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The Effect of Higher Stencil Tension on Printing Performance

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Scope

In this article we will examine if there is a measurable difference in the printing performance when using stencils which have a higher tension than is commonly accepted in the industry. Alpha's new tensoRED™ High Tension Frame System will be introduced during this wider examination. We will examine their effect in terms of controlling variation in critical deposit volumes and what, if any effect on positional accuracy can be seen.

Background

Metal stencils are used in printing solder paste onto PCB's in the initial steps of the manufacture of electronic assemblies via the SMT assembly process. Holding the stencil under sufficient tension during the printing operation is an important factor to achieving well defined and registered solder paste deposits.

Attaining consistently precise deposit volumes significantly influences the resultant solder joint size and therefore the final integrity and reliability of the end product. Consistency is particularly important now we have decreasing pitches on 'blind' partial and full array devices such as QFN, CSP and LGAs which prohibit post soldering inspection unless using X-Ray systems. Increasingly miniaturised passive devices with smaller and smaller solder joints also places more demand on solder joint consistency.

The following figure illustrates that when Area Ratio decreases as a result of shrinking feature sizes on a fixed stencil thickness the 'noise' in the process increases as indicated by the Standard Deviation of the Transfer Efficiency (print volume). This would be considered the primary source of deposit variation.

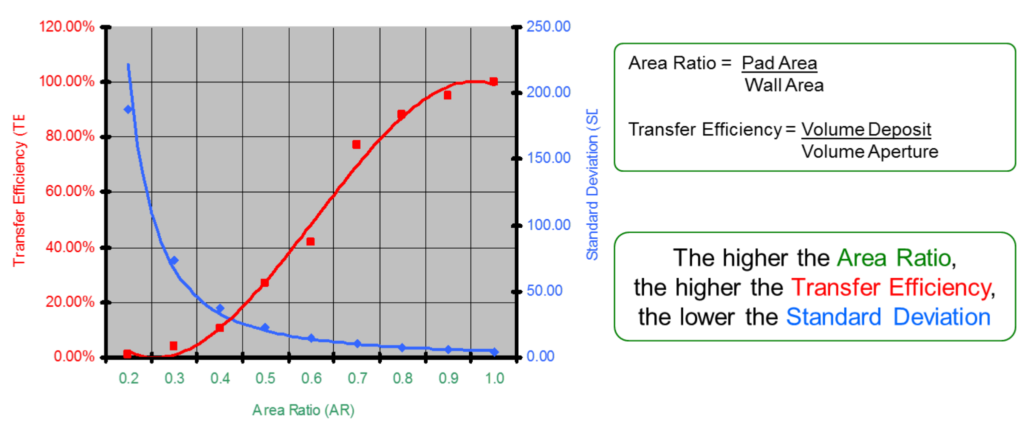

Figure 1. The relationship between Transfer Efficiency and Standard Deviation vs. Area Ratio for a fixed stencil thickness

Historically, tension was imparted to the stencil by permanently gluing it onto either a mesh of polyester or stainless steel, which itself had been pre-tensioned and attached to a frame. This resulted in what became the industry standard known as “mesh mounted” stencils. Efforts to lower costs and overcome problems with tension loss in these stencils in operation resulted in several alternative tensioning methods without the need to permanently glue the stencil to a frame. These are commonly known as “foil only” stencils.

The basic principle of all the various foil only systems currently available is the same. The stencil pattern is created on a sheet of metal (the foil) and then this is placed into a supporting “master frame”, which both secures it and imparts tension. Typically this involves outward extension of the master frame or feature within it by applying force using mechanical levers, springs or pneumatic tubes.

Whilst these offer several benefits in terms of cost, a common industry perception is that these “foil only” systems do not always deliver as good a printing performance as the meshed mounted alternative. Both long term reliability of the master frame and lower initial tension levels compared to mesh mount are two commonly mentioned shortcomings. Some adaptations of foil only systems are also perceived to have increased Health and Safety concerns from the unprotected sharp edges of the thin metal sheets. This latter problem was overcome by the development of edge protecting extrusions on the foil that acted as both a handling aid and a locational interface between the foil and the frame.

Despite these perceptions, Alpha’s observation is a continually increasing use of foil only systems, primarily driven by both cost and stencil storage space requirements. Alpha’s Tetra master frame and Tetrabond foils are one of the systems that has enjoyed this growth in use over the last 20 years. Therefore addressing the two most common customer concerns raised, namely long term reliability of the master frame and raising the level of tension achieved have remained a focus of our development priorities. This has resulted in our new tensoRED™ master frame.

