Depaneling: a study in yield and productivity: saw systems can provide a low stress and fast alternative to hand breaking methods. (End-of-Line Processes)

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Depaneling is an overlooked step in surface-mount production and involves the separation of a single piece from its carrier frame (the scrap) and its sibling printed circuit boards (PCBs). Ironically, when considering the overall value-add equation of assembly, and the cumulative impact of each additive process, little attention is given to depaneling, which is one of the most critical steps in the assembly process.

Literally, millions of dollars in capital equipment are allocated to placement systems, reflow and inspection to maintain a high degree of process control. Then, in many cases, boards are simply snapped apart in an uncontrolled fashion. In reflow, thermal ramp rates are managed and thermal soak periods controlled; in placement, loads are monitored to ensure joint and component integrity. However, the loads a panel is subject to after assembly technology has been deployed--giving parts 100% of their value--are invariably ignored or given minimal consideration.

Various manual tools are available to assist the process and limit the exposure of the product to strain. But, none of these alternatives has any level of control other than the individual who is operating the tool.

The one factor that has consistently driven higher levels of sophistication in the depaneling process has been component density. As a board shrinks in size and its component count stays static or increases, it becomes more susceptible to joint failure when a bending load is applied. This issue was particularly evident in the telecom industry, as the reduced size of the device (handset) and increased functionality became enormous drivers to sales volumes. Automated depaneling machines became a necessity to yield and cost control.

The bottom line drivers for automated and repeatable process-driven machines are twofold. First, the total cost of the circuit is often lost when failures occur due to a poorly controlled depaneling process. Reworking a delaminated product is simply not feasible. Second, and more insidious, are field failures. A fractured joint or a delaminated board may not show itself during test but will fail as a result of thermal cycling (use) and environmental exposure. The tangible costs such as warranties and intangible costs such as customer loyalty involved at this stage are difficult to quantify. However, many studies have shown that intangible costs often outweigh tangible costs by a significant margin.

The downturn in the economy and, subsequently, the electronics industry has affected both automated equipment manufacturers and users. Budgets are currently being applied cautiously in areas that bring yield improvement and quality control rather than productivity. While this concern is immediate, we all must continue to keep a close eye on the continued growth of electronics and the impact it makes on our daily lives.

The issue for manufacturers is speed of design and time to market and maintaining basic margins from manufacturing. With slimmer margins, increased competition brings more pressures for product functionality. This demand is creating denser and denser circuits and a need to reevaluate the depaneling process. Yield improvement along with productivity are the key differences between making money and losing money. Depaneling, often overlooked, provides a huge opportunity to improve both.

The five basic methods of depaneling are:

* hand break

* pizza cutters, nibblers (assisted hand break)

* punches

* routers

* saws.

The nine basic considerations for selecting a suitable process are:

1. circuit design and sensitivity

2. productivity

3. initial capital cost

4. floor space available

5. ongoing costs such as tooling

6. frequency of changeovers

7. circuit end use and potential for user reclaim

8. consumables such as cutting tools

9. operators' skill sets (first to third shift).

A consumer product with a very low value will be singulated by hand. Product value and production volumes do not demand any other depaneling method than the simplest process. Electronics circuits, on the other hand, should be looked at in greater detail.

In the case of a new product, where the panelization of circuits can still be affected, consider how final assembly will be conducted and panel designs will be made complementary to the process. For instance, saws can only cut in straight lines and do not need V scores. Routers can cut radii and straight lines but are slower and demand pre-routed slots. Punches need tabbed circuits with minimal material to minimize strain and maximize tool life.

Multilayer circuits, prone to delamination, should be given a degree of consideration with respect to design flexibility and production volumes. Even a single- or double-sided product may evolve into a multilayer circuit as functionality demands increase; thus, future designs should be factored into depaneling strategies.

The one question that has remained open for debate is how individual depaneling processes impact the circuits in terms of the strain applied and potential defects created at the very end of the manufacturing process. To establish a degree of baseline information, the following tests were carried out. Currently, no industry specification indicates allowable strain on a given circuit. If a specification did exist, it would be highly debated. Common sense dictates that, if a circuit and its components are to function for the expected life of the product, a minimal degree of bending (strain) should be applied to the circuit through its assembly and separation from the parent carrier.

A commonly held view is that 1000 micro strains is the maximum exposure to which a circuit should be subjected. The strain measurement is taken as close to the point of separation as possible, depending on individual panel design and sensitivity.

