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Mechanical Cracking

The Major Cause for Multilayer Ceramic Capacitor Failures

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Introduction

Due to its brittle nature, multilayer ceramic capacitors are more prone to excesses of mechanical stress than other components used in surface mounting. One of the most common causes of capacitor failures is directly attributable to bending of the printed circuit board (PCB) after solder attachment. Excessive bending will create mechanical crack(s) within the ceramic capacitor. Mechanical cracks, depending upon severity, may not cause capacitor failure during the final assembly test. Over time moisture penetration into the crack can cause a reduction in insulation resistance and eventual dielectric breakdown leading to capacitor failure in service.

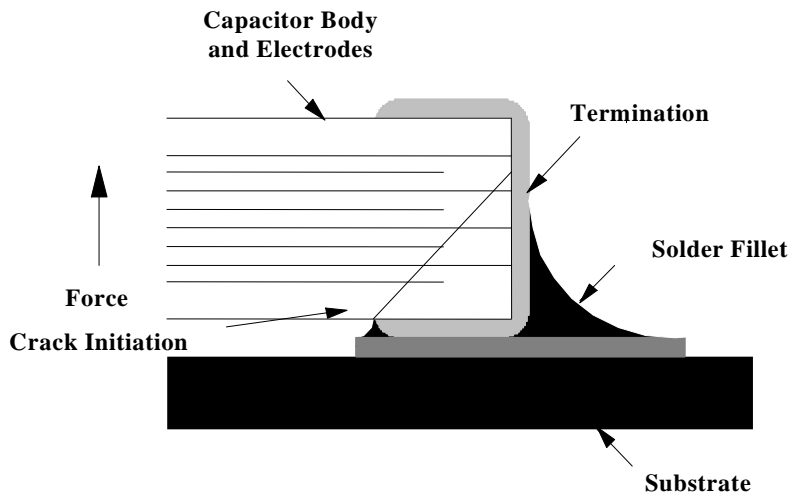


Fig 1. Mechanical Crack

Example of capacitors issued by customers to Syfer for failure investigation:





Potential Causes

Mechanical cracks are created by excessive mechanical stress after the capacitors have been soldered onto the substrate.

Excessive mechanical stress can be the result of the following:

- Exceptional Circumstances
 - Interference fit. For example, physical abuse.
- Normal Circumstances
 - Assembly design.
 - Board de-paneling causing the PCB to bend.
 - Automatic test equipment employing a “bed of nails” as contacts. Faults often occur at, or in close proximity to, support pillars within the test jig. Vacuum fixtures can also cause excessive PCB bend.
 - PCB distortion/ warp caused by storage conditions or uneven PCB designs. Frequently distorted PCBs are straightened after the soldering process causing the capacitors to mechanically crack.
 - Radial/ through hole component insertion especially if there is a tight fit between the radial leads and PCB hole.
 - Attachment of rigid fixtures such as heat sinks.
 - Fitting IC’s, connectors into solder mounted sockets with no support.
 - Methods of transportation/ storage and handling during process stages allowing the PCB to bend.
 - Fixing completed sub-assemblies into the final assembly. For example, employing a snap fit operation or by over-tightening fixing screws.



Corrective Actions

Extensive bend tests performed at Syfer including bench-marking against competitor's products has proven that:

- i. Syfer capacitors pass the International Specifications ⁽¹⁾ defining robustness of termination criteria.
- ii. The bend test performance of Syfer's sintered termination capacitors is comparable with competitor's sintered termination product.

Note (1): For International Specifications and Syfer Bend Test Methods refer to Syfer Application Note AN0002 Bend Testing.

The only effective methods of resolving mechanical cracking issues are:

- i. Reduce the mechanical stress being exerted on the capacitors.
- ii. And/ or increasing the process window so that the mechanical stress exerted onto the ceramic section of the capacitor is reduced.

