Damaged Package Elimination: A Study and Adaptation of Top Package Unit Stopper in FT-2026 Handler Onload Singulation Process

Dean Earian F. Arago
Angelo D. Catamco
Victor Partolan

Final Test, Engineering Department
Nexperia Philippines Inc., Philips Avenue Light Industry and Science Park 1,
Cabuyao, Laguna, 4025 Philippines
DeanEarian.Arago@nexperia.com
Angelo.D.Catamco@nexperia.com
Victor.Partolan@nexperia.com

ABSTRACT

Nexperia is known as one of the leading providers of power solution products, enabling efficiency not only in the automotive sector but also in industrial, mobile, and consumer applications. As a leading expert in the development and production of essential semiconductors, Nexperia Assembly and Test Cabuyao (ATCB) is committed to delivering remarkable products while ensuring high quality.

To achieve a seamless and flawless transition, continuous improvement with the aim of transformation is inevitable.

This paper will walk you through an analysis of and strategies for overcoming challenges that might be overlooked in the early stages of equipment design. It will cover improvements not only in the original equipment manufacturer (OEM) design but also in enhancing the functionality and reliability of parts to produce high-quality and robust products. Design analysis focuses on reducing stress induced in the package, as well as achieving cost savings on tools and reducing man-hours.

Through the analytical and in-depth approach of DMAIC, coupled with the application of design and functional analysis, the researchers generated an optimum solution to resolve potential package-induced defects. Resulting in 97% reduction of stress exerted in the package as well as eliminating non-value-added activities during preventive maintenance.

Implementation of all identified corrective actions, appropriate setup and controls significantly reduce known induced package rejects.

1. 0 INTRODUCTION

In ATCB final test process, a rotating turret type handler is utilized wherein each unit is electrically tested and visually inspected. This rotating turret is responsible for transferring singulated units on a sequence of module from unit onload to unit orientator, testing, laser marking, automated optical inspection (AOI), reject and taping.

The study focuses on a specific yet crucial process in the final test handler – the unit onload singulation process. The singulation process separates each unit from the carrier tube to the onload linear track controlled by the separator and the onload unit stopper. These modules move synchronously to ensure that the unit is continuously entering in a single file line preventing unit to fall out or jam on the onload linear track. The unit stopper, as the name suggests, stops the units as it moves the stopper arm up and down catching the unit at the end of the onload linear track. Then the unit separator moves back and forth to individually take and hold the units properly during pick up of rotating turret assembly. At an abnormal condition, both processes can induce package stress on the units and that lead to different package defects.

1.1 Problem Statement

In WW2305, there was an observed ramp of Reject Bin Analysis (RBA) increase of 0.35% from 0.16% level. Refer to figure 1 for the RBA hits. 17 batches, equivalent to 241K units, were held in both WIP and for delivery tagged with potential risk. Further analysis shows that rejects are related to package induced defects such as damage package and dent on heatsink signature.

Figure 1. Reject Bin Analysis (RBA) Hits

1.2. Objective

Given the data as shown in figure 1, below are the researchers' objectives:

- Identify and reduce or eliminate the defects that contributed to the 0.35% increase in RBA hits during WW2305.
- Pinpoint the handler processes in the Final Test where it is possible to replicate and induce stress that will result in the specific defect defined
- Provide a robust and sustainable solution and implement controls to avoid repetition of the defect.

1.3. Scope and Limitations

The study will only focus on the reduction or elimination of the final test specific defect signatures induced by the related module on ASM FT2026, SOT669, SOT1023, and SOT1205 package.

2. 0 REVIEW OF RELATED WORK

"Not Applicable"

3.0 METHODOLOGY

The methodology used for this paper is the DMAIC system where it is divided into 5 phases, the Define, Measure, Analyze, Improve and Control. The researchers decided that it would be an easier and effective way to format the methodology.

3.1 Define Phase

As part of the study, this paper will show the potential package defects that are specific to the Final Test Station that is induced on the identified handler module that impact the product test reliability and analysis on the defect mechanism to fully understand the root cause of the problem.

3.1.1 Package Defect Signature Analysis

Three (3) identified defects were analyzed to classify the commonality in terms of its signature induced in the package, see figure 2 for reference. Observed damage package (DPK) on the 3 reject units, among the rejects 1 has dent on heatsink (DTH) signature. Based on the characterization as shown in figure 2.

