TEST EQUIPMENT INTELLIGENT EDGE SOLUTION FOR PACKAGE CRACK PREVENTION

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ABSTRACT

Package Crack is a serious event in test manufacturing. It can result in significant losses of resources and engineering man hours, as well as compromise the quality of products delivered to customers.

One of the main causes of package crack issues is the deterioration of machine parts, which often goes undetected and causes damage to the device under test. To address this problem, the authors propose an intelligent edge solution in test manufacturing that can prevent quality issues. This solution uses an accelerometer sensor to measure the vibration data and analyze it to identify the worn out condition of the equipment part and automatically stop it from running.

This paper describes the patented system for monitoring and controlling an integrated circuit testing machine, focusing on the development and implementation of the Intelligent Edge Solution for package crack prevention.

1. 0 INTRODUCTION

This paper describes the system solution that was developed as part of an internal 8D corrective action process. The paper does not cover the details of the 8D process itself, but rather focuses on the solution that was implemented to address the problem.

This solution aims to enhance quality by eliminating defects and outliers. One of the sources of defects was die crack / package crack caused by handler parts wearing out or misaligning. The question was whether vibration could be a way to detect these failure modes. A commercial vibration sensor with data logging function was used to test the idea. The goal of the test was to measure the difference in vibration between normal and abnormal conditions. The test results showed a higher peak in vibration for the abnormal conditions, indicating that vibration could be a useful indicator of equipment problems.

This idea was applied to detect handler plunger cylinder wear out and plunger cushioning failure on test handler. These failure modes could lead to package crack. However, the commercial vibration sensors were not suitable. The issues with the commercial sensors were that they were passive, meaning that they only recorded the events and did not alert or stop the equipment, and that they were too big to fit in the tight spaces where they needed to be installed. This prompted the development and implementation of a homegrown vibration sensor system that could monitor the equipment in real time and automatically shut it down when the vibration levels exceeded a certain threshold.

This project aims to design, develop, simulate, collect data, and implement a vibration sensor system that can identify worn out plunger cylinder / no plunger cushioning and avoid package crack. The project will explain the Failure Mode and its relation to package crack. It will also describe the difficulties faced and the solutions applied or planned.
The proof of concept for using vibration to detect abnormal equipment condition was achieved by using a market available vibration sensor and comparing the vibration readings between normal and abnormal equipment condition. A preliminary design prototype was created considering the challenges on the system size, sensor placement, equipment interface for Autostop, and data logging capability. Simulation was conducted to verify the design's detectability. Data collection was done by installing a prototype to a Production Handler and recording the vibration without activating the Autostop function. The prototype was improved based on the collected data. A pilot run was done before fully implementing the system on the target Handler type with Autostop activated. Some challenges were still encountered after implementing the system such as system loopholes that can bypass the flag and invalid flags caused by resistive relay that led to further improvement by adding auto email notification and changing the mechanical relay to Solid State Relay.

2. 0 REVIEW OF RELATED WORK

2.1. Proof of Concept

Proof of Concept was conducted using a vibration sensor that is commercially available to compare the normal and abnormal condition of a piece of equipment (a screw that is loose). The results are displayed in Figure 1, which shows that the peak vibration is higher in the abnormal condition than in the normal one. This demonstrates that vibration can be a useful parameter to monitor the condition of equipment.

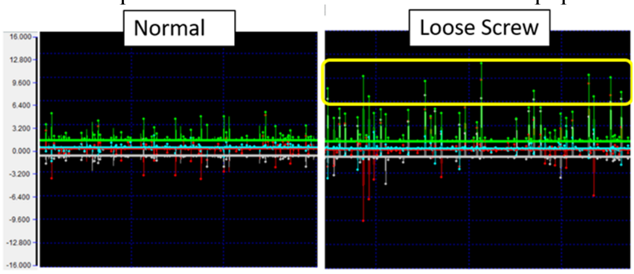


Fig. 1. Vibration comparison of Equipment Assembly at normal and abnormal condition (loose screw).

2.1. No Plunger Cushioning and Package Crack

Cushioning is a feature of cylinders that slows down the piston's speed when it approaches the end of its stroke. This reduces the impact on the cylinder components and minimizes the vibration transmitted to other parts of the machine. Cushioned cylinders are commonly used on plunger heads in most test handlers, to ensure a smooth and gentle movement of the device to the test site. If the cylinder loses its cushioning due to wear and tear, it can cause package crack. This happens when the plunger head moves forward without slowing down and hits the CUH (Contact Unit Holder) with force (Figure 2). The plunger head stops abruptly (Figure 3), but the lead backer and the device continue to move forward due to inertia. The socket CBG (Center Body Ground) then acts as a pivot point and cracks the device (Figure 4).