Reliability of Foil Tensioning Systems

To understand the areas of any master tensioning frame that can adversely affect reliability, we need to look at what sort of frames currently exist. Frames can be divided into multiple categories of construction for tensioning method and operation:

METHODS OF TENSIONING

- Mechanical, either leaver action or locking strip(s) within frame.
- Pneumatic (bladder/tube only, either filled once to tension or permanently connected to air to maintain tension)
- Combination of pneumatic opening and mechanical closing (e.g. air bladder/tube in frame to release tension and springs to apply tension)

METHODS OF LOADING/UNLOADING

- Self-Contained
- Requires a loading station for actuation

METHODS OF FOIL/FRAME INTERFACE

- Holes or slots (various pitches and number) in the foil on 2 or 4 edges to engage on pegs, pins or teeth, often with a cam type action.
- Extrusion/stiffener either bonded or mechanically joined to foil with extrusion in one section or multiple sections joined via corner connectors. These extrusions engage on teeth or paddles normally moving in an arc action.

Alpha's tensoRED™ is an innovative mechanical expanding frame system which generates a high tension in the foil directly in the required axis and consistently achieves tensions higher than our current Tetra systems.

It achieves this without the need for pneumatic tubes within the frame section to actuate the interlocking features.

The frame/foil interface is a continuous element within the frame extrusion itself allowing the foil to sit extremely flat to the frame with minimal distortion.

By not using inflatable tubing in the design the opportunity for their potential failure and subsequent maintenance requirement is removed.

With tensoRED™ compressing the frame itself to allow foils to be loaded/unloaded is achieved using a simple mechanical loading station, no air supply needed.

tensoRED™ is designed to work with Alpha's Tetrabond foil system and is also compatible with other similar foil edge extrusions.

How much more tension?

Several methods for measuring "tension" on steel stencils exist, including instruments designed for measuring tension in polyester mesh, displacement methods when a weight is applied to the foil and strain gauges applied to the steel. Although all of these methods produce results often quoted in units of N/cm this can be misleading if making direct comparisons. Factors such as the foil thickness and conversion from displacement and strain measurements to tension can influence any final N/cm result, potentially leading to a significant bias in any quoted reading.

For the purpose of the article a single method, a tension meter designed for measuring polyester meshed tension, was used throughout. This is sufficient to allow comparative differences in tension to be determined, but caution should be exercised when making direct comparisons with data obtained using alternative measuring methods.

The following table shows typical tension readings from two "high tension" type frames compared to one of the current leading "standard" tension master frames.

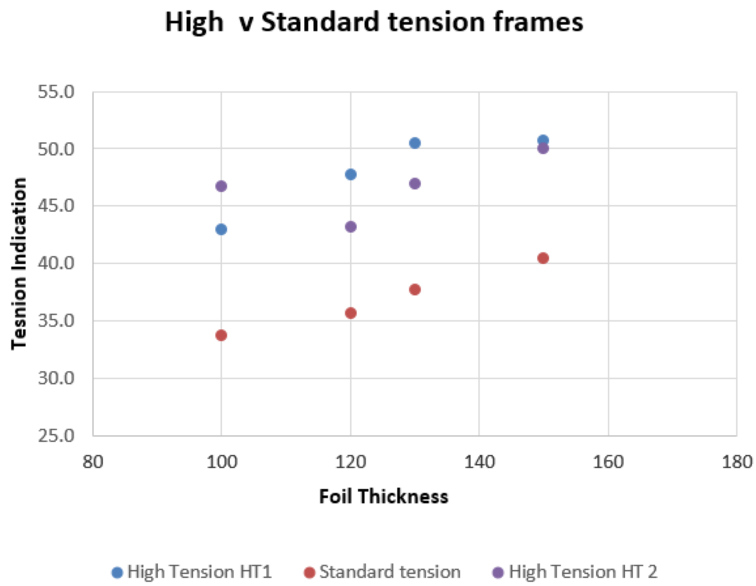

Figure 2: Tension comparison two high tension frames versus a standard tension system

How does Higher Tension Impact Printing Performance?

Current trends are for both paste deposit sizes to get smaller and stencil thicknesses to decrease in order to maintain the correct Area Ratio for efficient paste release. A common belief is that movement in the stencil during the printing operation becomes more noticeable, hence the now growing interest in 'high tension' stencil systems to potentially control it.

One possibility is that this movement is like a drum skin, in that there is either a vertical deflection or vibration on stencil release. The tighter the skin, (stencil) the less the vertical deflection, resulting in better control of the variations in paste deposit. Interestingly, some stencil tension meters actually measure foil deflection in the Z plane as a proxy for actual tension in the X/Y plane.

Foil movement as the foil gets thinner could be considered to be the second source of deposit variation (the first source being caused solely by Area Ratio reduction as illustrated in Figure 1).

In the following series of tests the print performance of high tension systems was compared to standard tension. This was done on two occasions, each study using a different PCB, Printer and SPI combination.

All foils used were new and a comparative study of consistency with extended use of higher tension stencils has yet to be made.

