt tension.	Mounting screws that hold on the motor and gear may lose during production.	Check the mounting screws every PM schedule (every 6 months)	3	F. Mijares	Done
			Design a stopper to hold the not to lose even the mounting screws will be loose.	2		

Generated preventive and corrective actions on motor belt tension by installing stopper (see Figure 13) to hold the motor from losing and implement preventive maintenance schedule every 6 month.

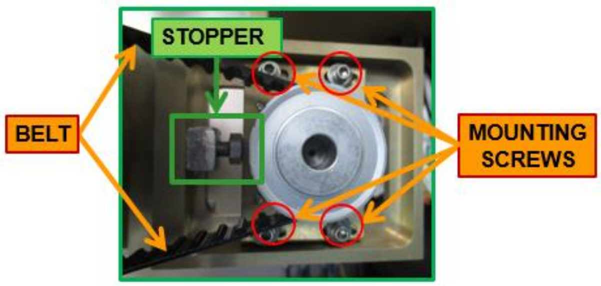


Figure 13. Belt Tension Stopper

4.0 RESULTS AND DISCUSSION

After all the improvement was implemented, the TEUD trend was reduced from an average of 22.3% to 8.4% with 13.9% improvement as shown in Figure 14.

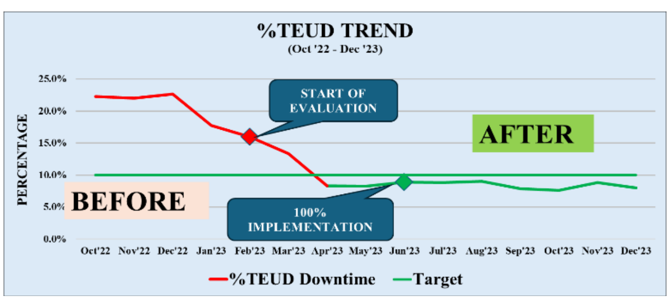


Figure 14. TEUD Trend (Before and After)

Overall Equipment Efficiency trend **improved by 23.5%** from an average of 51.9% to **75.4%.** See Figure 15.

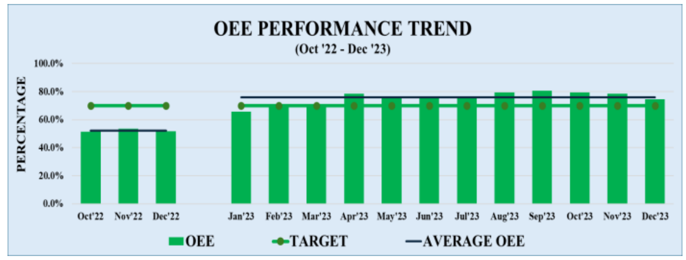


Figure 15. Overall Equipment Efficiency Trend

5.0 CONCLUSION

After implementing and completing all actions, machine performance efficiency significantly improved, and the machine error occurrence was reduced.

6.0 RECOMMENDATIONS

It is recommended to fan-out these learnings to other machines. Future studies are recommended for plans to zero out the errors.

7.0 ACKNOWLEDGMENT

We would like to thank all the Integrated Lines Team for their sincerest appreciation and full extended support. To our beloved family, friends, and colleagues who wholeheartedly supported them to make this project fruitful and successful.

8.0 REFERENCES

1. Electroglas EG4090 Film Frame Maintenance Manual

9.0 ABOUT THE AUTHORS

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