(1) No plating seepage was observed on the portion where the mold material was removed.
(2) Two of the 3 rejects with damage package (DPK) have the same indentation observed in ST2 location.
(3) One unit with dent on heatsink (DTH) has a scrapping at back moving from left to right based on accumulation of plating at endpoint.

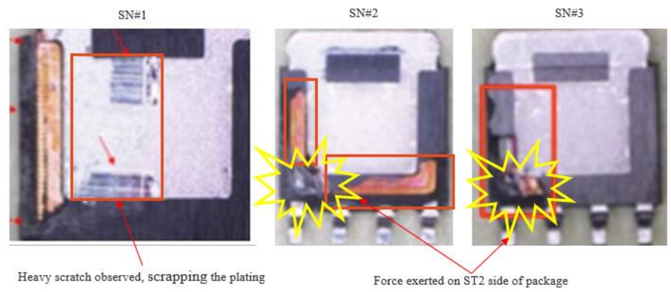


Figure 2. Actual Image of Package Defect

Focusing on the dent on heatsink (DTH) defect, the initial hypothesis is that the process condition must have a sliding motion that can induced scrapping at the back side of the package.

3.1.1 Package Defect Signature Analysis

Further defect analysis shows that:
(1) Damage package is only observable in the back side on the unit
(2) Scrapping was observed on the back side only
(3) Scrapping originated from left to right of the package
(4) Accumulation of plating material observed at termination point

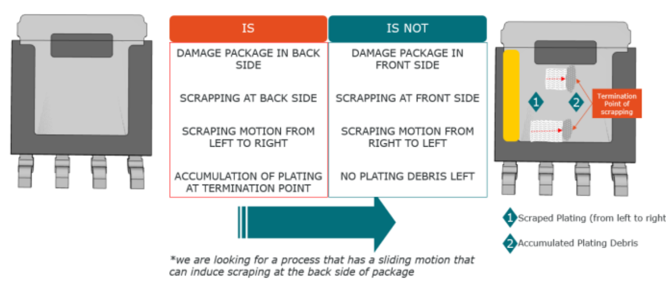


Figure 3. Is/Is Not Analysis

3.2 Measure Phase

The measure phase is focused on process mapping and OCAP data consolidation in preparation for analysis phase.

3.2.1 Process Mapping

From the characteristics of the defect, process and stress mapping analysis were conducted to efficiently narrow down the machine module that can induce the damage and dent on heatsink defect. Shown in figure 4 the handler process mapping.

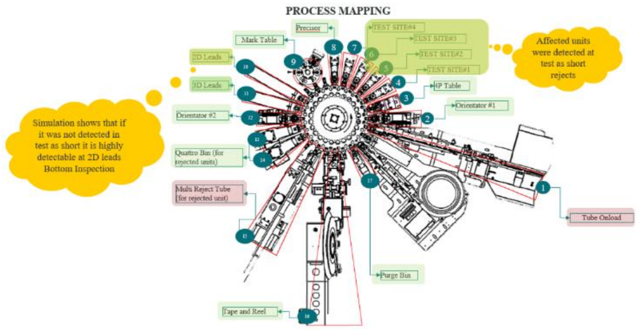


Figure 4. Handler Module Process Mapping

3.2.2 OCAP Hits Data Consolidation

OCAP Hits would help the researchers in pinpointing the root cause of the defect and focus the improvement phase on that specific module or component.

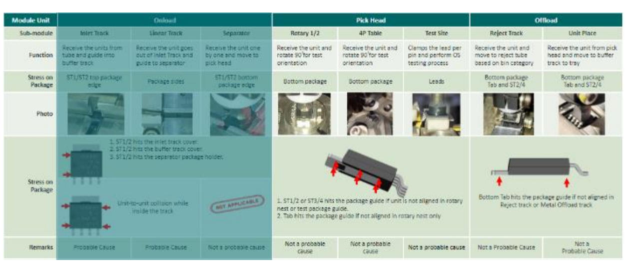
3.3 Analyze Phase

The analyze phase is done to identify the root cause of the defect to properly assess the situation and give an adequate solution in the improvement phase.

3.3.1 Stress Mapping Analysis

Stress mapping analysis was conducted to examine thoroughly the module's function, unit movement, and the stress on package of each sub-module may produce. This analysis highlighted the specific module that needs to be verified as the probable cause of the package defect. Shown in figure 5 the identified process station in handler.