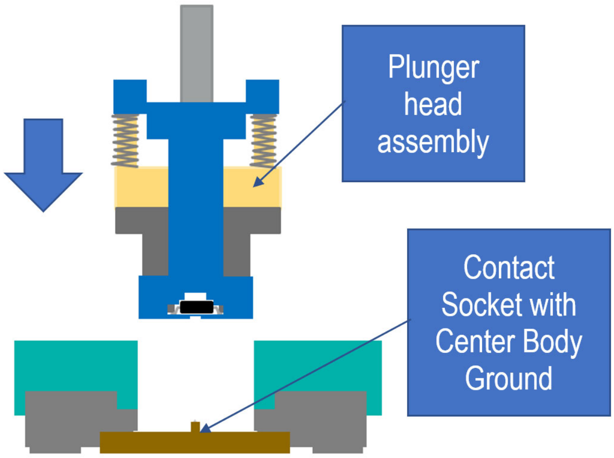


Fig. 2. Illustration of Plunger head assembly and contact socket with center body ground.

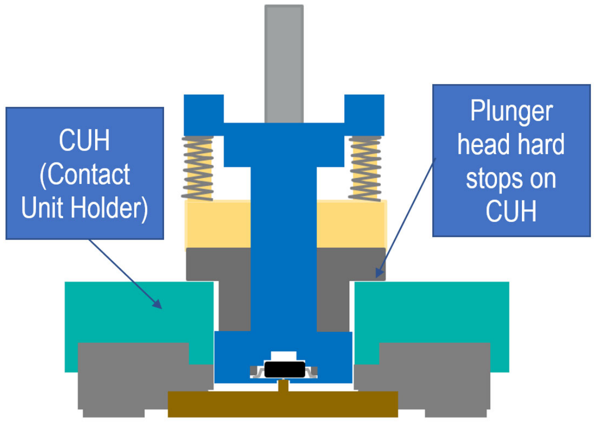


Fig. 3. Plunger Head hard stops at CUH.

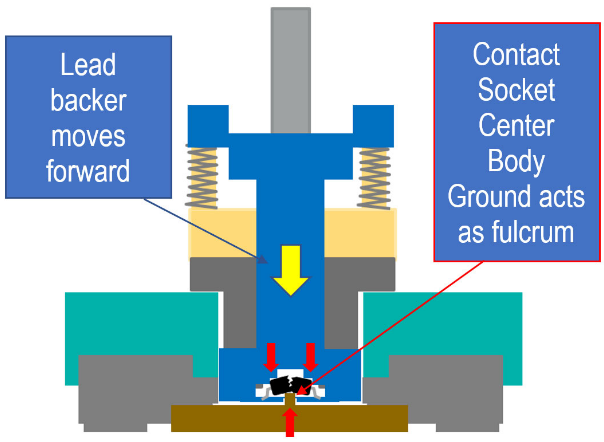


Fig. 4. Lead backer and device moves forward due to no plunger cushioning and CBG acts as fulcrum resulting to Package Crack.

The images in Figure 5 illustrate the effects of plunger wear and lack of cushioning on the package integrity. The top package shows visible signs of lead backer tool marks, and the bottom package shows center body ground tool marks indicating excessive pressure between the plunger and the package during the plunging process.

Fig. 5. Sample pictures Package Crack with tool marks.

3.0 METHODOLOGY

3.1. Applying the Concept to detect Worn out Plunger No Cylinder Cushioning

The idea of vibration analysis was used to identify plunger wear / lack of cushioning that could cause package crack on test handlers. Various sensors available in the market were evaluated (Fig. 6), but none of them satisfied the criteria. The limitation of the market sensors is that they are passive and can only detect abnormal events after manually reviewing the logs. They also do not have any active control or shutdown capability for the equipment. The size of the market sensors was another issue as they were too big to fit in the narrow spaces where the sensors had to be installed. This prompted the development and deployment of a homegrown Vibration Sensor System that can monitor the equipment in real time and automatically stop it when the vibration readings exceeded a certain threshold.

