MLCC Application Notes

Common Cracking Modes in Surface Mount Multilayer Ceramic Capacitors

Frequently asked questions regarding mechanical cracking.

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Abstract

This paper provides an explanation of bending and impact cracks in a question and answer format readers find most helpful.

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Common Cracking Modes in Surface Mount Multilayer Ceramic Capacitors

by Chen Davis, Steve Maloy and John Wegman

Introduction: A problem that occurs when handling and mounting multilayer ceramic capacitors (MLCCs) is the failure of the component due to mechanical cracking. This is most often detected at electrical test as a leaky or shorted component.

Question 1: What are the main causes of mechanical cracking in MLCCs?

There are two main causes of mechanical cracking. The first is impact cracking, which occurs during the placement of the component on the printed circuit board (PCB). The second is flex cracking due to bending or board flexure. Impact cracks are typically caused by improper setup of the pick-and-place machine, while bending cracks are typically caused by excessive board flexure after soldering the component to the PCB.

Question 2: How can impact cracking be distinguished from flex cracking?

Impact cracking will appear on the surface of the component, usually as a discolored circular or half-moon shaped crack at or near the center of the capacitor (see Figure 1). These small cracks can evolve into larger cracks as the additional stresses of subsequent processing are applied to the component, including those stresses caused by bending of the PCB.

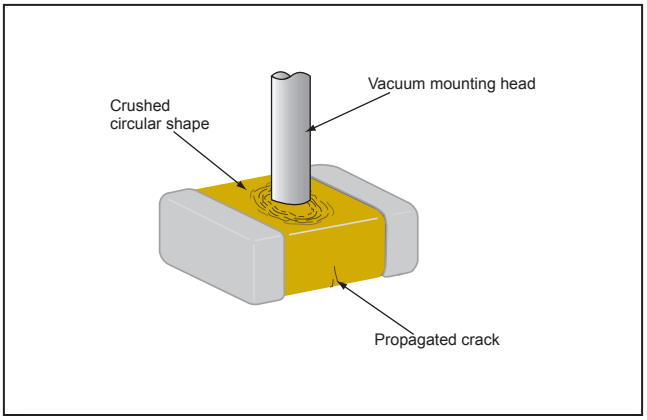


Figure 1-Circular Cracks caused by pick and place mounting head

The signature bending crack will appear as a "Y" crack or 45° crack when viewed by cross-section (see Figure 2). The crack may or may not be apparent to the external surfaces of the MLCC. Bending cracks are typically located in proximity to PCB contact points or depaneling plains.

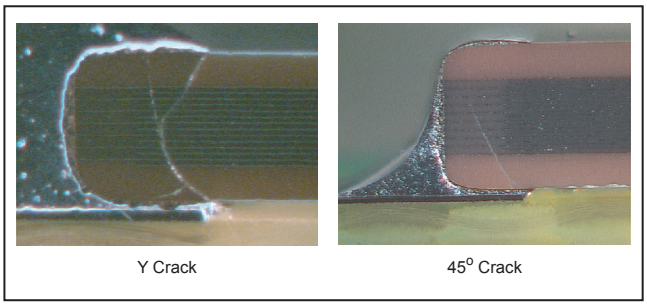


Figure 2-Typical Bending Cracks

Question 3: How can the pick-and-place machine setup cause cracking?

The mounting head on pick-and-place machines uses a vacuum pipette or centering jaws to position the component. The X, Y, (and especially) Z direction adjustments are critical to avoid striking the component off target.

Of course, excessive downward (Z) force can break a ceramic capacitor. But if the mounting head applies ample force to an area other than to the center of the ceramic, the stress on the capacitor during placement could still become significant enough to crack the component (see Figure 3).

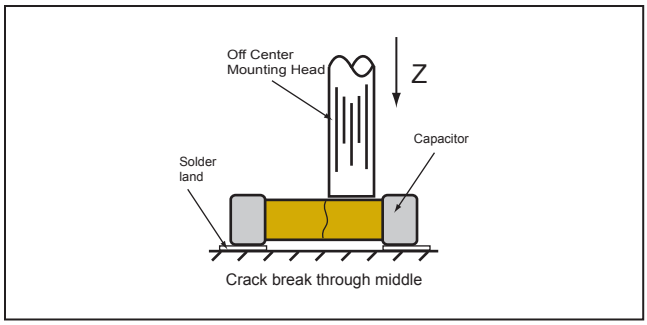


Figure 3-Off Center Mounting Head Cracks

Also, the size of the mounting head can cause cracking. A mounting head with a small diameter will focus the force of placement during mounting. This can cause cracking of the MLCC because there is less area to distribute the force (see Figure 4).