(1) Inlet Track
(2) Linear Track
(3) Separator



Module Unit	Onload			Pick Head			Offload	
Sub-module	Inlet Track	Linear Track	Separator	Rotary 1/2	4P Table	Test Site	Reject Track	Unit Place
Function	Receive the units from tube and guide into buffer track	Receive the unit goes out of Inlet Track and guide to separator	Receive the unit one by one and move to pick head	Receive the unit and rotate 90°for test orientation	Receive the unit and rotate 90°for test orientation	Clamps the lead per pin and perform OS testing process	Receive the unit and move to reject tube based on bin category	Receive the unit from pick head and move to buffer track to tray
Stress on Package	ST1/ST2 top package edge	Package sides	ST1/ST2 bottom package edge	Bottom package	Bottom package	Leads	Bottom package Tab and ST2/4	Bottom package Tab and ST2/4
Photo								
Stress on Package	1. ST1/2 hits the inlet track cover. 2. ST1/2 hits the buffer track cover. 3. ST1/2 hits the seperator package holder. Unit-to-unit collision while inside the track		NOT APPLICABLE	1. ST1/2 or ST3/4 hits the package guide if unit is not aligned in rotary nest or test package guide. 2. Tab hits the package guide if not aligned in rotary nest only			Bottom Tab hits the package guide if not aligned in Reject track or Metal Offload track	
Remarks	Probable Cause	Probable Cause	Not a probable cause	Not a probable cause	Not a probable cause	Not a probable cause	Not a Probable Cause	Not a Probable Cause

Figure 5. Process Station Stress Mapping

3.3.2 Verification of Results

Verification was done to on the offload on onload to determine where the defects were induced. Simulations were done in these modules to replicate the defect and confirm the focus of the improvement.

3.3.2.1 Tube Offload (Reject Track) Verification

Based on the verification, defect signature was not duplicated as shown in figure 6.

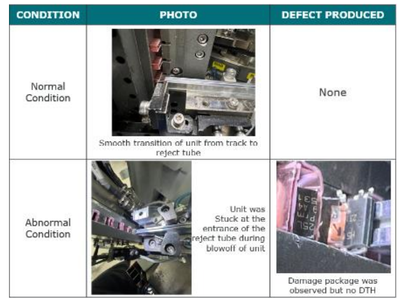


Figure 6. Reject Track

3.3.2.1 Tube Onload (Inlet Track / Outlet Track / Separator Assembly) Verification

During the validation on the tube onload assembly, it was observed that defect signature was duplicated under normal condition of the unit separator as shown in figure 7.

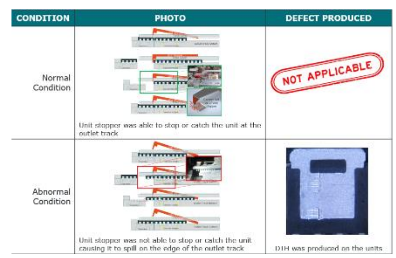


Figure 7. Tube Onload

3.3.2.1 Leading OCAP Hits Related to Separator

In ATCB Final Test, multiple handler models were used such as ASM FT2030, ASM FT2026 and Nortech. All handler models have the same unit onload mechanism specifically to unit separator. During abnormalities on the unit separator movement there is an error prompt, “Unit Separator Error” which is tag as critical handler error recorded as OCAP. Wherein 50% of the hits are concentrated in FT2026 handler as shown in figure 8.

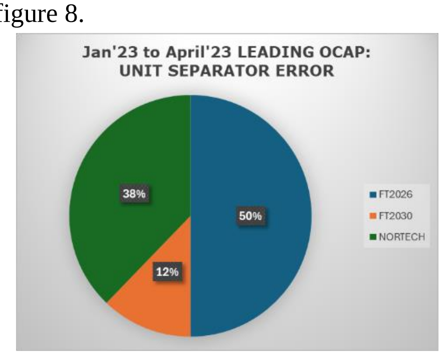


Figure 8. Leading OCAP for Unit Separator Error

3.3.4 Pareto of FT2026 OCAP Hits

SOT669 package is the top contributor on Unit Separator OCAP hits for FT2026 Handler with an average of 4 hits on each set up, as shown in figure 9. Indicating that SOT669 set up is the top priority to check for abnormality in set up.