TEST 1 – OBSERVATIONS ON VARIATION IN PRINT TRANSFER EFFICIENCY

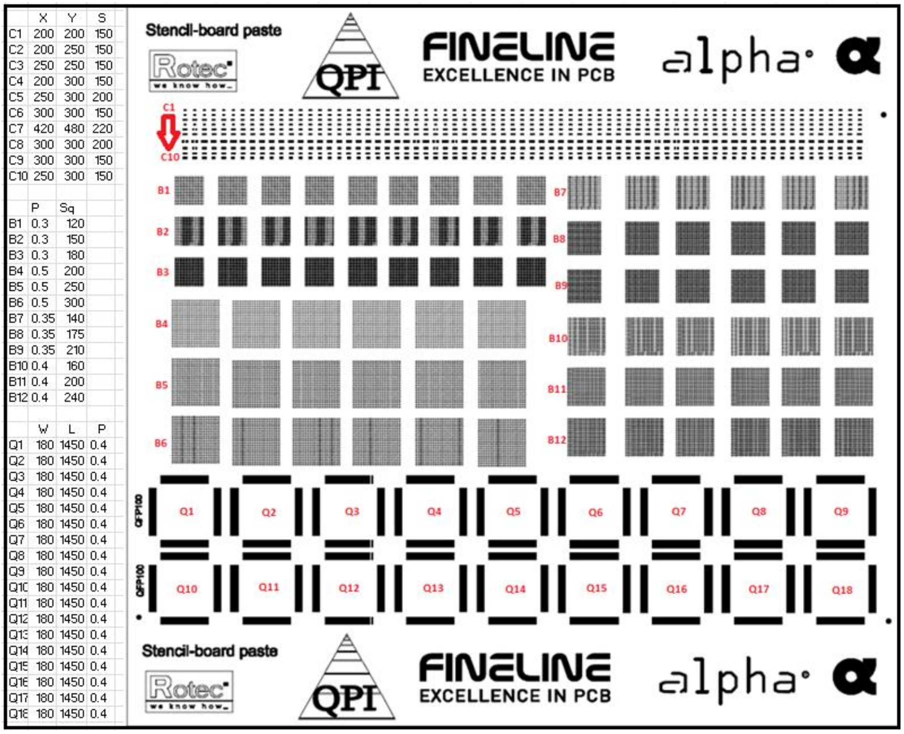

Figure 3. Test PCB

Printer	SpeedPrint SP710
SPI system	SAKI BF3-Si
Stencil (Foil)	100µm LCSS Alpha Tetra Bond (same Foil used on all 3 frames)
Frame/Foil combinations.	2 off High Tension, 1 off Standard Tension
Paste	ALPHA® CVP-390 M17 in PS4

In this trial the same set of test boards, stencil and paste were used across each of the runs and only the frame type was varied. For each run the stencil was primed with an initial 5 prints, dry wiped using the printer's under screen cleaner and then the measurements were taken from the subsequently printed test board sequence.

The following histogram (Fig. 4) shows the distributions of print Volume in % Transfer Efficiency on a 250µm feature.

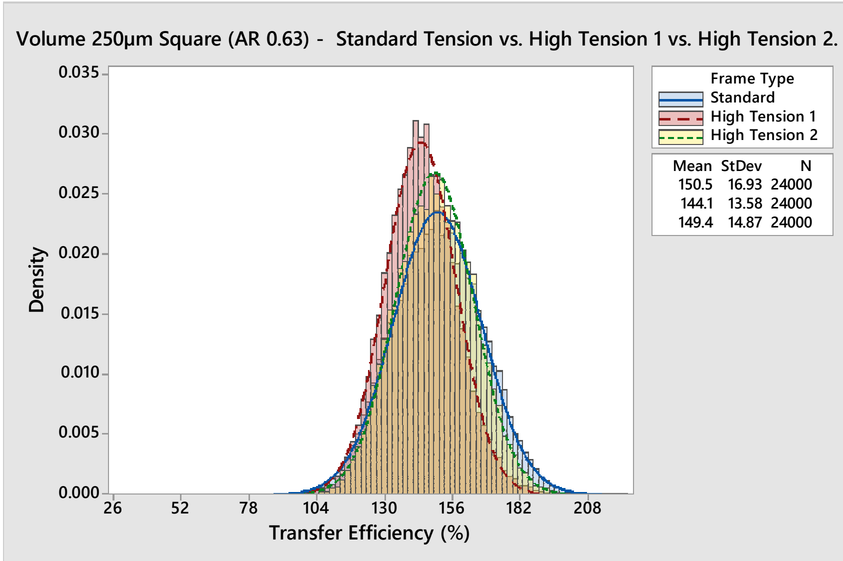

Figure 4. Comparison of Print Transfer Efficiency, 250µm Sq. feature on three frame systems with 100µm LCSS Foil

In this first set of results for a 250µm square feature (Area Ratio of 0.63) the volume response shows the smallest variation (by Standard Deviation - SD) for the High Tension (HT) systems when compared to standard system. If we assess this volume variation by testing for equal variances we are able to conclude that the differences in SD are statistically significant.

