UNDERFILLING USING CONTINUOUS PATH MOTION CONTROL

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INTRODUCTION

Flip chip underfill technology has been enabled by dispensing for decades. Nordson ASYMTEK has served this application since flip chips emerged as important devices in electronic packaging. While the name of the technology hasn’t changed, flip chip technology itself has evolved -- and the actual requirements for dispensing underfill have changed along with it. Today, an expanding number of applications are using flip chip package devices with rigid substrates. This article presents how automated fluid dispensing systems have evolved with the new technologies and the latest solutions for increasing speed and units per hour (UPH) in these new underfill applications.

NEW TECHNOLOGIES

Five years ago most flip chips were used in PCs. Now, many other devices, like application processors, RF components and DRAM, use this technology. And, the number of these new devices has exceeded the number of traditional flip chips.

Compared to traditional flip chips, these new devices have different configurations in terms of die size, die thickness, bump numbers, bump pitch, bump gap, substrate size and so on. Typical configurations in traditional and new flip chips are compared in this table:

CONFIGURATIONS	Traditional Flip Chip	Newer Flip Chip
Die size (X x Y mm)	10 x 10	8 x 8
Die thickness (µm)	780	250
Bump Number	6000	500
Bump pitch (µm)	150	80
Bump gap (µm)	75	40
Substrate size (X x Y mm)	40 x 40	14 x 14

These different configurations change the underfill process in terms of the amount of underfill fluid deposited and the technique for dispensing it, such as the number of passes the dispenser makes. The underfill volume is affected not only because die sizes are different, but also because the bump gaps and die thickness are different. The bump pitch/bump gap shrink impacts the fluid flow speed; the tighter the gap, the slower the speed. Also, when the space between adjacent die is narrower, the fluid must be deposited in a thinner line. To get the correct volume of fluid underneath the die, the dispenser deposits a thin amount of fluid which then flows under the die, then the process is repeated, making multiple passes until the desired volume of underfill material is applied. The narrower or tighter the gap, the less fluid can be applied at each pass, thus the more passes have to be made, slowing down the process.

The number of passes is also dependent on the height of the die. The volume of underfill deposited next to the die is determined by dividing the total volume of fluid needed by the number of passes.

DIFFERENT DIE LAYOUTS

These newer flip chip devices also require a different die layout for flip chip production. The traditional way of placing die is to handle singulated flip chip devices, where a die is bonded onto a substrate. A boat carries about 10 devices spaced a certain distance apart which is determined by substrate size, the number of devices and boat size. With these new applications, the die are carried by strips that contain tens of dies. Instead of the boat-spacing defining the placement, the substrate size determines the distance between the die on the strip.

Typical underfill amount, pass number and die layouts for traditional and new underfill methods are:

TYPICAL VARIABLES	Traditional Flip Chip	Newer Flip Chip
Underfill amount (mg)	12	6
Pass Number	1	6
Carrier type	Metal boat	Strip
Die numbers on carrier	around 10	around 70
Distance between dies (mm)	30~40	4~6

A traditional 2x7 boat die layout for flip chip is two even rows of 7 die spaced evenly apart. A strip die layout for flip chips might be 14x5. Examples can be seen in Figures 1 and 2.