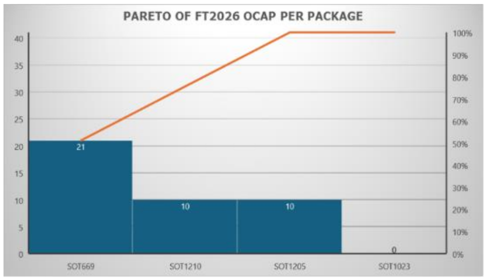


Figure 9. Pareto of OCAP Hits

3.3.5 Fishbone Diagram

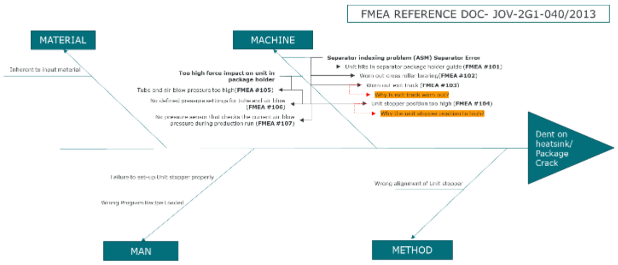


Figure 10. Fishbone Diagram

3.4. Improve Phase

Based on the findings in the analyzing phase, the root cause of the problem is the unit stopper. The improvement phase will focus on the analysis and improvement of the unit stopper for ASM FT2026.

3.4.1 Measurement of Parts and Components

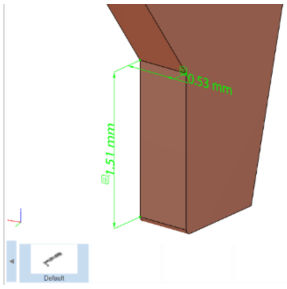


Figure 11. Old Unit Stopper Dimensions

The figure above shows sample dimensions and measurements that is going to be relevant to the stress calculations and analysis. This includes the measurements where the unit makes contact within the old unit stopper, the separator, bottom track and the new unit stopper.

3.4.2 Measurement of Forces Applied

The force applied by the movement of unit is determined using force measuring tool. The separator assembly is removed and is replaced by the force measuring tool at the end of the outlet track. The machine performs a jog run and then every set of units that was blown into the track was measured. The max force used is 25.7 N.

Figure 12. Unit Force Measurement

Using a spring force calculator, the force exerted by the unit stopper spring is calculated. The required data is the standard measurements of the spring, its material and type of spring end. The force used is the True Fmax which is 4.531 N.

The force exerted by the separator is measured using a Gram Force Meter. The meter is placed at the position where the extended unit will be during its defect inducing event. This is about one unit in length were the force exerted is 3.465 N.

Figure 13. Separator Force Measurement

The forces applied to the unit are critical to be determined because of the stress limit of the package. According to FA study, the package can only withstand a cumulative force of 80N and a maximum accumulated stress of 114 MPa.

3.4.3. Stress Analysis on Normal Operation

The total stress that the package is experiencing during normal operation is determined by adding all the stress that different components induce to the package. This includes the stress due to the unit stopper, due to the separator collision and to unit-to-unit collision. The formula for stress that is going to be used is its simplest form, Force over Area.

$$\sigma_{Stress} = \frac{Force}{Area}$$

$$\sigma_s = \frac{Force}{LW}$$

$$\sigma_T = \frac{Force}{\frac{(L_1 + L_2)}{2} H}$$

The total accumulated stress experienced by the package is 64.34 MPa well below the stress limit of the packaged determined by FA which is 114 MPa.

3.4.4. Stress Analysis on Defect Inducing Event

Using the recorded conditions, the stress experienced by the package during the defect inducing defect was calculated using the same stress analysis. The factors considered were the stress induced by the unit stopper, by the unit to separator collision, unit to unit collision and the unit to bottom track scraping. It was determined that the accumulated stress experienced by the package is about 153.36 MPa, well above the stress limit that the package.

3.4.5 Stress Analysis of the Old Unit Stopper

The flexural stress experienced by the unit stopper will be compared to the fatigue stress limit of Beryllium-Copper, the material which the unit stopper is made of. Using the formulas for flexural stress, a stress analysis was performed to determine whether the unit stopper will bend or deform during operation.

$$\sigma_f = Flexural\ Stress$$
$$M = Bending\ Moment$$
$$I = Centroidal\ Moment\ of\ Inertia$$
$$C = Geometric\ Distance$$
$$\sigma_f = \frac{MC}{I}$$
$$\sigma_{Rectangular} = \frac{M\frac{h}{2}}{\frac{bh^3}{12}}$$

Fatigue Stress is the stress required to deform a material during repeated cycle of operations. The fatigue stress of Beryllium-Copper is 250 MPa while the calculated flexural stress of the unit stopper is 493.56 MPa. This is well above the limit which means that the unit stopper will deform during normal operation and will induce defects once worn out.