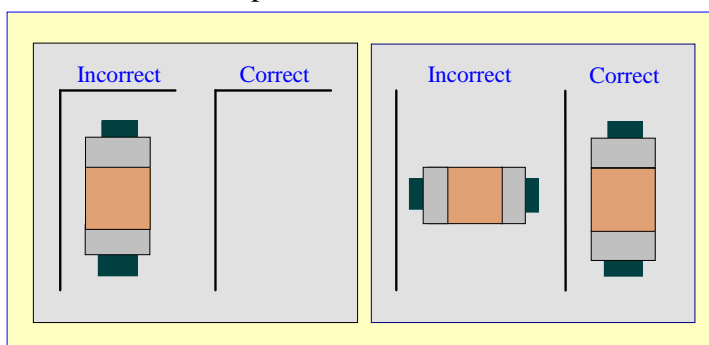
ATE, functional tests and reliability tests have limited success in identifying capacitor failures caused by mechanical cracking.

- Assembly Design/ Manufacture Considerations

Mechanical stress can be influenced by a number of different factors associated with the design of the assembly and assembly manufacture. These factors include:

- PCB design – copper power and ground planes.
A PCB design resulting in an uneven metal distribution (usually caused by large power or ground planes) can result in PCB warpage during the soldering process caused by the different Thermal Coefficient of Expansion rates between the copper and the epoxy fiber glass. If large power/ ground planes are required then cross hatching the copper area may prove to be useful.
- Position/ orientation of the capacitor on the PCB in relation to the edge of the PCB and other components/ attachments.

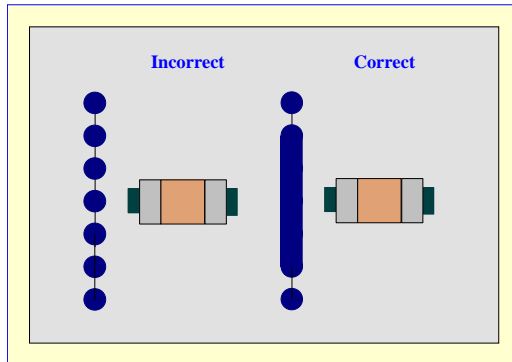
Capacitor placement not recommended in the corner of the PCB.



Recommended capacitor orientation with respect to PCB edge (denoted by black lines).

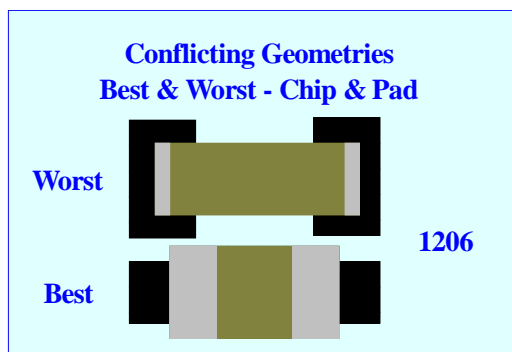
Note: Stress zone is typically within 5mm of PCB edge or fixing point.

Use of PCB slots



Using a slot along the depanelisation edge reduces the level of stress exerted onto the capacitor by approximately 50%.

- Solder pad/ land sizes.



Reducing the pad/ land size can reduce the level of stress exerted onto the capacitor by approximately 50%.

- Use of Adhesives.
Depending upon the type of adhesive used, the effect can be a significant reduction in the bend strength of a capacitor. For example, during experiments approximately 50% of the PCB bend was required to crack a capacitor fixed with adhesive when compared to a capacitor not fixed with adhesive.

- Review Production Processes

Mechanical cracking occurs after the capacitors have been soldered into position. Subsequent flexing of the PCB creates mechanical stress within the capacitor that if sufficient can result in the capacitor being mechanically cracked.



When mechanical cracking has been identified as the cause for capacitor failures the typical approach for customers is to review the production process for any obvious process stage including handling and transportation that may be bending the PCB. If no obvious stage is identified then the next step is to remove samples of capacitors from assemblies at different process stages and then subject the capacitors to sectioning/ internal examination to determine if the capacitors have been cracked. The shape of mechanical cracks is shown in Fig.1.