Testing Procedure

Introduction

The term strain refers to the relative change in dimensions or shape of a body, which is subjected to stress. Strain [member of] = ???1/[1.sub.0] is a pure number. The purpose of this testing was to determine the magnitude of the strain on a circuit board during different depaneling operations. Stress loads were not calculated due to unknown material specifications and the varying nature of the material.

Equipment

The scanner and software used in the study provided fast, simultaneous acquisition and digitization of multiple channels of various analog inputs. The full-featured software provided flexible graphic presentation along with data reduction and scanning interval control (up to 10,000 samples per second per channel).

Two different types of strain gages were used. The first one was a small, three-element, 45[degrees], rectangular, stacked rosette. The second was a small, 45[degrees], rectangular, single-plane rosette in a compact geometry. The resistance for both was 350 ohms. Gage #2 was preferred over Gage #1 because the soldering process was easier and the gage structure was more rugged.

The first depaneling method tested was sawing. At speeds of two inches per second and six inches per second, cutting was accomplished with a 240 diamond-grit 3 in. outer diameter, 0.020 in. thick saw blade.

The second method tested was hand break. The panel was placed on a fixture with a break-line edge. While holding the panel steady with one hand, the panel was bent downward with the other hand until the boards separated. The third depaneling method tested was routing. Cutting speeds applied were one and two inches per second; one cut was made with a cutting speed of three inches per second. Router bit diameter was 0.062 in.

Test Arrangement

Prior to testing, strain gages were attached to the circuit boards using epoxy adhesive for proper bonding of strain gages. Strain gages were attached to glass fiber-reinforced epoxy circuit boards (Figure 1). Chosen gage locations were assumed to be areas where most of the strain would occur during depaneling Figure 2).

[FIGURE 1, 2 OMITTED]

The circuits were then cut at varying distances from the point at which the strain gages were positioned with the goal of determining strain relative to the following parameters: speed of cutting, feed rate of process and distance from strain gage.

Results

Table 1 shows the total values as compared to the same ones at a certain distance with routing.

Table 2 shows routing at one inch per second at a distance of 2 mm as the comparison value.

Routing is by far the least stressful of all the processes. However, when considering routing as an alternative to a V score panel hand break process, it does not compare from the standpoint of productivity. But, circuits with pre-routs incorporated in the design leave minimal material to be removed, thus making the routing process reliable and safe with cut speeds keeping pace with most production line tact times. The influence of the feed rate of the bit through the material (Figure 3) is interesting when considered with the results for faster bit RPM (Figure 4). Higher RPM introduces less strain and should be used in parallel with higher feed rates to offset the higher levels of strain applied, thus balancing the process.

[FIGURE 3, 4 OMITTED]

Sawing at speeds similar to those of a routing process results in stress being applied to the circuit at acceptable levels, albeit slightly higher than a routing process. As the feed rate for the saw increases, so, too, does the degree of strain exerted (Figures 5-7). However, the levels are well within acceptable norms, and the relative rates of productivity are three times that of routing (Figure 8). In reality, the degree of productivity is significantly higher, as the sawing process does not demand the pre-route paths and is cutting though solid material. Also, note that the fixturing of an), circuit can enhance or degrade the process by allowing a higher degree of support to the circuits in process.

[FIGURE 5-7]

Conclusion

Depaneling, like many other processes, remains an essential part of electronics assembly. It will continue to evolve to meet the new challenges of the next generation of electronics circuit designs. Routing will always have its place in manufacturing as a flexible and well-proven method of separating single panels from a parent carrier where a nonlinear profile is demanded, as with most consumer products. The advent of increased density in industrial electronic products is bringing with it a need for greater focus on depaneling methods used if yield and field failure rates are to be well managed. This particularly relates to V-scored layouts. Saw systems designed with robust and flexible fixturing systems provide a low stress and fast alternative to hand breaking methods, while bringing all the qualified benefits of an automated process to bear.

TABLE 1: The total values as compared to the Same ones at a certain distance with routing.

Distance	Router 2 in/s	Saw 2 in/s	Saw 6 in/s	Hand Break
2	1	1.63	2.13	9.17
28	1	1.16	1.40	15.94
45	1	1.01	1.31	20.95

TABLE 2: Routing at one inch per second at a Distance of 2 mm as the comparison value.

	Cutting Speed (in/s)	Distance to cut (mm)	Relative to Routing
Router	1	2	1.00
Router	1	20	0.45
Router	2	2	1.51
Router	2	28	0.87
Router	2	45	0.66
Saw	2	2	2.46
Saw	2	28	1.01
Saw	2	45	0.66
Saw	6	2	3.1
Saw	6	28	1.22
Saw	6	45	0.87
Hand breaking			11.70
Hand Breaking			13.84