The Max Deflection and Angle of Deflection were also calculated to show how much deformation occurred on the unit stopper using the following formulas.

$$\delta = Deflection$$
$$P = Load\ (Force)$$
$$E = Modulus\ of\ Elasticity$$
$$\theta = Angle\ of\ Deflection$$
$$\delta_{Max} = \frac{PL^3}{3EI}$$
$$\theta = \frac{PL^2}{2EI}$$

The Max Deflection of unit stopper is about 1.3 mm, its angle of deflection is about 0.1 degrees, and its total deflection is 2.4mm.

3.4.6 Design of the New Unit Stopper

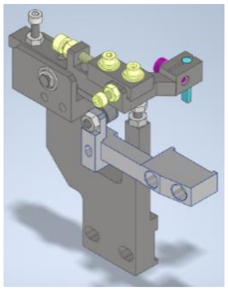


Figure 14. New Unit Stopper 3D Model

Using the Stress Analysis done to the unit and the unit stopper, the researchers designed a concept for a new design of the unit stopper based on the design of FT2030, NY20 and NTH24, where the unit stopper has a larger surface area and holds the unit on the top instead on its side.

The initial concept and design of the new unit stopper was given to the ASM Supplier for fabrication and modification.

3.4.6 Design of the New Unit Stopper

After the installation and qualification of the new unit stopper design, stress analysis was conducted. The total stress induced by the process was calculated to be 33.99 MPa which is well below the limit determined by the FA. The same factors were considered in calculating the total accumulated stress on the package.

3.5 Control Phase

For the control phase, this deals with the qualification run of the new unit stopper and the updating of related documents.

3.5 1 Qualification of the New Unit Stopper

After the installation of the new unit stopper, it would go under qualification. The standard procedure is to run 3x qualification lots. The qualification lots would then undergo 100% visual inspection.

- No CRP/CHP observed on the 3x SL batches.
- No separator error or jam encountered using the new unit stopper design.

- No Short rejects observed (2x SL batches – non-Taiko, 1x SL batch – Taiko)

DEVICE	BATCH_SO	QTY	SHORT	Remarks	100%VI Result After Test
BUK9Y6R5-40H	MLPC15334400	3000	7 - Invalid Short Reject	1st SL Batch – Non Taiko	NO REJECT FOUND
BUK9Y6R5-40H	MLPC15489500	10500	0	2nd SL Batch – Non Taiko	1PQ REJECT, PQ#1 – FM =1
BUK7Y2R0-40H/C5	MLPC16371100	13,500	0	3rd SL Batch - Taiko	NO REJECT FOUND

Figure 15. Pilot Machine Qualification Results

3.5 2 Updating of Equipment Manual

The technical drawing of the new unit stopper that includes the list of parts, part number and dimensions are added to the machine manual to document that the new unit stopper is officially part of the machine.

3.5 3 Updating of Equipment FMEA

The Equipment Failure Mode-Effects Analysis of ASM FT2026 has been updated to replace the old design with the new one. This update would help the engineers to properly assess the risks of the new unit stopper and align the documents pertaining to the PM of the machine.

