APPLICATION OF PACKAGE STRESS REDUCTION STUDY: REENGINEERING OF CHUTE PUSHER SPRING HOLDER ASSEMBLY FOR CLIPBONDED HANMI TRIM AND FORM MACHINES

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ABSTRACT

One of the leading products of Nexperia is Clipbonded packages. A clip is used to create a connection between the die and its leads. The assembly is then encapsulated with a layer of an epoxy molding compound to protect the die and interconnects (clips) from external forces that can damage it. But since then, one of the top challenges that the semiconductor industry encountered are package crack defects.

A contact and stress measurement were done to ensure that there will be no package cracks on the Clipbonded products. The mapping showed that there is a pusher in the Trim, Form, and Singulation area that could cause package crack when it encounters machine error. Although there is process control for those machine alarms, it further increases the processing time of the products. To reduce the stress on the package during machine error, a modification on the pusher was done. It proved effective after decreasing the stress from 315MPa to 89MPa to the package which prevented defects from occurring.

1. 0 INTRODUCTION

Nexperia, a renowned global semiconductor manufacturer, has gained recognition for its broad spectrum of high-quality automotive product applications, including Air Bags, Anti-lock Braking Systems, and more. Setting industry standards, they provide the highest capacity across various packages and consistently invest in expanding their capabilities. The company is dedicated to securing the long-term availability of their manufacturing processes and products, establishing a dependable foundation upon which their customers can rely with confidence.

Nexperia has numerous sites in Europe, Asia, and the Americas. Clipbonded packages are the main products of Nexperia Philippines Incorporated (ATCB) covering 90.90% of production capacity of the Power department as shown on Fig. 1.

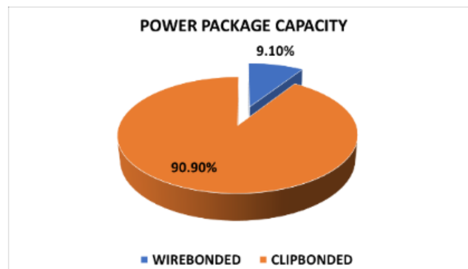


Fig. 1: Power Package Capacity.

Clipbonded packages such as SOT669, SOT1023, SOT1205, SOT1210 are examples of surface mounted devices which require their leads to be formed through the process of Trim, Form, and Singulation.

In ATCB, Trim, Form, and Singulation process has the top leading Out of Control Action Plan or OCAP contributor on Clipbonded Midend Area with 74.19% of total leading OCAP occurrence last 2022. Fig. 2 shows the breakdown of leading OCAP per station in the Midend area. Fig. 3 shows the Trim and Form had increasing leading OCAP trend starting in 2021.

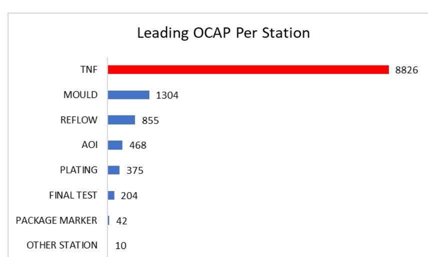


Fig. 2: Leading OCAP at Midend Area per Station

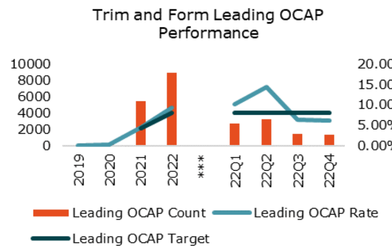


Fig. 3: Trim and Form Leading OCAP Performance

Fig. 4 shows the Pareto chart of Trim and Form Leading Indicators wherein the chute motor overload error is the 2nd highest leading OCAP contributor with a percentage of 18.03% last Y2022 next to 2D Barcode not read (2D BNR) which is a non-critical machine error that does not contribute to product stress. Chute motor overload is the top critical machine error that may cause package cracks. With this, every lot affected will undergo 100% manual visual inspection.