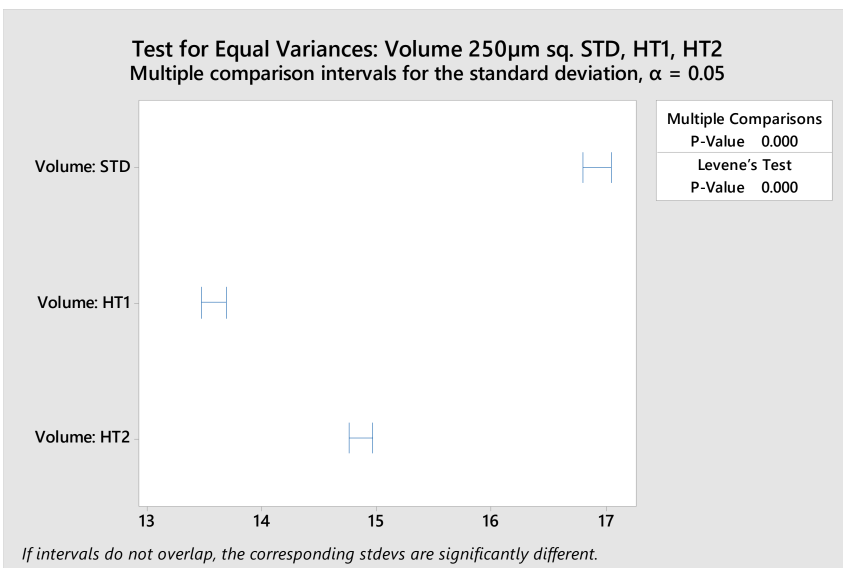

Figure 5. Test for equal variances on Standard Deviations of Print Transfer efficiency, 250µm feature on three frame systems with 100µm LCSS Foil

Deciding if the difference in SD has practical implications to your printing will depend upon the process tolerances to which you want to run. On a HT system these improvement figures over the standard unit could lower the measured Transfer Efficiency range by between 12.4 and 20.0 (working on process tolerance of Mean ± 3σ).

The next histogram (Fig.6) shows the distributions of print Volume in % Transfer Efficiency on a 300µm feature.

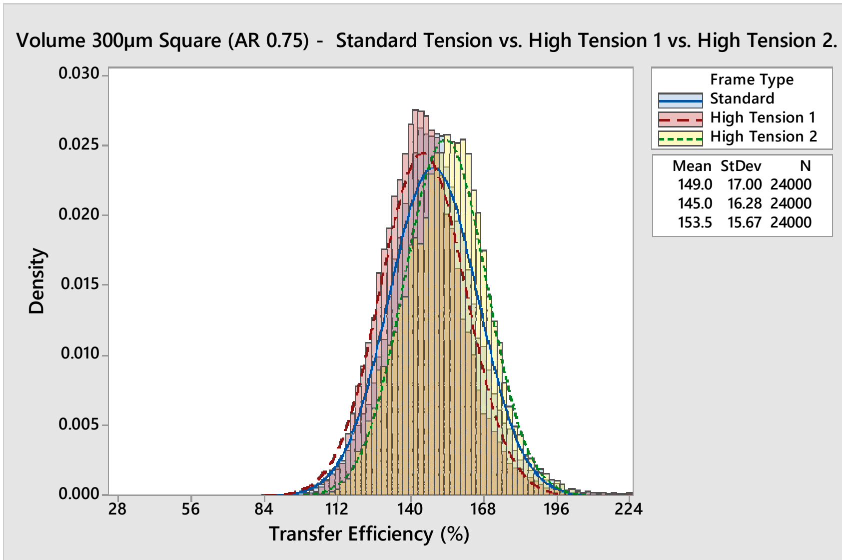

Figure 6. Comparison of Print Transfer Efficiency, 300µm Sq. feature on three frame systems with 100µm LCSS Foil

