Manual vs. Automatic Stacking of LTCC Layers.

By James E. Ellis, President, Credence Engineering, Inc., Tempe, Ariz.

The use of Stacking machines for building up a stack of ceramic sheet layers goes back several years. The main purpose in creating the stack of layers is for the purpose of laminating those layers into a single block. This block is then cut into individual parts which, when fired, become active ceramic circuit boards that are typically used for military, RF, and Microwave applications. The process of stacking these layers has always been a manual operation where an operator places the first layer onto a fixture that has a set of locating pins that correspond to registration holes that were punched in the tape way back at the beginning of the entire process. Each sequential layer, in turn, is placed correctly onto the locating pins until all of the layers are correctly stacked. The stack is then wrapped in a water tight bag and placed into a high pressure lamination chamber where the layers are forced together with high pressure and heat for a prescribed amount of time. Once laminated, the block can be cut into its individual circuits or it can be fired with the parts being separated later.

The problems encountered with the manual stacking operation fall mainly into two areas:

1) Loss of product due to an error in the stacking sequence. Any layer put on the stack either out of correct sequence or in an incorrect orientation will render the stack useless.
2) As line widths and vias get smaller due to advances in equipment and materials or in application requirements, the need for better alignment becomes a real issue.

The stacking Machine solves both of these issues. It stores the layers internally and automatically pulls from the correct batch of layers in proper sequence so that as long as the layers are entered into the machine correctly, the machine will pull them correctly preventing scrap due to a stacking error. The stacking machine also provides better layer-to-layer alignment through the use of high tech imaging equipment and micro-motion stages that line up Fiducials to design coordinates. The stacking machine utilizes heat staking electrodes to spot weld each sequential layer to the prior layer. Once the stack is complete, it is then bagged and sealed and laminated as described earlier.

The Stacking Machine provides four main services:

1) The Stacking Machine correctly sequences the layers within the stack as the design intended. These layers often look so much alike that it is possible, without proper handling procedures, that the operator could inadvertently stack the layers out of sequence in a manual process.
2) The Stacking Machine aligns the layers to each other better than what tooling location pins can achieve. Manual fixtures can typically produce +/- 12.5 µ layer-to-layer accuracy. Stacking Machines typically can reach +/- 5 µ accuracy.
3) The Stacking Machine provides greater stacking throughput. A manual stacking operator can reach speeds of 6 seconds per layer with no Mylar carrier and approaching 10 seconds per layer with the Mylar carrier. A Stacking Machine can reach times as fast as 5 seconds per layer.
4) The Stacking Machine provides a durable connection between layers so the stack can be reliably bagged for lamination.

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The Stacking Machine is very expensive and that leads to the obvious question: Can the manual stacking process be improved substantially to provide adequate safety in sequencing, improved alignment, greater throughput and a good method of keeping the stack together through lamination?

Yes. Yes. Yes. And yes.

1) The layer sequencing problem can be easily overcome through a technique that we will call “Gathering”. Gathering is the manual process by which the lots of layers are placed on counters in the correct sequence as well as orientation (Top vs. Bottom etc). The operator picks up a single layer from each lot and performs a “Pre-Stack” that can be inspected and verified. Each Pre-Stack is placed in a tray or bin so the layers remain correctly sequenced. During the actual Stacking process the layers are taken from the Pre-Stack one layer at a time and placed on the tooling fixture. The Mylar backing is removed from each layer as it is placed. This process continues until all of the layers in the bin have been placed onto the tooling fixture. Through careful process control the manual method of stacking can be very accurate and consistent.

   This Gathering process can also be semi-automated for a fraction of the cost of a Stacking Machine by use of a Vertical Carousel. The Vertical Carousel is an automated storage and retrieval system that provides simplified inventory management of many types of items. These systems provide very dense storage capability as well as instant retrieval of any item within its domain. The Storage and Retrieval Systems are typically large in size, but store an amazing amount of inventory. A smaller version of the Storage and retrieval System, the Credence SR -24 is an integrated work-station that is specifically set up for small parts sequential assembly. Each bin is sequentially positioned within the operator’s reach and, once the component (or layer) is removed from its bin, while the operator is positioning that part (layer) into place, the next part in sequence is being automatically brought to the forefront within the operator’s reach. This process is repeated until the entire assembly (Stack) is complete. This eliminates the possibility of an incorrect sequence since each layer is scanned into the carousel and presented to the operator in its correct sequence. The SR-24 has 24 bins for parts and is very compact in size as opposed to the larger inventory carousels. It can store up to 20 different sequence programs and can have a bar-code, RFID, or 3D Matrix reader to simplify the storage and retrieval process. Larger storage volume is available.
2) Alignment Accuracy can be improved for the manual stacking process if we understand the things that cause misalignment. The number one issue that results in misalignment during manual stacking is tape stretch or layer stretch. Each layer must be placed onto a tooling fixture that has pins corresponding to the registration holes in each layer. These pins must be tall enough to reach through the entire stack so that they maintain alignment from layer to layer. As the early layers in the process are placed onto the pins, it is very easy to get the holes onto the pins on one side of the layer. The operator has to pull the layer to get the remaining holes to stretch over their respective pins. This results in slight layer stretch which usually results in slight layer-to-layer misalignment. This problem can be overcome by having an alignment fixture where the pins are just as long as needed for each layer that is put onto the stack. That means that when the operator starts the process, the pins are only a single layer thickness tall. Once the first layer is placed onto the tooling fixture the pins are now two layers thickness tall… and so on. We achieve this by building into the

stacking fixture a mechanism which increments the pins upward as each layer is placed onto the tooling fixture. This, in essence, eliminates the need to stretch the layer because the pins are always just a layer thickness high. Alignment accuracy of +/- 8 µ can easily be achieved with this type of fixture. As long as your product is designed with via diameters and via landing-pads that can stand this amount of misalignment, You should yield quite nicely.

3) The Stacking Machine has a higher throughput , but it is only by a narrow margin. You would have a hard time using throughput as a justification parameter especially since the Stacking Machine is so sophisticated that it will surely have its share of technical downtime that will never be regained. Also, if throughput is an issue, it is significantly cheaper and quicker to implement a second manual stacking station.
4) The Stacking Machine utilizes a set of welding electrodes to weld the layers together as they are stacked. The completed stack must then be placed onto a tooling set of some sort so that the lamination process does not distort the stack. There always has to be a flat tooling plate on which the stack is placed. This tooling plate provides a good surface finish that is transferred into the product during lamination. It also provides rigidity so the stack is held flat during lamination. This has definite effects on flatness during firing. The manual tooling sets already provide both of these functions. The pins provide good alignment without welding and the flatness and surface finish of the tooling plate can be as good as you need to achieve the desired results.

   A factor that needs to be mentioned here is that because the Stacking Machine does **not** use tooling pins for alignment, but aligns with cameras, it can create a parallelogram effect where each layer that is stacked is positioned out of location in the same direction as the previous layer (although within specifications). As the layer count increases, the stack moves further away from true position where the last layer that is placed is now “Out-Of-Spec” with respect to the very first layer that was placed. This never is a problem with manual stacking because all layers are vertically aligned with the pins in the tooling plates.

In conclusion, the Stacking Machine, although sophisticated, can provide economic advantage, but it only seems to make economic sense where the labor cost of stacking is significantly high or where the line and via geometry of the product are at the smallest limits of what a good manual stacking process can achieve. Since the Manual Stacking Process is very inexpensive and easy to implement, the Stacking Machine option can be postponed until it is absolutely needed.