An example of a typical investigation would be to remove capacitors from assemblies after completing the following stages:

- Soldering
 - Depanelisation
 - Insertion of radial components including connectors and IC's into sockets
 - ATE
 - Fixing the completed sub-assembly into the final assembly.
- Syfer Capacitor Enhancements Offered

Syfer offers a polymer termination that effectively reduces the mechanical stress being exerted onto the ceramic section of the capacitor by approximately 50%. The polymer termination is being used by a variety of customers and requires no changes to the customer's assembly process.

For further details refer to Syfer Application Note AN0001 Polymer.

- Test Methods

There is no 100% guaranteed method for being able to test capacitors that have been mechanically cracked. The success of the tests conducted relies on the extent of the mechanical cracks – wider cracks are more likely to fail.

Examples of tests conducted by customers:

- Dry Heat/ Steady State. Assemblies powered in a hot dry environment to accelerate the breakdown of the capacitors.
- Damp Heat/ Steady State. Assemblies powered in a hot humid environment to try to drive moisture into the crack and cause capacitor failure.
- Temperature Cycling. Assemblies are temperature cycled with the purpose of opening the crack to cause capacitor failure.
- Vibration and Shock. Assemblies are subjected to vibration/ shock tests with the purpose of opening the crack to cause capacitor failure.



- X-Ray. Customers have tried to employ x-ray solder joint inspection equipment to try to detect mechanical cracks with very limited success.
- Scanning Acoustic Microscopy.

The tests conducted have depended upon the equipment available to customers and the success of tests has varied.

Depaneling Methods

Depaneling is the process of separating individual PCB's from a main panel (usually after the soldering operation) and can present a high risk of mechanically cracking ceramic capacitors. There are various depaneling methods employed, some of which present a greater risk when compared to other methods.

As a guide, depaneling methods include:

Depaneling Method	Benefits	Negatives	Comments
Manual Break-Out	Flexibility. No tooling costs/ changes. No software set-up.	High risk of mechanical cracks. Labour intensive. Not consistent. Potentially high scrap rate.	Not generally recommended though frequently used
Scissor Shearing/ Guillotine	Low tooling costs. Minimal/ no software set-up. Ease of operation.	Severe shock – high risk of mechanical cracks. Potentially high scrap rate.	Not generally recommended.
Blanking/ Die Shearing/ Punch-Out	Fast processing times. Virtually any PCB shape.	High tooling costs. Potential for shock – depending upon supporting fixtures. Less flexibility – tooling changes required.	Usually used for processing high volume of assemblies.
Circular Rolling Blades	Low tooling costs. Minimal/ no software set-up. Ease of operation. Less stress exerted when compared with Shearing.	Some machines are operator dependant. For example, operators hold PCB sides – excessive mechanical stress can still be created.	Frequently used by customers processing low to moderate volume of assemblies.
Sawing	Wedge-shaped knives shear panel with gentle rocking motion along the whole length of the section to be cut – less stress exerted.	Some machines are operator dependant. For example, operators hold PCB sides – excessive mechanical stress can still be created.	Exerts less mechanical stress when compared with manual, guillotine, blanking and circular blades.



Depaneling Method	Benefits	Negatives	Comments
Routing	Flexibility. Virtually any PCB shape. Reduces mechanical stress. No/ minimal tooling changes required. Good quality PCB edge finish.	Software set-up. Relatively slow processing times. Initial costs when compared with some of the other depaneling systems.	Exerts less mechanical stress when compared with manual, guillotine, blanking and circular blades.
Laser Cutting	Flexibility. Virtually any PCB shape. No mechanical stress. No/ minimal tooling changes required.	Initial costs and maintenance costs. Depaneled edge often charred and can be jagged. Extra cleaning process possibly required to remove charring.	Very good regarding no mechanical stress but is costly and not frequently used by customers.
Water Jet	Flexibility. Virtually any PCB shape. *No mechanical stress. No/ minimal tooling changes required.	Initial costs and maintenance costs. Process can be slow. Noisy operation. Water removal and treatment environmental issues.	* There are conflicting reports regarding the level of stress exerted onto the PCB. Also, water jets appear to be rarely used.

When reviewing depaneling methods it is recommended that customers contact equipment manufacturers to help evaluate what type of system is most suitable based on processing times, flexibility, costs and mechanical stress exerted.