Market Available Products	Features	Size	Price	Max Sample Rate	Range (gF)	Recording Length
A	3-axis vibration	58mm x 33mm x 23mm	$83	100 Hz	±3g	168 Hrs
B	3-axis vibration	95mm x 28mm x 21mm	$210	200Hz	±18g	15 minutes
C	3-axis vibration	76.2mm x 39.4mm x 20.6mm	$344	3,200 Hz	±16g, 200g	42 minutes
D	3-axis vibration	89mm x 112mm x 26mm	$599	256 Hz	±50g	4 hours
E	3-axis vibration with pressure and temp	76mm x 29mm x 15mm	$1,000	3,200 Hz	±16g, 200g	15 hours
F	3-axis vibration with pressure and temp	76mm x 29mm x 15mm	$1,250	20,000 Hz	±25g, 100g, 200g, 500g, 2000g	6 hours
G	3-axis vibration	39mm x 23mm x 72mm	$1,271	1,600Hz	±15g, 200g	6Hours
H	3-axis vibration, temp, humidity, tilt, roll condition	17.17mm x 28.83mm x 5.59mm	$2,400	4,096 Hz	±200g	15 minutes
I	3-axis vibration with pressure and temp	76mm x 29mm x 18mm	$2,950	20,000 Hz	±100g, 500g	4 hours
J	3-axis vibration	72mm x 72mm x 22mm	>$6,000	20,000 Hz	±20g, 50g, 250g	4 hours
K	3-axis vibration and temp, options for humidity, pressure	37 cu. In	>$7,500	3,200 Hz	±2g to 500g	1 hour

Fig. 6. Different market available sensors

3.2. Initial Development – Breadboard Prototype

The first step in creating the custom vibration system was to build a breadboard prototype (Figure 7) that included a microcontroller, an accelerometer module, and a micro SD card module. The prototype was then tested against a commercial sensor to evaluate its performance and accuracy.

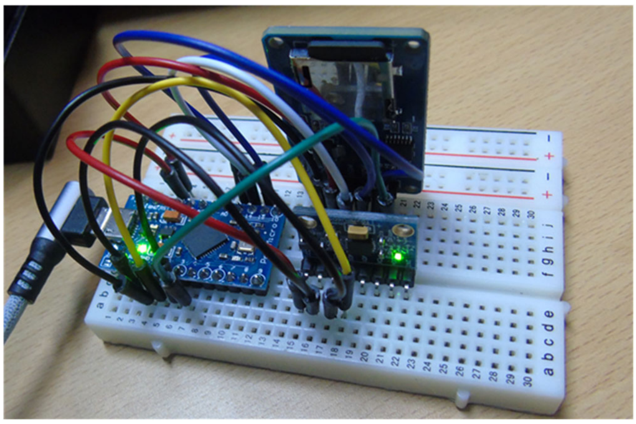


Fig. 7. Breadboard Prototype

The market sensor was attached together with the breadboard prototype with double sided tape. The prototype with the market sensor were then shook several times to let them record the vibrations.

Graphical results of the vibration measurements are shown in Figure 10. The prototype has higher sensitivity than the market sensor. It has captured peak vibrations of -10 to 16 gForce compared to only -4 to 6 gForce from the market sensor. It also has higher sampling frequency where the market sensor only recorded around 1,000 data points compared to more than 13,000 data points from the prototype. The prototype was better than the market sensor.

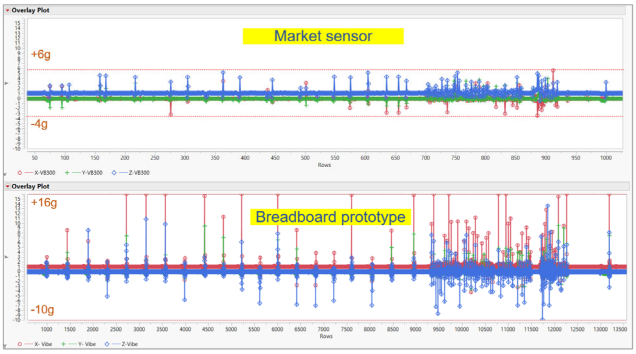


Fig. 8. Graphical result vibration measurements of market sensor vs Breadboard Prototype

3.3. PCB Prototype

The next step in the development was to create a PCB prototype that included a microcontroller, an accelerometer sensor module, a micro SD card module, a clock module, and a mechanical relay. The accelerometer sensor module was designed to be detached from the controller and connected by wires, so that it could fit into narrow spaces in the Handler. The mechanical relay was used to communicate with the Handler and trigger an auto stop function. The clock and micro SD card modules were used to collect and store data from the sensor.