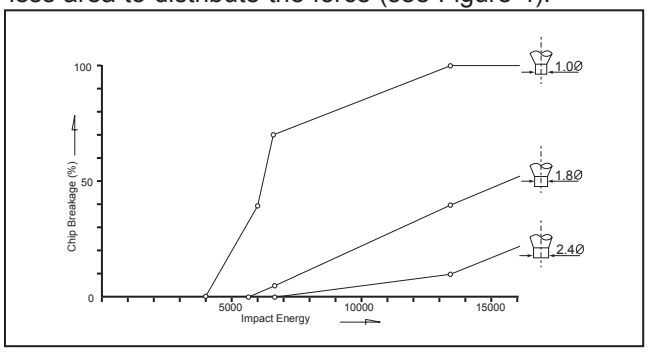


Figure 4-Comparison of applied mounting force vs mounting head diameters

In addition, the debris left on the PCB can also cause the capacitor to crack. During the placement of the capacitor, the uneven surface of the PCB will cause an uneven distribution of downward forces to the capacitor when placed. Thus, the capacitor can crack (see Figure 5).

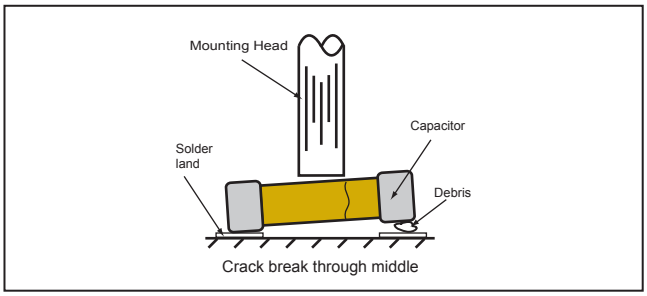


Figure 5-Crack caused by uneven surface

Question 4: How does PCB bending cause cracking?

When the MLCC is mounted onto the PCB, it becomes part of the board. While the FR-4 material used for most PCBs is somewhat rigid, flexure can occur. The ceramic body of the MLCC will not bend with the board, and consequently will be subjected to tensile stresses (see Figure 6).

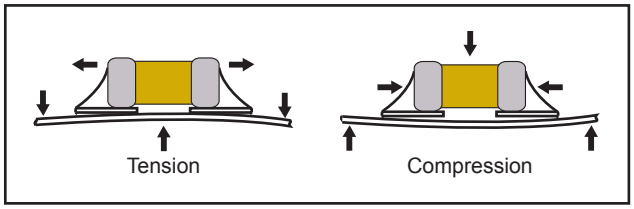


Figure 6-Tension and Compression bending forces causes by bending.

Ceramic materials are strong in compression but weak in tension. When the tensile force becomes greater than the inherent ceramic material strength, a crack will occur.

A factor that influences bending strength is solder fillet amount. The recommended solder fillet height is 50% ~ 75% the height of the capacitor. Too much solder will increase the pulling force on the MLCC during bending (see Figure 7).

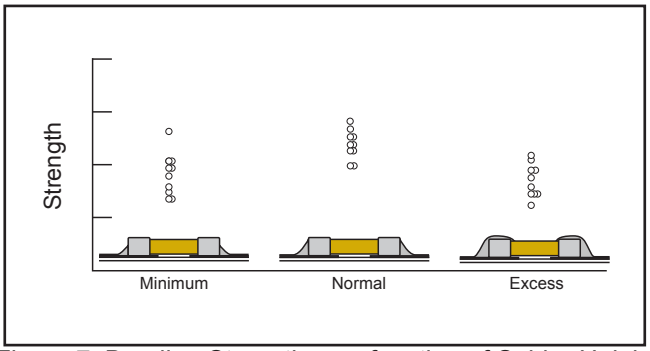


Figure 7: Bending Strength as a function of Solder Height

Uneven solder amounts will create an uneven stress distribution over the MLCC, concentrating stress on one end and subsequently cracking it (see Figure 8).

Solder pad dimensions are also important. In addition to allowing for placement variances, correct pad dimensions will allow balanced solder fillets to form during the soldering process. Pad dimensions other than manufacturer specifications are not recommended.