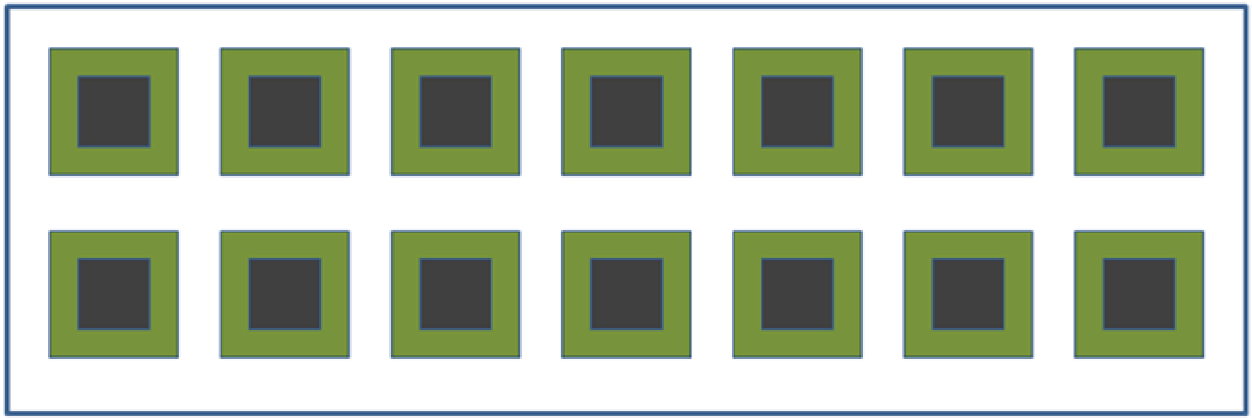

Figure 1: 2 x 7 Boat Die Layout for Traditional Flip Chip

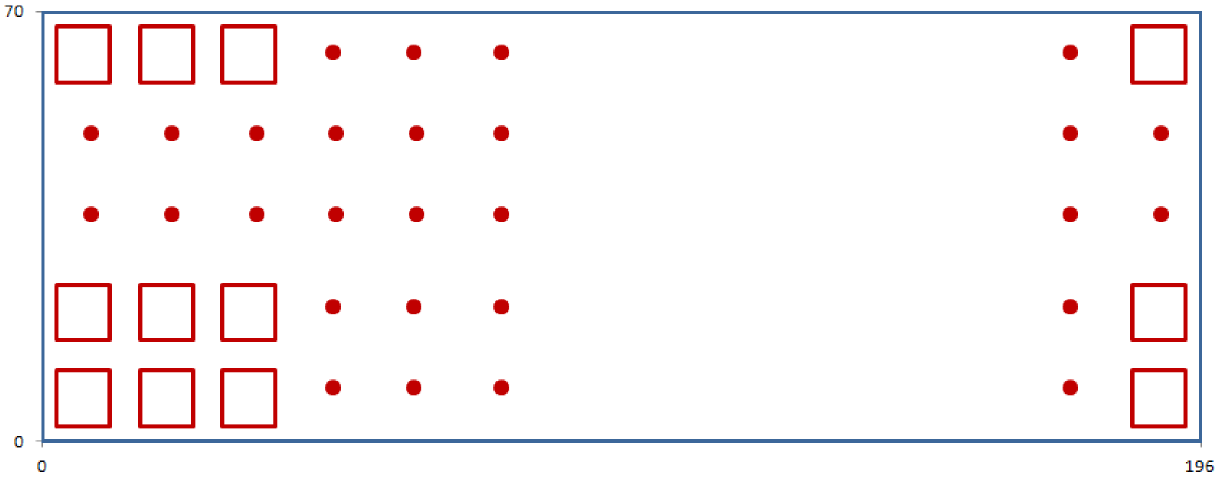

Figure 2: 14 x 5 Die Strip Layout for New Flip Chip

Traditional and new flip chips require different dispense head movements in I-path underfill dispensing. I-path is dispensing underfill on only one side of a die. In traditional dispensing, where the total volume of fluid needed to underfill a die is deposited in one pass, dispense head movement is in a straight line along the row of die. Because of multiple passes, new flip chips make the head speed increase significantly to about 10x the rate. However, the fluid flow rate would usually reduce significantly down to 1/5 or so for the new flip chips because of their thin die thickness: thin dies need thin fluid to prevent fluid from coming over the die top. The head speed thus usually increases to just a few times rather than 10 times. The calculation to find the dispense head speed for these new flip chip applications is:

Original speed (S) x (8mm/10mm die side length) ÷ (50% down of Underfill amount) x (6x pass #) x (1/5 of flow rate)
= S x 8/10 x 2 x 6 x 1/5 = S x 1.9

In conventional I-path underfill dispensing, the dispense head ramps up, accelerating before the first die, and moves at constant speed over the die while jetting underfill dots close to the die side. After depositing the underfill, the head stops once, moves to the next die, stops near the next die, then has to accelerate again to reach the speed required for dispensing. This cycle continues until all the dies in the row have been underfilled. This type of motion control is convenient because the head can leverage its fastest speed for non-dispensing movements between dies, contributing to a UPH increase.

With the new flip chip underfill configuration, the distance between each die is relatively short versus its faster dispensing head speed. Once the dispense head is stopped, it needs longer acceleration and deceleration distances before and after each die to ramp up to the speed needed to jet the underfill precisely alongside the die and decelerate before starting the process again. The acceleration and deceleration paths begin to overlap between die. As a result, the dispense head needs to backtrack after deceleration so there is a long enough path to get a running start, so to speak, so it can reach the required dispense speed without overshooting the dispense start point on the next die. Figure 3 shows the backtrack problem caused when the dispensing speed goes up.