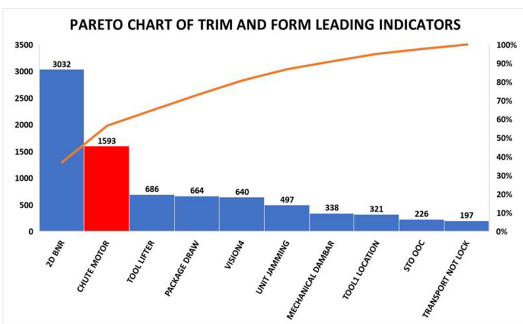


Fig. 4: Pareto chart of Trim and Form Leading Indicators

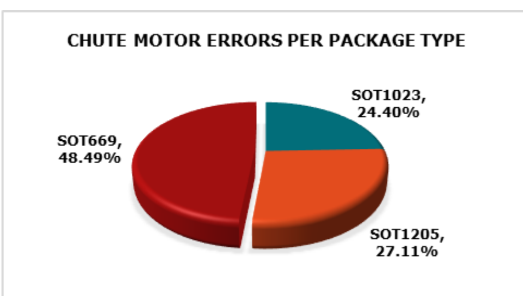


Fig. 5: Chute motor error per package type pie chart

Fig. 5 shows that SOT669 is the highest package contributor for chute motor error.

The objective of this paper is to reduce the stress from 315MPa to ≤ 114MPa on the units due to Chute Pusher Overload Error at Trim, Form, and Singulation Hanmi Machines for SOT 669 Clipbonded Package by the end of May 2023.

2. 0 REVIEW OF RELATED WORK

2.1 SOT669 Package Strength

According to Bacolor and Encarnacion (2021), the only allowable force that a package can withstand before it cracks is a cumulative force of 50N. Fig. 6 shows the simulation of package crack using Universal Testing Machine.

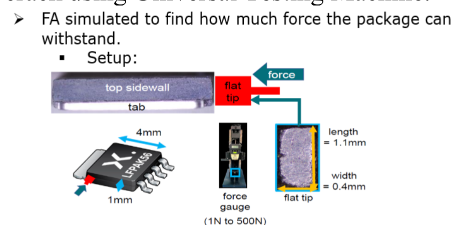


Fig. 6: The setup and position of the probe in the package during simulation

2.2 Stress Study at Trim and Form

The package undergoes different machines before being packed and shipped to the customers. These machines have constant contact with the package with varying areas during assembly. It will then stress the package until it creates cracks. Calculations were made to determine the maximum stress a package can withstand (refer to APPENDIX A).

A cumulative stress of 114MPa max will only be used for units that are being hit on the plastic surface by mechanical contacts during assembly.

3.0 METHODOLOGY

3.1 Define Phase

Contact Mapping at Trim and Form Hanmi Machine

Based on the OCAP hits, the Chute Pusher Overload happens in the output module of the Hanmi Trim and Form machine, shown on Fig. 7. Contact mapping was conducted in the output module by manually controlling the machine to identify what mechanical parts are in contact with the units during normal process. Table 1 shows the validation result.

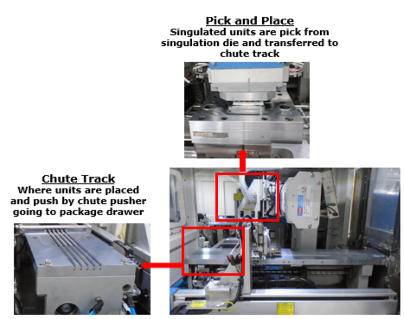


Fig. 7: Output Module of Trim and Form Hanmi Machine

Assembly	Mechanism	Validation
Unit Pick and Place	Touchdown (Pick and Place) -Uses a rubber vacuum pad to pick the unit from the singulation die and place it on the chute table.	Contact the package heatsink.
Chute Table	Chute Pusher -A motor-powered pusher that pushes the unit from the chute table to chute cover.	Contact on the side of the package.

Table 1: Trim and Form Hanmi Machine Stress Validation

3.2 Measure Phase

Force Measurement

Force measurements at the identified locations were conducted to get the force induced in the package during normal process. Fig. 8 shows the Kistler Charge Meter used in measuring the said force in Newtons (N). It uses a probe to get the force by allowing the package to contact the probe.