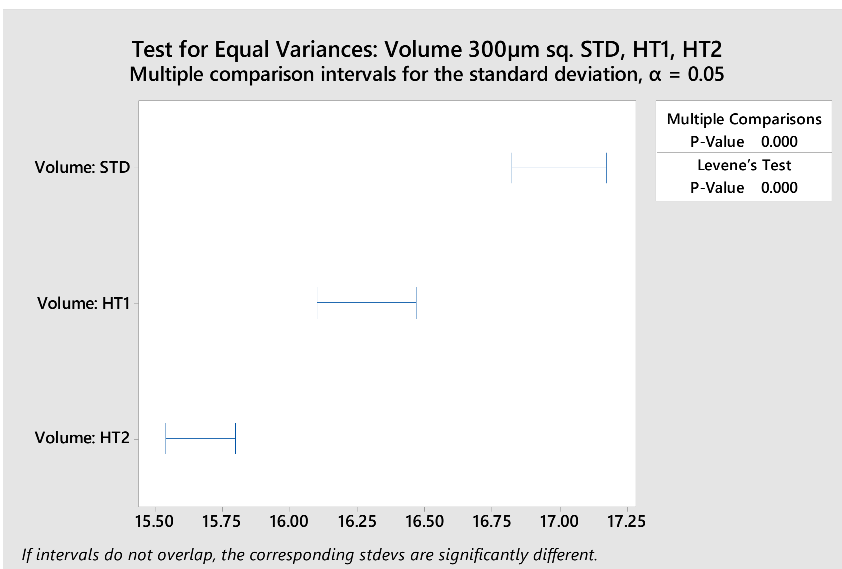

Figure 7. Test for equal variances on Standard Deviations of Print Transfer efficiency, 300µm feature on three frame systems with 100µm LCSS Foil

The performance of the 300µm feature in the same test again indicates HT systems give lower variation, this also proves to be statistically significant. On a HT system these improvement figures over the standard unit could lower the measured Transfer Efficiency range by between 4.2 and 8.0 (working on process tolerance of Mean ± 3σ).

Conclusion Test 1

The observations from the data on this test support the view that there is potential to reduce the print deposit variation by using a higher tension stencil.

TEST 2 – OBSERVATIONS ON VARIATION IN PRINT TRANSFER EFFICIENCY AND POSITIONAL ACCURACY OF DEPOSITS

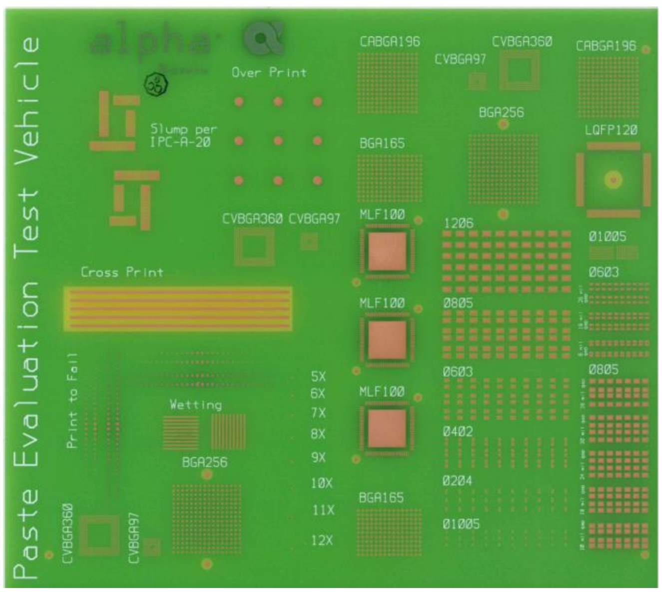

Figure 8. Test PCB

Printer	DEK Horizon 3X
SPI system	Parmi Sigma X
Stencil	80 µm, 100µm and 130µm thickness LCSS
Frame/foil combinations.	Standard Tension and High Tension
Paste	ALPHA® CVP-390 M17 in PS4

In this test the same boards and paste were used across each of the runs. Three stencil thicknesses were used studying both a high and standard tension frame. The stencils were primed with an initial 5 prints, dry wiped using the printers under screen cleaner and then the measurements were taken from the subsequently printed test boards.

The following histograms (Fig 9 to Fig 14) show a selection of results for distributions of print volume (Transfer Efficiency) in %, across three foil thicknesses for two feature sizes 250µm and 500 µm round. There is no data point for 250µm on 130µm foil as this Area Ratio will not print.

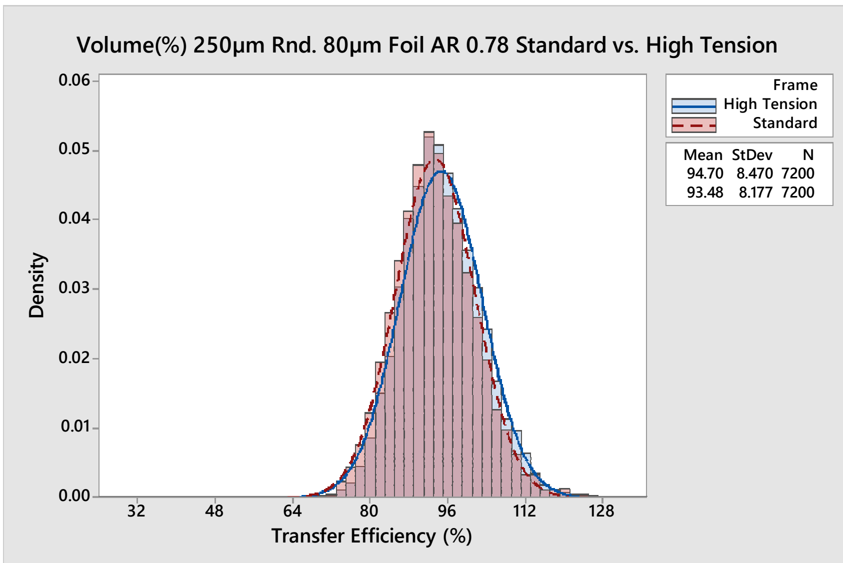

Figure 9. Comparison of Print Transfer Efficiency, 250µm Rnd. feature on standard vs. high tension frame system with 80µm LCSS Foil