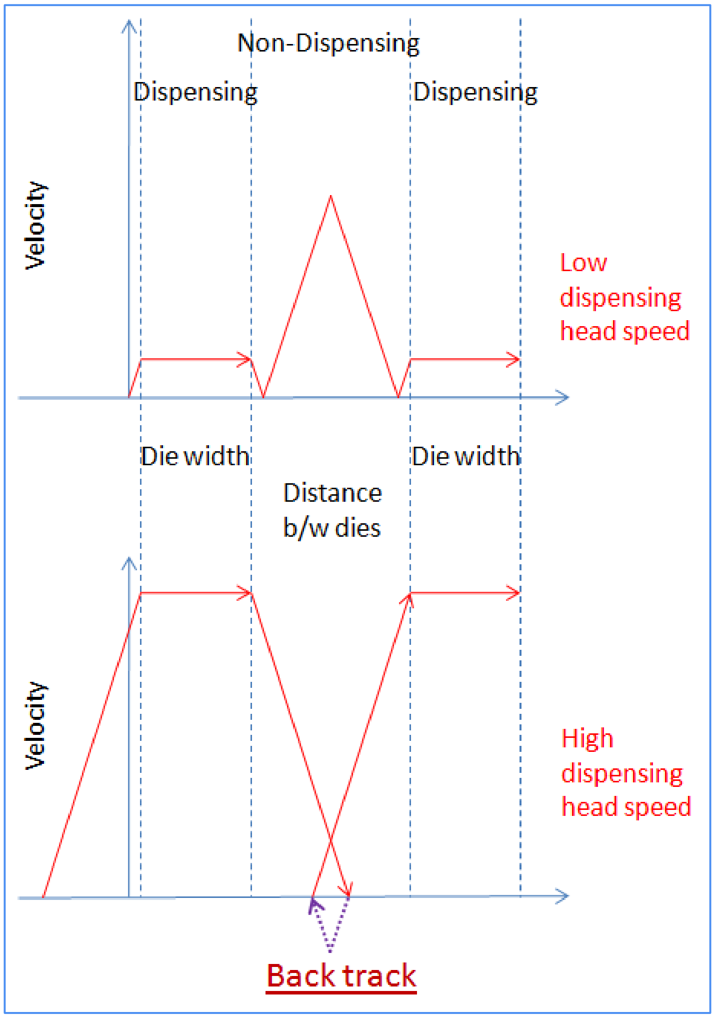

Figure 3. Back Track Issues are Related to the Width of the Device Die and The Distance Between Die

This backtrack happens because of the relative relationship between dispensing head speed and the distance between dies. For example, if the distance between dies is far enough apart, backtracking is not necessary, even when the dispensing head speed increases. But if the distance is short enough, it will happen even when the speed isn't increasing. Compared to traditional flip chips, the new ones have the quite likely situation to necessitate backtracking.

CONTINUOUS PATH MOTION CONTROL

Recently, a new software feature has been developed for jetting underfill for these new die and die configurations. It eliminates the need for backtracking, acceleration, and deceleration, and thus saves time, increasing UPH. It is referred to as Continuous Path Motion Control. In this process, instead of stopping to move between die, backtracking, ramping to speed, dispensing, and decelerating, the dispense head maintains a continuous speed and direction throughout the process.