Fig. 8: Kistler Charge Meter

To measure the force in Chute Track, the machine was set in manual mode and chute pusher was moved in upward position as shown on Fig. 9.

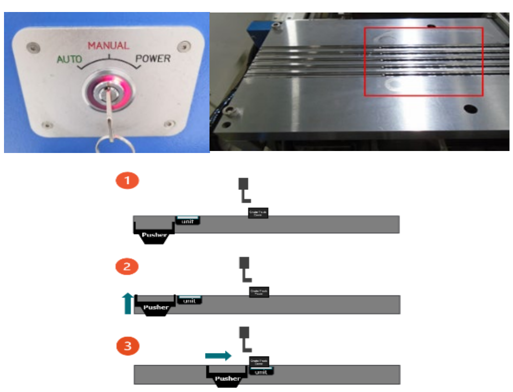


Fig. 9: Manual Mode and Chute Pusher Upward Position

The measuring tool probe was placed on the track near the last contact area of the pusher to unit as shown in Fig. 10. Pusher "move" was manually activated until it touches the measuring tool probe. The charge meter was reset to zero before use. Measurements were recorded.

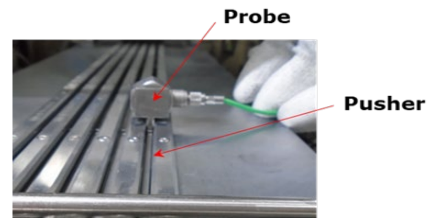


Fig. 10. Measurement Tool Probe Placement in Chute Track

Based on Table 2, the chute pusher exceeded the 50N threshold during the abnormal process. This results in potential package cracks whenever a machine error occurs.

Condition		Pick and Place	Chute Pusher
Current set-up	Ideal Force (N)	0.4	2.4
	Abnormal Overload Force "Jamming Collision" (N)	-	54.6

Table 2. Trim and Form Assembly Force Measurement

After measuring the force, the stress can now be recalculated (refer to APPENDIX B) for each mechanical part as shown on Table 3.

Condition		Trim and Form	
		Pick and Place	Chute Pusher
Current	Area (mm^2)	-	0.17
	Normal Operating Force (N)	0.4	2.4
	Normal Operating Stress (MPa)	-	14.12<114
	Abnormal Operating Force "Jamming Collision" (N)	-	54.6
	Abnormal Operating Stress (MPa)	-	315.0

Table 3. Trim and Form Assembly Force Measurement and Stress Calculation

Table 3 shows the updated force and stress data which clearly shows that during machine errors, the 114MPa threshold has already been exceeded. It means there is already a crack on the unit when the error occurs. This is evident in the line because if this error occurs, the units are scrapped, and lots affected undergo 100% manual visual inspection.

3.3 Analyze Phase

Chute Pusher Analysis

The Chute Pusher has a spring that helps it retract when there is unit jamming in the chute track. Fig. 11 shows how the sensor will trigger the alarm and machine stoppage once the pusher retracts to 0.5mm.

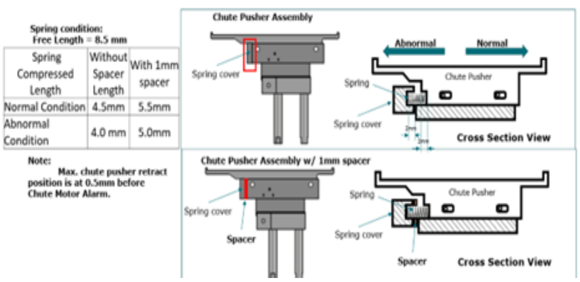


Fig. 11: shows the difference between the chute pusher with and without the spacer. The spacer increases the spring length which absorbs more impact.

Despite the machine alarm, the force readings and stress calculation showed above threshold levels. Upon checking the assembly, the spring is already near its solid length. The spring solid length or maximum compressed length is attained when all coils of the spring are in contact with each other. Now if the spring is at its maximum compressed length, that means it can no longer accept load or force after machine error. It also means that at the point of impact, the package will absorb the force which creates package crack.