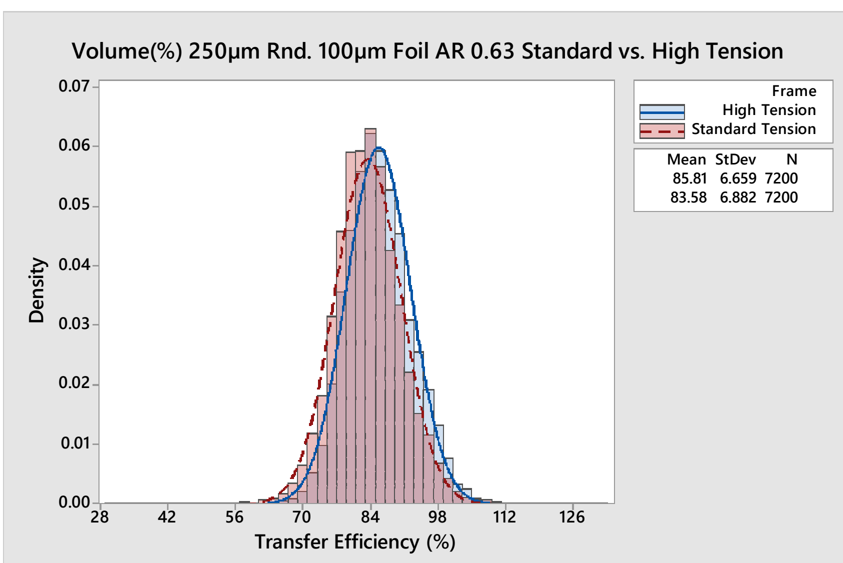

Figure 10. Comparison of Print Transfer Efficiency, 250µm Rnd. feature on standard vs. high tension frame system with 100µm LCSS Foil

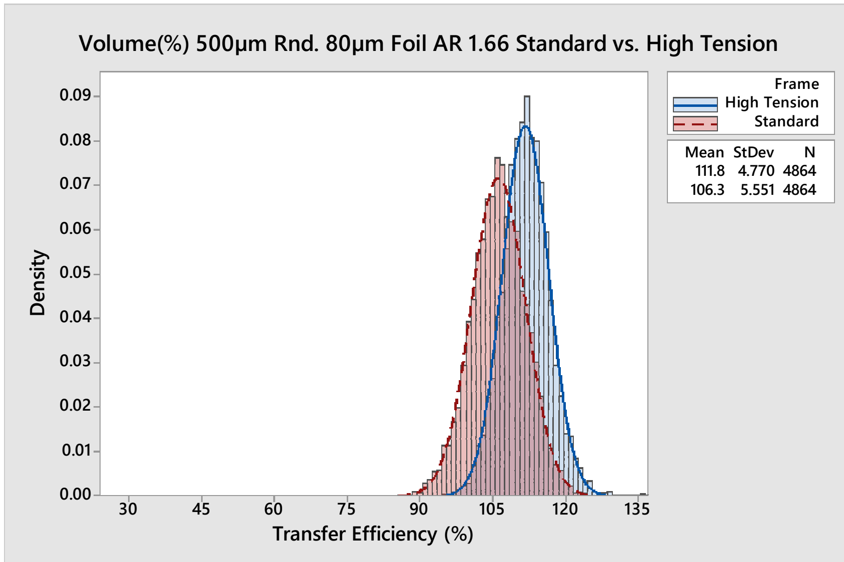

Figure 11. Comparison of Print Transfer Efficiency, 500µm Rnd. feature on standard vs. high tension frame system with 80µm LCSS Foil