1.Next Higher Level	2. Focus Element	3. Next Lower Level or Characteristic Type	1. Next Higher Level Function and Requirement	2. Focus Element Function and Requirement	3. Next Lower Level Function or Requirement or Characteristic Type	1. Failure Effects (FE) to the Next Higher Level Element and/or End User	Severity (S) of FE	2. Failure Mode (FM) of the Focus Element	3. Failure Cause (FC) of the Next Lower or Characteristic
	Onloader Unit stopper mount Assembly	Stopper Base		Singulates the units before entering.	Holds the entire Unit Stopper Assembly	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Misaligned Base Set-up
		Cam Mount Support			Uses compressed air to move back and fort	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Misaligned Mount Set-up
		Cam Mount			Holds and attaches the cam follower to the Cam Mount Support	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Misaligned Mount Set-up
		Cam Follower			Transfer the back and fort movement of the Cam Mount Support to the Stopper Cam	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Worn Out Cam
		Flange Ball Bearing			Allows the up and down movement of the stopper arm	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Missing bearing
		Arm Shaft			Holds in place the Stopper Arm into the Stopper Base	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Worn Out Shaft
		Compression Spring			Compresses when the Stopper Arm moves up then pushes it back down while decompressing	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Worn Out Spring
		M3 Stopper Pin			Limits the up and down range of the Stopper Arm	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Damaged Pin
		Stopper Cam			Converts the back and fort movement of the cam follower to an up and down motion	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Worn Out Stopper
		Stopper Arm			Is contact with the Stopper Cam to move the stopper up and down	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Misaligned Arm Set-up
		Stopper Linkage			Connect the Unit Stopper Mount perpendicularly to the Stopper Arm	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Misaligned Linkage Set-up
		Unit Stopper Mount			Holds the Stopper Rod in position	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Misaligned Mount Set-up
		Unit Stopper Rod			Uses the up and down movement of the Stopper Arm to individually block and allow units to enter	Decrease on Efficiency due to increase on manual assist to feed unit / Unit Missing At Place	3	Unit Stuck-up	Damaged or Worn Out Rod

Figure 16. Updated E-FMEA

3.5 4 Updating of the PM Checklist

Finally, the checklist for the quarterly preventive maintenance of the machine was updated to remove the old design and add a new one. This indicates which parts of the new unit stopper was to be checked, cleaned, or replaced. This also included the direction to replace the unit stopper rod annually during PM.

Tube Onload		
Tube Onload & Buffer Track	Not worn out	
Onload inlet track to buffer linear track to Front Tube support alignment check	Properly align	Adjust any onload inlet track or tube support assembly if necessary.
Separator Vacuum Filter	Not clogged	
Check Unit Stopper	Not defective	
Check UNIT STOPPER ROD(D3,1.5) (for New design: 12NC = 790056020757)	Not worn out	Replacement every year
Check ONLOADER UNIT	Not defective	

JOT-2H0-040/4093 2024-08-24
4240475

Figure 17. PM Checklist - JOT-2H0-040/4093 updated under CN Number: 4230786

3.5 5 Updating of the PM Work Instruction

The work instruction for preventive maintenance was also updated to ensure the proper care and checking of the new unit stopper is done during PM.

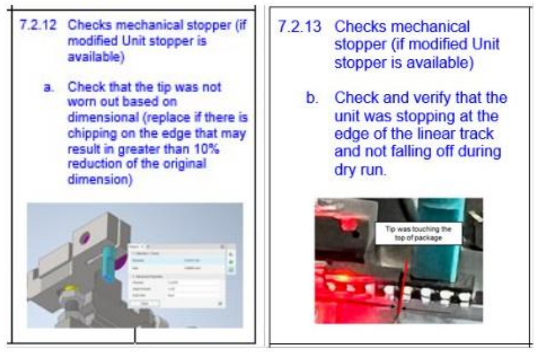


Figure 18. Preventive Maintenance Work Instruction/Procedure - JOV-2H0-040/3079 updated under CN Number: 4240140

4.0 RESULTS AND DISCUSSION

This is where the paper discusses the summary of results that the researchers have done in the improvement and control phase of the methodology.

4.1 Comparison of New and Old Unit Stopper

Percent Reduction			
Category	**Percent**	**Old**	**New**
Total Stress	**47%**	64.34168	33.9923
Total Force	**27%**	77.1000	55.9310
Stress Due to Unit Stopper	**97%**	31.40581	1.0564

Table 1. Percent Stress Reduction

The stress induced by the new unit stopper is compared to the stress induced by the old unit stopper. The old design induces 31.4 MPa of stress on the unit while the new design only induces 1.05 MPa seeing a 97% stress reduction.

4.2 Comparison of New Unit Stopper to Other Handlers

Stress Due to Unit Stopper Comparison			
Handler	**Stress**	**Force**	**Area**
FT2026 Old	31.4058	25.7000	0.8183
FT2026 New	1.0564	4.5310	4.2890
FT2030	1.7683	2.0000	1.1310
COHU NY20	1.3645	2.1000	1.5390
Nortech NTH24	1.9196	2.1500	1.1200

Table 2. Stress due to unit stopper comparison

The new design is then compared to the counter parts where its design was based. The new unit stopper may induce a significantly larger force of about 4.28 N while its counter parts on the other handlers was just around 2 N, it only produces a smaller amount of stress of about 1.05 MPa.