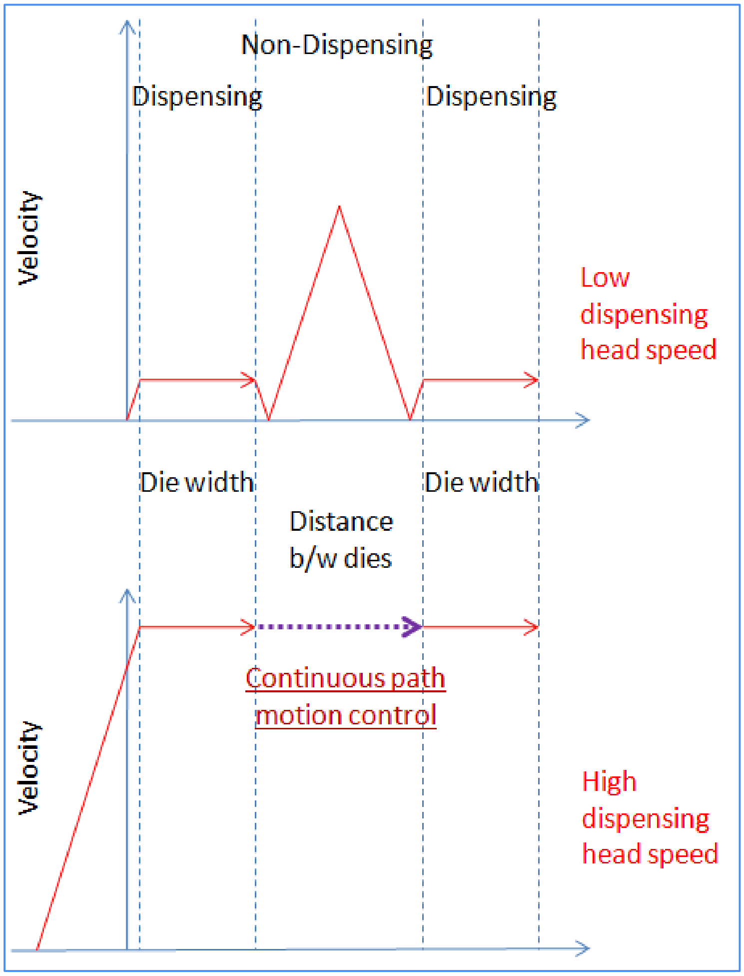

Figure 4: Continuous Path Motion Control

This continuous path software feature saves significant time when spacing between die is small, by enabling continuous motion at high dispense speeds. The dispense head is programmed to jet (dispense) the exact amount of fluid in precisely the correct place. As a result, UPH will increase for underfill dispensing. However, cycle time savings is not an exact reflection of UPH improvement, because the underfill process involves many steps. These include loading/unloading, detecting the fiducials, height sensing, and dispensing (or jetting), which includes both dispensing and non-dispensing movements.

When cycle time test data of 20 strips with 70 die on a strip was evaluated using continuous path motion control as compared to conventional underfill methods that used backtracking, there was about a **27% improvement in UPH with continuous path**. This was due to a 40% dispensing cycle time savings at 15mg/sec flow rate and 95mm/sec speed. This doesn't include loading and unloading. The continuous path increases UPH even when compared to underfill methods that don't include backtracking because stop-and-go movements between the die are eliminated. In fact, it saves 23% dispensing cycle time at 9mg/sec flow rate depending on actual die layout, dispensing conditions, flow rate and other factors.

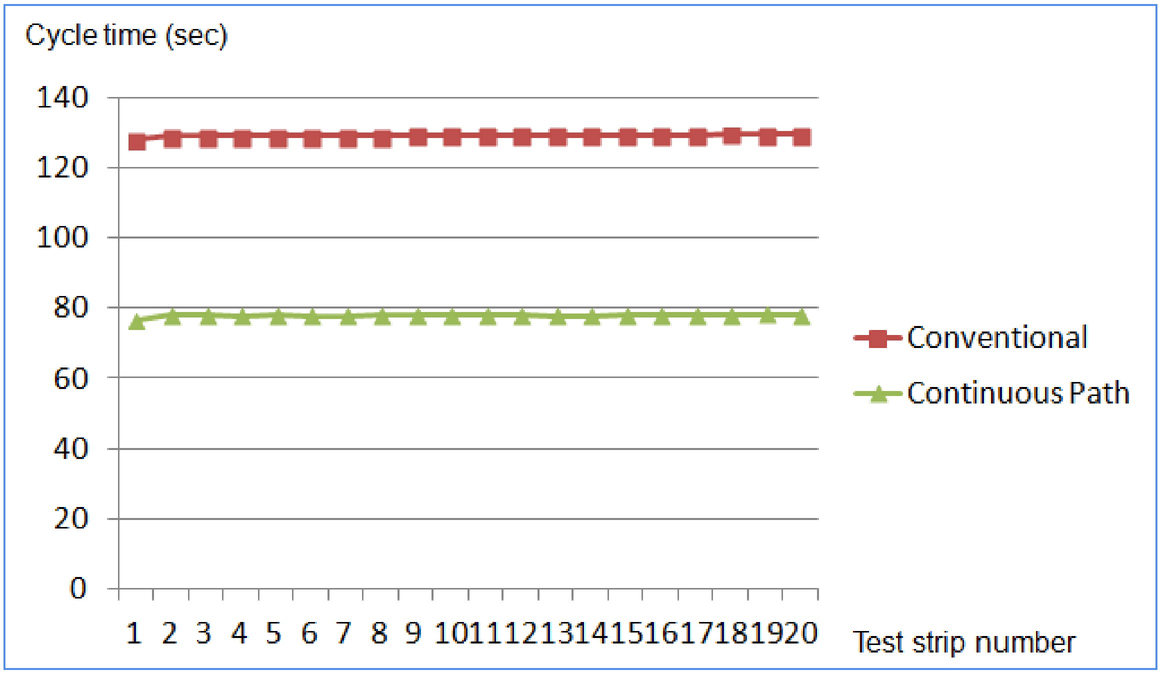

Figure 5: Cycle Time Difference in 20 Strips Between Conventional & Continuous Path Motion Control

CONCLUSION

New applications that require underfilling of parts that are smaller and closer together, especially where volume production and speed are required in manufacturing, are pushing manufacturers to explore new methods for applying underfill. Using continuous path motion control enables the manufacturer to take advantage of the increased speed that results from thinner, more closely spaced die.

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