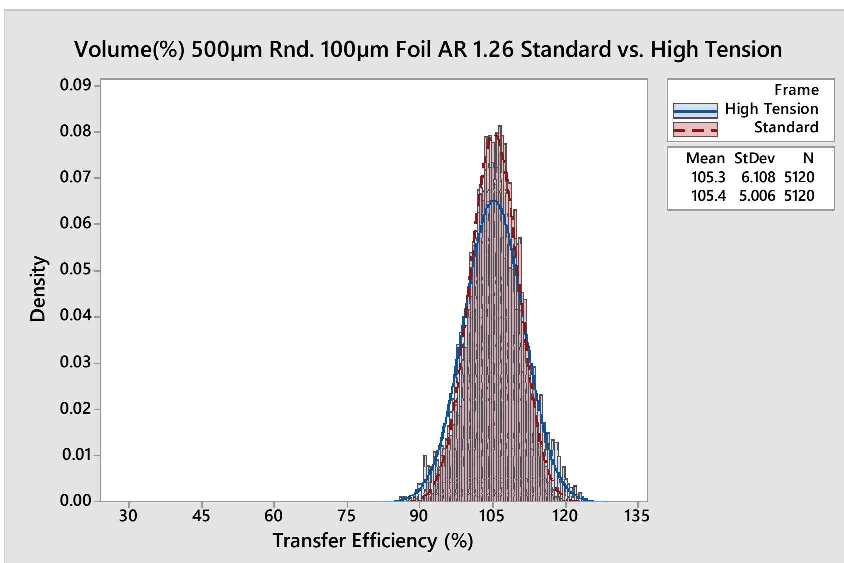

Figure 12. Comparison of Print Transfer Efficiency, 500µm Rnd. feature on standard vs. high tension frame system with 100µm LCSS Foil

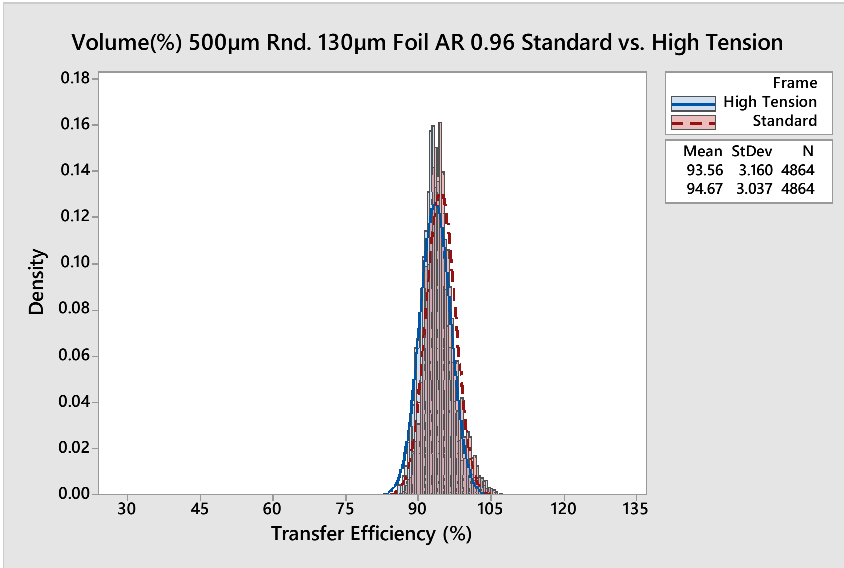

Figure 13. Comparison of Print Transfer Efficiency, 500µm Rnd. feature on standard vs. high tension frame system with 130µm LCSS Foil

With this second set of data the case for high tension stencils producing a significant reduction in print deposit variation is not indicated, as in the first test. Each of the distributions pairs was tested for statistical significance to any difference and the results tabulated here:

Foil Thickness	Feature Size (µm)	Distributions Different (Statistically Significant)	HT<ST
80	250	No	N/A
100	250	No	N/A
80	500	Yes	Yes
100	500	Yes	No
130	500	No	N/A

Conclusion Test 2

It is not possible to conclude from this data that any of the differences observed between higher tension and standard tension systems are significant enough to produce noticeable changes in the printing performance.

ADDITIONAL OBSERVATIONS FROM TEST 2 ON POSITIONAL OFFSETS OF DEPOSITS

Although not the principle purpose of the investigations, there were some interesting observations on the impact of stencil tension on the reported positional offsets of the deposits. X/Y Offset SPI data for the deposits is shown in the following scatter plots. We know that this is not simply from variation in the PCB batch itself as the same population of boards was printed in each test (cleaned between test runs).

Comparing the difference in the offsets produced by the standard and high tension systems, in any one direction, it appears to get larger as the foil gets thinner. The range for the High Tension system is largely constant in either direction, however with the standard tension system it gets worse as foil thickness reduces.

- Does this represent an ability of higher tension to prevent foil distortion (ripple) under the action of the squeegee in thinner foils?
- Does this effect print bleed?

This phenomenon may well be worthy of further study.