4.3. Machine Performance: Separator Error Trend

The jamming error was significantly reduced on the pilot handler, showing that the new design is applicable for the ASM FT2026 machine. The immediate reduction in errors was observed during the start of the fan out in handlers running big packages and in 2024 the team observed a spike in error, but this is due to handlers running small packages. This made the team to also fan out the design on these handlers where we also saw an immediate decline in separator errors.

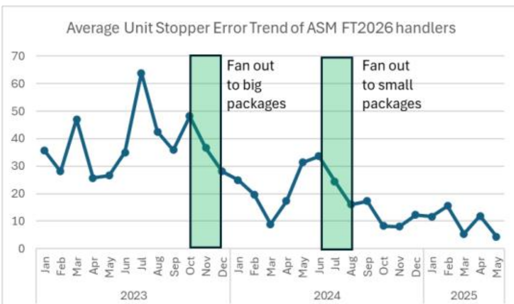


Figure 19. Average Unit Index Separator Error

5.0 CONCLUSION

Driven by the ATCB's mission to deliver products with the highest quality, the researchers designed an ASM FT2026 Unit Stopper which has been an effective replacement for the edge stopper (old design). The stress induced to the package was reduced by 97%.

Compared to the unit stoppers of ASM FT2030, COHU NY20 and Nortech NTH24, which are all top package unit stoppers, the new unit stopper design of ASM FT2026 has the lowest induced stress to the package.

Since the new unit stopper design would only require replacing the unit stopper rod instead of replacing the whole unit stopper assembly, it incurred a savings of about $ 15.6K USD.

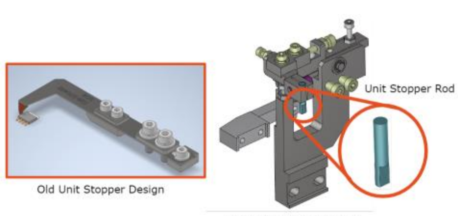


Figure 21. Old vs New Unit Stopper Design

	Big Packages			Small Packages			
Description	Qty	Price	Cost	Qty	Price	Cost	Total
Unit Stopper Assembly (Old)	40	$ 345.52	$13,820.80	16	$ 155.55	$2,488.80	$16,309.60
Unit Stopper Rod (New)	40	$ 11.90	$ 476.00	16	$ 11.90	$ 190.40	$ 666.40
Savings							$15,643.20

Table 3. Projected Indirect Savings

6.0 RECOMMENDATIONS

The new unit stopper design will be the default design for all ASM Handlers in the future and the top package design unit stopper will be the default type of unit stopper that all future test handlers will have. This will be included in the PO Spec of Nexperia when buying new handlers.

7.0 ACKNOWLEDGMENT

The researchers behind the paper would like to thank Gareth Hughes our ATCB General manager and Debbie Alcala our Engineering Director for the constant inspiration for innovation and improvement, their Sr. Manager, Edwin Ang for his continuous support and encouragement always; their Managers Joebert Saballas and Evelyn Pacio for the consultations and guidance that helped the advancement of the project; and to the Equipment Engineering Team for the technical support in the project.

8.0 REFERENCES

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9.0 ABOUT THE AUTHORS

Dean Earian Arago, Licensed Mechanical Engineer from Mapua University, Intramuros Manila. Started in Nexperia Philippines as a Cadet Engineer and currently working as a Jr. Equipment Engineer for Power Clip-Bond Backend Final Test Engineering.

Angelo David Catamco, Graduate of B.S. Electronics Engineering from International Correspondence Schools – Greenhills San Juan Metro Manila. Hired at Philips Semiconductors Philippines, Inc. as Production Operator at SMGD Final Test. Became Equipment Engineer at Nexperia (Former Philips).