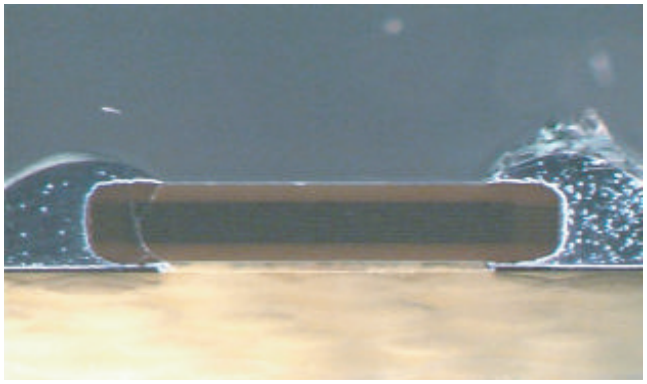


Figure 8-Bending Crack Induced by Too Much Solder

Question 5: What other ways can MLCCs become cracked?

While it is possible capacitors could be supplied already cracked in its incoming packaging, it is not likely. Most MLCC manufacturers take great care to ensure final inspection and shipment is done correctly. Cracking modes other than impact and handling can include thermal, in-circuit testers and H_2 absorption.

Question 6: How can a capacitor user detect cracking?

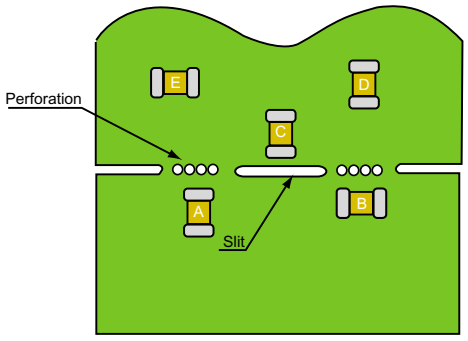
It is recommended more resources be spent on the prevention of cracks than detection; however, detection is possible by using in-circuit resistance testers. Once a capacitor becomes cracked the resistance will drop.

Note: Use caution to avoid board flexure and direct component contact.

Question 7: How can a capacitor user prevent cracks?

Proper placement set ups and minimal board flexure is the key. Depaneling the PCB after mounting is an especially delicate process. Any bending to separate the boards will induce stresses such as those discussed above. In addition, the proximity and orientation of the MLCC with respect to the separation plane is vital. Perforation and slits of the PCB should be designed away from the MLCCs. The mounting of the MLCCs should be parallel with the perforation in order to have the least stress applied to the capacitor. An MLCC oriented parallel to the break line and away from contact points is the optimum placement direction.

This is illustrated in Figure 9. Component A will experience the highest stress during depaneling, followed by components C and D. Components B and E are in optimum orientation, but E will experience the least stress due to its distance from the break line. Placing the MLCC farther away from the break line is better, as stresses increase with proximity to it.



The stress in capacitors is in the following order.
A > B = C > D > E

Figure 9-Component Arrangement on PCB

In addition to PCB depaneling and transferring, assembly can cause board flexure. Finished PCB often must be affixed (screwed, clamped, etc) to a housing. Care must be taken to handle the finished PCB in robust locations to avoid bending stress. A seemingly innocent handling technique can be devastating if not carefully excerised.

Any type of board flexure should be avoided in the assembly process. For instance, belts and conveyors should have low transition angles. PCB transport should occur with the whole board supported evenly, and care should be taken when loading the PCB in to mounting jigs or other machinery.

Pad dimensions and solder paste amounts coupled with heat profiles that stray away from manufacturer's specification may produce solder fillets of varying height/strength. Even if the solder appears to have formed an acceptable bond, improper heating will give the solder fillet less strength.

Finally, downsize the component to its smallest available case size. The cracking potential is significantly reduced as the body size of the MLCC is decreased.

Note: Refer to TDK's MLCC Catalog and Application Manual for more information.

Conclusion: Multilayer ceramic capacitors should be handled very carefully during mounting, soldering and handling. Any damage incurred during these processes, no matter how small, can contribute to premature component failure. *Handling a PCB with soldered components should be done with care to avoid any bending of the board.* If the steps outlined in this paper are followed, MLCC cracking can be avoided successfully.

References:

1. TDK Ceramic Products Business Group, "Types of cracks that may occur during handling", Technical Report, August 1992.
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3. Puligandla, P. and Colangelo, J., "Preventing Passive Component Failures on PCBs", Surface Mount Technology, February 1999, p. 64.
4. Maxwell, J., "Cracks: The Hidden Defect", Technical Information Bulletin, AVX Corp., 1988.

End of Report

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