The PCB prototype was tested on a Test Handler to find the optimal location for the sensor that would provide a high signal-to-noise ratio. The main problem that the sensor was supposed to detect was the wear and tear of the plunger cylinder, so the sensor was attached to different parts of the plunger cassette, including the cylinder itself, but none of them gave satisfactory results. The best signal was obtained by placing the sensor on the Contact Unit Holder (CUH), which acted as a hard stop for the plunger head. This made sense because if the plunger cylinder lost its cushioning ability, it would hit the CUH with more force and cause a higher vibration on the sensor.

However, this was not an ideal solution because the CUH was a removable part of the Handler and did not belong to it permanently. The sensor should be fixed to the Handler itself and this was achieved by making a 3D printed spring-mounted sensor holder assembly (Figure 9). This assembly allowed the sensor to press against the CUH when it was installed on the handler and measure the vibrations transmitted by the plunger heads to the CUH.

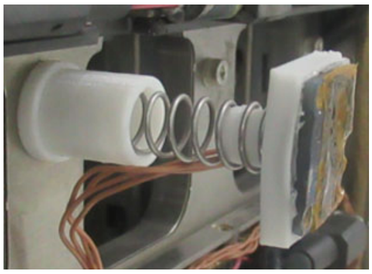


Fig. 9. Spring mounted sensor holder assembly

3.4. Detectability Simulation

With the sensor in place, simulation was performed to check the detectability of the vibration system comparing normal condition versus abnormal condition “No cushioning”. Simulation results are shown in Fig. 10 with 10X higher gForce vibration for the abnormal condition “No Cushion”.

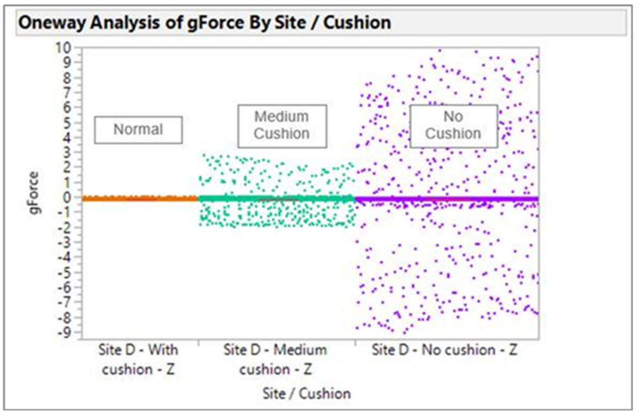


Fig. 10. Results No Cushion Simulation

3.5. Test Handler Interface Autostop

The Test Handler has an existing CGM (Continuous Ground Monitor) system. The CGM monitors the ground condition of the different handler assembly. If there is a ground problem, the CGM will stop the Handler. The vibration system was connected to one of the ground points of the CGM. To stop the handler, the vibration system will open the ground connection thru the relay. CGM will register this as a ground fault and will then stop the Handler. If the ground fault was made by the ground point connected to the vibration system, CGM will display an “evibe alert” on the CGM display panel (Figure 11).

Fig. 11. CGM display vibration alert

3.6. Final Vibration System Design

Final design of vibration sensor system consists of microcontroller, optocoupler module, mechanical relay, clock and micro SD module. Optocoupler module was added to connect to the Handler light pole and allows the system to detect vibration only when the Production green light is on. This avoids false alarms during equipment repair or maintenance. The key features of the system are shown in Table 1.

Table 1. Vibration System Features

No	Features
1	Real Time detection and Handler Autostop of "No Plunger Cylinder Cushioning"
2	Read the vibration only during Handler Production status to prevent flags during equipment verification / repair
3	With Date, Time, and gForce data logging capability for data analysis
4	Automatic memory management: create log files per date and automatically delete old log files more than a year from the current date

4.0 RESULTS AND DISCUSSION

The Handler was equipped with the vibration system to monitor its condition during production run. Figure 12 illustrates an example of the system detecting and stopping an abnormal event caused by excessive vibration. The vibration data logs revealed that the equipment's performance was deteriorating gradually until it crossed the threshold set by the system. The root cause was identified as no plunger cushioning, which resulted from the wear and tear of the plunger cylinder and the cylinder guide pin. The problem was resolved by replacing the damaged parts and adjusting the cushioning. This demonstrates the system's ability to identify the abnormal situation in the Production environment.