Victor Partolan, Graduated B.S. Mechanical Engineering from Manuel S. Enverga University Foundation Lucena. Started in Nexperia Philippines as a Technician II and currently working as a Jr. Equipment

Engineer for Power Clip-Bonded Final Test Engineering

10.0 APPENDIX

A. Force Applied by Unit Movement

Force	Number of units in tube					
	10	20	40	60	80	100
Min	1.5	3.5	5	8.2	16.6	12
Max	4.3	5.9	8.7	10.7	25.7	15.7
Average	3.17	4.63	6.37	9.63	20.22	13.55

B. Force Applied by Unit Stopper

Rates and Loads	
Spring Rate (or Spring Constant), k	0.160 N/mm
True Maximum Load, True Fmax	4.531 N
Maximum Load Considering Solid Height Fmax	3.001 N

C. Force Applied by Separator

Separator Force		
Trial	**Half Unit Distance**	**Full Unit Distance**
1	145	450
2	120	400
3	170	340
4	150	340
5	140	260
6	145	200
7	145	450
8	160	375
9	140	300
10	145	350
Average	**146**	**346.5**
Force (N)	**1.46**	**3.465**

D. Unit Stress Analysis

Unit Stress Analysis (Normal Operation - Old Unit Stopper)		
	Value	**Unit**
Total Stress	**64.3417**	**Mpa**
Total Force	**77.1000**	**N**
Stress Due to Old Unit Stopper	**31.4058**	**Mpa**
Force (Unit Movement)	25.7000	N
Area (Unit Stopper Surface)	0.8183	mm^2
Length	1.5440	mm
Width	0.5300	mm
Stress Due to Unit-to-Separator Collision	**26.9661**	**MPa**
Force (Unit Movement)	25.7000	N
Area (Area of Unit Side)	0.9530	mm^2
Length Top	3.7170	MM
Length Bottom	4.0000	mm
Height	0.2470	mm
Stress Due to Unit-to-Unit Collision	**5.9698**	**MPa**
Force (Unit Movement)	25.7000	N
Area (Area of Unit Side)	4.3050	mm^2
Height	1.0500	mm
Width	4.1000	mm

Unit Stress Analysis (During Defect - Old Unit Stopper)		
Total Stress	**153.36**	**Mpa**
Total Force	**58.33**	**N**
Stress Due to Unit Stopper	**54.48**	**Mpa**
Force (Stopper Movement)	25.7000	N
Area	0.47	mm^2
Length	0.8900	mm
Width	0.5300	mm
Stress Due to Unit-to-Separator Collision	**2.2042**	**MPa**
Force (Separator Movement)	3.4650	N
Area (Area of Unit Side)	1.5720	mm^2
Length	4.0000	MM
Width	0.3930	mm
Stress Due to Unit-to-Unit Collision	**5.97**	**MPa**
Force (Unit Movement)	25.70	N
Area (Area of Unit Side)	4.31	mm^2
Height	1.05	mm
Width	4.10	mm
Stress Due to Unit-to-Bottom Track Scraping	**90.71**	**MPa**
Force (Separator Movement)	3.4650	N
Area	0.04	mm^2
Length	3.8200	mm
Width	0.0100	mm

Unit Stress Analysis (Normal Operation - New Unit Stopper)		
	Value	**Unit**
Total Stress	**33.9923**	**Mpa**
Total Force	**55.9310**	**N**
Stress Due to Unit Stopper	**1.0564**	**Mpa**
Force (Spring)	4.5310	N
Area (Unit Stopper Surface)	4.2890	mm^2
Stress Due to Unit-to-Separator Collision	**26.9661**	**MPa**
Force (Unit Movement)	25.7000	N
Area (Area of Unit Side)	0.9530	mm^2
Length Top	3.7170	MM
Length Bottom	4.0000	mm
Height	0.2470	mm
Stress Due to Unit-to-Unit Collision	**5.9698**	**MPa**
Force (Unit Movement)	25.7000	N
Area (Area of Unit Side)	4.3050	mm^2
Height	1.0500	mm
Width	4.1000	mm

E. Stress Analysis on Unit Stopper

Flexural Stress		
	Value	**Unit**
Flexural Stress	**493.56**	**Mpa**
Maximum bending Moment	**1283.26**	**N-mm**
Total Force	58.33	N
C	**0.50**	**mm**
Moment of Inertia	**1.30**	**mm^4**
Length	22.00	mm
Width	15.60	mm
Height	1.00	mm
Deformation Validator		
	Value	**Unit**
Fatigue Stress (Beryllium-Copper)	250.00	MPa
Flexural Stress	493.56	Mpa

Max Deflection		
	Value	**Unit**
Max Deflection	**1.27**	**mm**
Maximum Force	58.33	N
Length	22.00	mm
Moment of Inertia	1.30	mm^4
Modulus of Elasticity	125000	MPa
Angle of Deflection	**0.09**	**Degrees**
Unit Height	1.10	mm
Total Deflection	**2.37**	**mm**