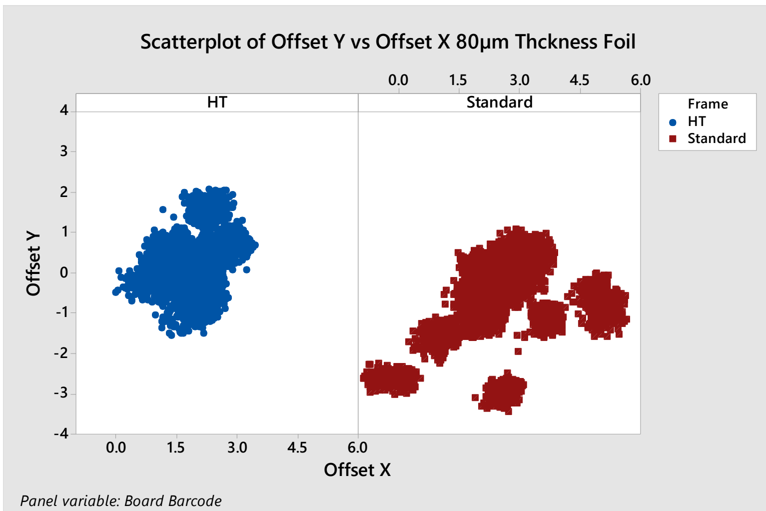

Figure 14. – Scatterplot of X/Y offset for print deposit 500µm Rnd. 80µm foil HT vs. Standard frame system

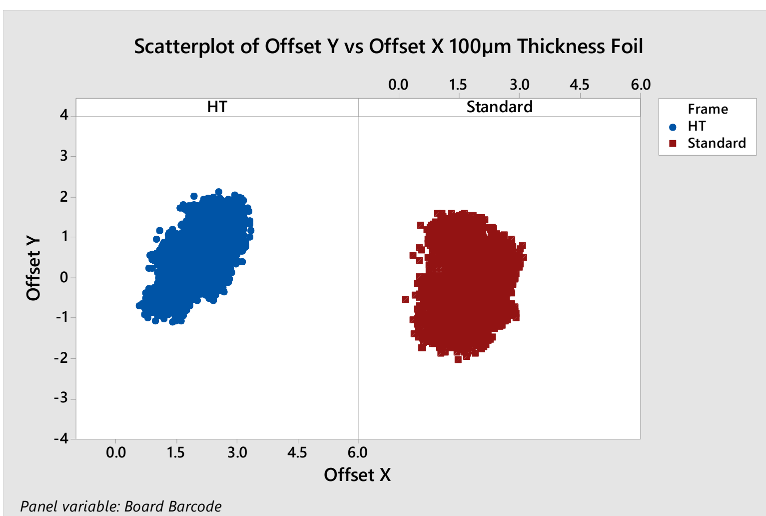

Figure 15. – Scatterplot of X/Y offset for print deposit 500µm Rnd. 100µm foil HT vs. Standard frame system

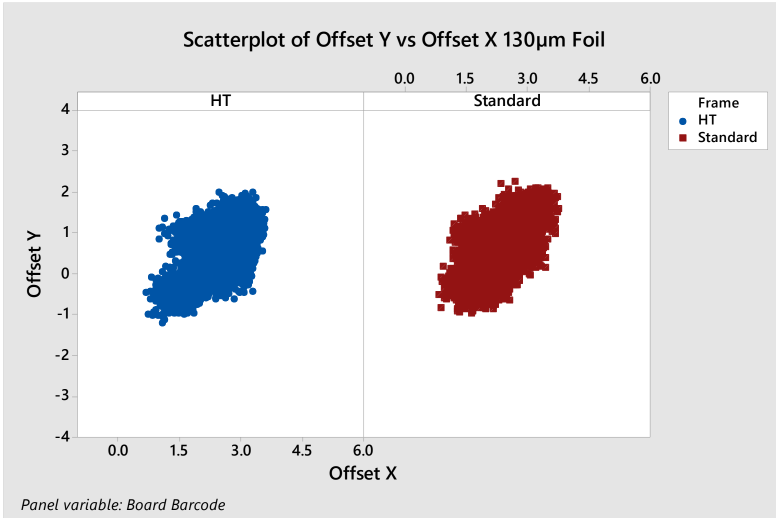

Figure 16. – Scatterplot of X/Y offset for print deposit 500µm Rnd. 100µm foil HT vs. Standard frame system

Overall Conclusions

Using a combination of high tension and standard tension frames, up to three foil thicknesses, two test vehicles designs, feature sizes (250 and 300 or 500µm), two printer types and two SPI systems it is possible to say that in this limited study the case for higher tension having the potential to reduce print deposit variation exists, in certain situations, but that it is by no means universal.

- It is possible to say from these results that the use of high tension frame systems does not negatively impact printing performance and offers potential for process improvement.
- In one test set up it was possible to measure differences that would be of significance in improving a print process (less print volume variation) on critical feature sizes. This correlates with some of the anecdotal evidence from customer's who insist on a high tension solution.
- Observations support the view that the positional accuracy of print deposits is impacted by tension and improved as tension increases, particularly as foil thickness gets thinner.

Frame tensioning systems that offer increased reliability and higher tension stencils can create an opportunity to improve print performance, Alpha's tensoRED™ master frame has been shown to provide that opportunity.

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