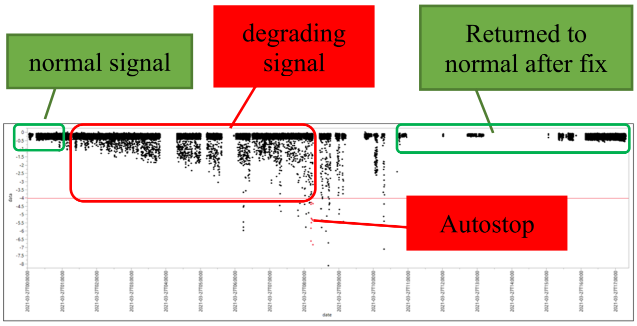


Fig. 12. Graphical data of vibration system on a Production Handler

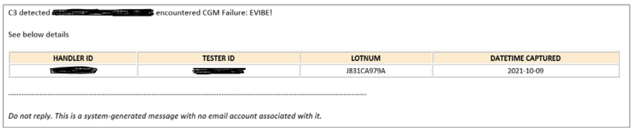
Summary of valid signals that the vibration system has detected to date is shown in Table 2. It indicates that the system can detect other failure modes besides the no plunger cushioning that it was designed for.

Table 2. Summary of valid signals

Failure Mode	Count
No Plunger Cushioning	4
Failure mode 2	2
Failure mode 3	1
Failure mode 4	1

4.1. Issues and Improvements

After implementation of the vibration system on the Handler, another package crack happened. Interview with Production personnel said that the vibration system did not flag any alert. To verify this claim, the vibration system logs, Handler logs, and CGM logs were reviewed. The vibration logs showed high vibrations and it did detect an abnormal condition on the Handler. The Handler logs also showed that there was a jam corresponding to a CGM fault. Lastly, the CGM logs showed that the error code on the CGM was 32768 which is the error code for the ground point connected to the vibration system. All the logs showed that the vibration system flag an alert, and someone cleared the alert and just continued running the Handler. This led to the development of auto email alert for the vibration system (Figure 13).


C3 detected [redacted] encountered CGM Failure: EVIBE!

See below details

HANDLER ID	TESTER ID	LOTNUM	DATETIME CAPTURED
[redacted]	[redacted]	J831CA979A	2021-10-09

Do not reply. This is a system-generated message with no email account associated with it.

Fig. 13. Sample auto email alert

Another problem encountered after some time is that several invalid flags occurred. The cause was the mechanical relays were becoming resistive and since it was connected to CGM which is sensitive to resistance, it was flagging it as a ground fault resulting to invalid vibration flags. Improvement was made to the system by replacing the mechanical relay with solid state relay (Figure 14).

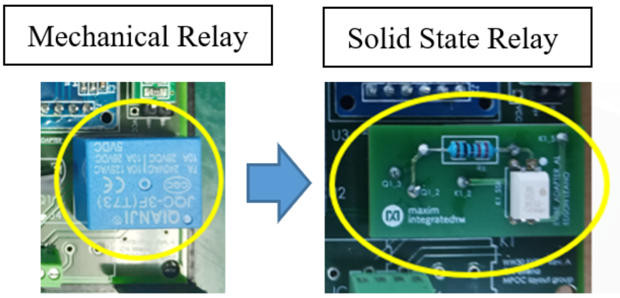


Fig. 14. Mechanical relay replaced with SSR

5.0 CONCLUSION

Vibration can be used as a leading indicator for test handler performance enabling it to be corrected before it impacts quality. This concept can also be applied to other equipment in the manufacturing processes.

The vibration sensor system presented was able to detect abnormal conditions of the handler not just the intended failure mode of "No Plunger Cushioning" but other failure modes as well. The system was able to stop the equipment prevent it from producing Package Crack or other related mechanical failure.

6.0 RECOMMENDATIONS

One of the limitations of the presented system is that it operates in isolation, without any network connection. This means that the datalog is stored locally and cannot be accessed or viewed remotely. A possible improvement would be to establish a network connection for the system and send the data to a server where it can be easily retrieved or monitored.

7.0 ACKNOWLEDGMENT

The authors would like to thank and acknowledge the contribution of our ADCV Equipment Engineer, and CGM team for their support in conducting Handler simulations and evaluations. CEE for designing the sensor mounting assembly. PCB Layout for providing the PCB layout and boards. IT team for C3 code development and auto email notification. This project would not have been completed without their support.

8.0 REFERENCES

1. https://www.clippard.com/cms/wiki/cushioned-cylinders
2. https://blog.rangercaradoc.com/what-is-hydraulic-cylinder-cushioning#:~:text=Cylinder%20cushioning%20is%20an%20arrangement,the%20end%20of%20the%20cap.

9.0 ABOUT THE AUTHORS

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