The solid length can be computed using the following formula:

Solid Length = wire diameter * active coils
Solid Length = 0.55mm * 7
Solid Length = 3.85mm

The current spring length is at 3.85mm which is already close to the compressed length of the chute pusher at 4.00mm for the machine to alarm.

Spring Allowance = 4.00mm – 3.85mm
Spring Allowance = 0.15mm

Based on the computations, the remaining compression length of the spring is 0.15mm. At this point, the force that the package receives an average of 54.6N, shown in the measure phase.

3.4 Improve Phase

Chute Pusher Spring Modifications

According to Hooke's Law, the force applied on a spring to compress or stretch varies directly to the displacement in the uncompressed length of the spring which can be shown in Fig. 12.

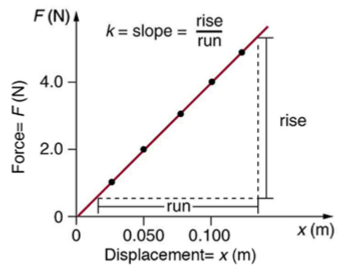


Fig. 12. The force applied on the spring increases as the spring is compressed.

In the Chute Pusher Assembly, the force that will compress the spring until machine error will be coming from the stuck-up unit. This means that reducing the force needed to compress the spring will also reduce the force on the unit.

In Fig. 13, the Chute Pusher Assembly contains a spring holder which houses the spring for the sensor. This holder also dictates the compressed length of the spring which is at 4.5mm. Modifying this holder to increase the initial compressed length can potentially reduce the force on the unit.

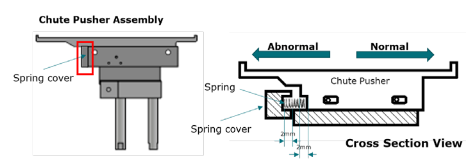


Fig. 13. A cross-section view of the chute pusher where the spring cover and spring aid in triggering the machine alarm during jamming.

A spacer is used to simulate the spring holder modification and then measure the resulting force using the Kistler Force Gauge. After inserting a 1.00mm spacer, the resulting average force was 15.13N Fig 14 shows the reduced force and calculated stress on the unit.

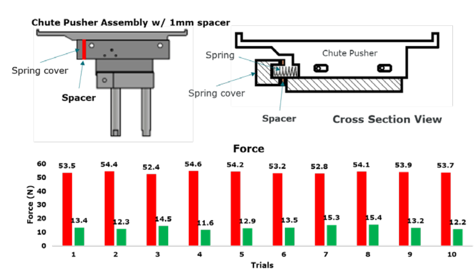


Fig 14. The spacer was placed in between the spring holder and chute assembly to reduce the force from an average of 54.6N to 15.13N.

The stress on the unit also decreased and spring allowance increased after installing the spacer which is shown on Fig 15.

Stress Calculation:

$$S = \frac{F}{A}$$

$$S = \frac{15.13N}{0.17\ mm^2} \longrightarrow \text{Reading from Kistler}$$

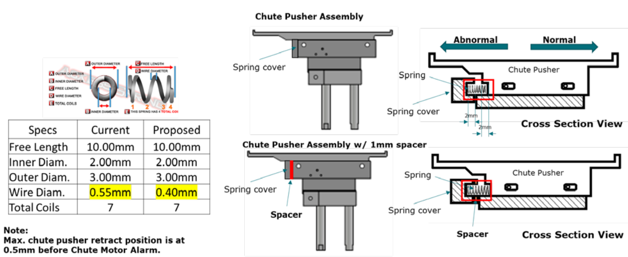
$$S = 89MPa < 114MPa$$

$$Spring\ Allowance = 5.00mm - 3.85mm$$

$$Spring\ Allowance = 1.15mm$$

Fig 15. Stress on the unit reduced from 315MPa to 89MPa. It also increased the spring allowance from 0.15mm to 1.15mm.

Another proposed solution to reduce the force and stress on the unit is to use a different spring wire diameter. The idea is to make the spring less rigid and thus require low force to compress and cause machine alarm. The configuration is shown on Fig 16 which also incorporates the spacer from earlier.



Specs	Current	Proposed
Free Length	10.00mm	10.00mm
Inner Diam.	2.00mm	2.00mm
Outer Diam.	3.00mm	3.00mm
Wire Diam.	0.55mm	0.40mm
Total Coils	7	7

Fig 16. Using a wire spring diameter of 0.55mm and 0.40mm and combining it with the 1.00mm spacer.

After the force measurements, the results were compared using a box plot shown in Fig 17.

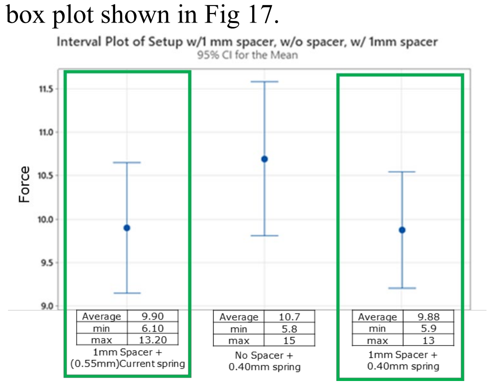


Fig 17. The interval plot shows significant reduction of force after combining the spacer and different wire spring diameters.

Based on the results from the interval plot, there are 2 setups that can be used to reduce the force. From here, the obvious choice would be using the 0.40mm wire spring diameter since the thinner the wire diameter, the less force it needs to compress.

A 2-sample T Test on Fig. 21 was used to compare and check if the 2 setups have significant differences.

Test

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

T-Value	DF	P-Value
0.05	57	0.962

Fig. 18. 2-Sample T-Test of 0.55mm and 0.40mm wire spring diameter.

The p-value 0.962 is greater than 0.05 from the 2-sample T-Test which indicates that there is no significant difference between the two springs as shown on Fig. 18.

According to Pyttel, B., larger wire diameter means the higher fatigue stress a spring can withstand. This shows that the 0.55mm can last longer compared to the 0.40mm wire spring diameter.

Based on those findings, the best setup to implement on the line is by increasing the chute spring holder to 1.00mm thickness and the current wire spring diameter which is 0.55mm as shown in Fig 19.

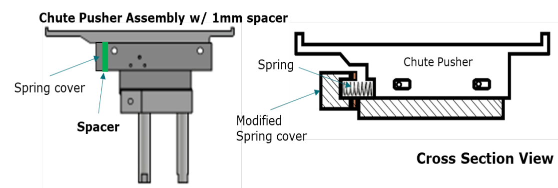


Fig 19. The best setup to implement in the line by modifying only the spring holder without sacrificing the life of the spring.

3.5 Control Phase

The modified chute pusher spring holder project was enrolled in the Quality Control Management or QCM with ID MC-20220728-139 as part of documentation and control in the ATCB. In the document, all old designs were depleted to prevent wrong installation of the spring holder.

4.0 RESULTS AND DISCUSSION

The modified spring holder was then created and installed to check the stress induced on the package during machine error. Table 4 shows that the modification has successfully reduced the stress from 315.0MPa to 89.0MPa.

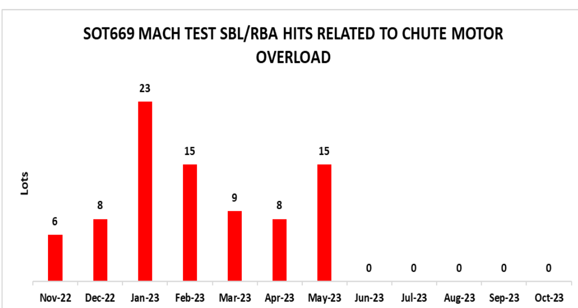
Condition		Trim and Form	
		Pick and Place	Chute Pusher
Current	Area (mm^2)	-	0.17
	Normal Operating Force (N)	0.4	2.4

	Normal Operating Stress (MPa)	-	14.12<114
	Abnormal Operating Force "Jamming Collision" (N)	-	54.6
	Abnormal Operating Stress (MPa)	-	315.0
Improved	Stress (MPa)	-	89.0

Table 4. Trim and Form Assembly Force Measurement and Stress Calculation

Installation on pilot machine was done last February 2023 which resulted in a significant reduction on SBL/RBA. Since all controls are effective on the pilot machine, full implementation was also done on the remaining three SOT669 Hanmi machines last June 2023.

There were no hits of package crack detected during Test SBL/RBA monitoring with Chute Pusher Overload Error on all Trim and Form Hanmi Machines. Fig. 20 shows the reduction of package crack issue detected during SBL/RBA hits on Hanmi Machines and Reduction of Chute Motor Overload OCAP Inspection.



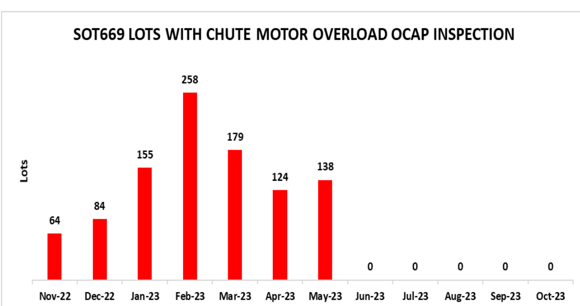


Fig. 20: SOT 669 Trim, Form, and Singulation Hanmi Machines - SBL/RBA Hits and Chute Motor Overload OCAP Inspection from 2023.

In addition to the decreasing of SBL/RBA hits on Chute Motor Pusher Overload, the Cross functional team amended the documented OCAP procedure.

They will no longer subject the lots to 100% manual visual inspection since the stress on the package has been reduced. The removal of the 100% visual inspection and simplifying the process disposition resulted in a projected cost avoidance of $37,259.14 annually.

5.0 CONCLUSION

To reduce the stress endured by the package, the thickness of the chute pusher spring holder was increased by 1mm. The adjustment has reduced the stress of chute motor overload from 315MPa to 89Mpa, which is already below the 114MPa threshold.

6.0 RECOMMENDATIONS

Contact mapping and stress calculation gives a closer look at the different processes and machines which can potentially induce package cracks. It shows how much force and stress is induced on the package during normal and abnormal process. However, it is by establishing the strength of the package that will tell where in the map will it fail.

It should also be incorporated in product material selection, equipment, and tool design specifications to ensure safety of the packages during assembly process.

7.0 ACKNOWLEDGMENT

The authors would like to thank the technical findings and lab instruments used from Nexperia (ATCB) – Failure Analysis Group. The Process and Equipment Engineering Team for supporting us in conducting field experiments in the Trim, Form, and Singulation Area.

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9.0 ABOUT THE AUTHORS

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10.0 APPENDIX

APPENDIX A – Stress Calculation

Formula:

$$S = \frac{F}{A}$$

where;
F = force acted on the package in Newtons (N).
A = area of contact to the package.
S = stress; force induced on the package per unit area (MPa).

Given:
$F = 50$ N

$A_{flat\ tip} = \text{L x W} = 1.1 \text{ x } 0.4 = 0.44\text{mm}^2$

$$S = \frac{50\ N}{0.44 mm^2}$$

Substitute values;

$$\boxed{S = 114\ MPa}$$

Round up and convert units to Mega Pascals (MPa);

APPENDIX B – Stress calculation during chute pusher error. (Abnormal Stress)

Formula:

$$S = \frac{F}{A}$$

Given:
$F = 54.6$ N

$A_{chute\ pusher\ tip} = 0.173\text{mm}^2$

$$S = \frac{54.6\ N}{0.173 mm^2}$$

Substitute values;

$$\boxed{S = 315.61\ MPa}$$

Round up and convert units to Mega Pascals (MPa);

$$\boxed{315.61\ MPa > 114 MPa}$$

Stress received by the package during chute pusher error.