Theoretical & Empirical Models of Print Gain

Analyzing Shoulder Angle & Compression

By Dr. Timothy Gotsick

Print is fundamentally two-dimensional, in that printed dots are characterized by their size and their position. But the dots on flexographic plates—the objects that create printed dots on press—are three-dimensional: They have size, position and a support height that can vary in shape—the dot "shoulder." The act of flexo printing is thus one of dimensional transformation and in transforming from 3-D to 2-D, we actually create a larger dot.

Here's a good comparison for the packaging designer: What happens if you unfold a 3-D box into its 2-D shape? It's a lot larger than the starting box, right? (Although perhaps not the most rigorous analogy, it fits so well I couldn't resist using it.) Here's a visual representation:

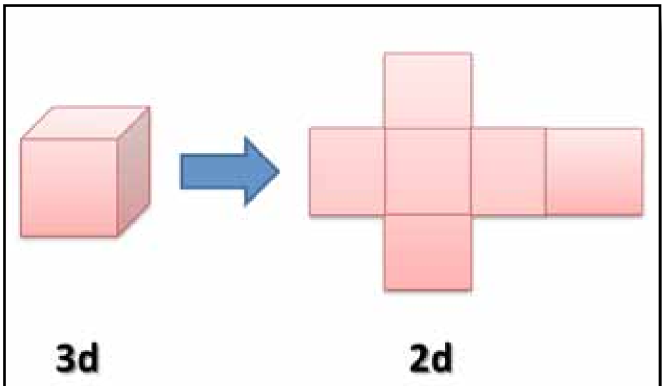

Image 1

STUDY TAKEAWAYS

- Critical angle where a dot fails under compression found between 72 degrees and 74 degrees
- Steepest shouldered dots failed at lowest compression levels; decreases in shoulder angle allow dots to absorb progressively more compression
- Dot with steepest shoulder angle showed hiccup in compression curve
- Contact patch growth inversely proportional to dot shoulder
- Contact surface of broader dots increased more rapidly than narrower dots

GRASPING GAIN

The increase in dot size that occurs from plate to print is known almost universally as gain. And although flexo printers the world over have come to accept it, compensate for it (somewhat) and generally live with it, it is at best a compromise between what we want to print and what we actually do. Surprisingly, for a phenomenon so common, so industrially relevant and so negative, relatively little work has been done on figuring out exactly what causes gain.

In recent years, as their ability to engineer a variety of flexo dot shapes has grown, flexographers have found that the shape of the dot shoulder can have a profound effect on print gain. In 2009, presenters described the enormous effect of dot shape on corrugated "fluting" at Flexographic Technical Association's Forum in Florida. In 2010, they discussed the merits of dot shape on flexo print performance at the legendary Louisville, KY Fall Conference "Great Plate Debate." As a group, we are convinced the biggest contribution that plate developers can bring to flexo print improvement is better dot shapes that gain less, better highlight dot stability and less change during long printruns.

Gain is the enemy and the better we understand it, the better we can fight it. Accordingly, a research team embarked on a program to study the origins of print gain and the factors that promote, or better yet, reduce it.

STUDYING DOTS

There are a lot of factors that contribute to gain, but because it is something that one can directly influence through platemaking, the effect of mechanical dot deformation (the shape change that occurs when someone compresses a dot against a substrate) was where the research started. It is difficult to observe dots in their natural environment (a printing

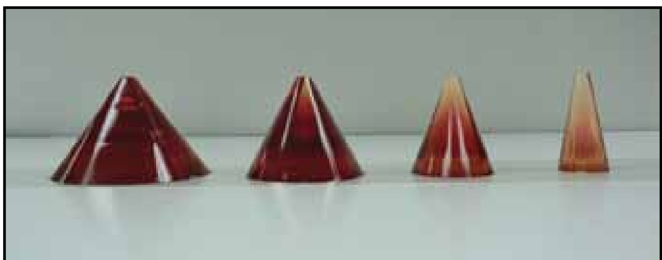

Image 2

press), so a model system of macroscopic dots that could be studied with the naked eye was created (see *Image 2*).

All dots were 70-mm. tall, had a 10-mm. diameter flat tip and were molded from the same photopolymer. The shoulder angles of the dots were (from left to right in *Image 2*) 53 degrees, 62 degrees, 71 degrees and 79 degrees. A material testing apparatus was modified to allow compression of the dots at a speed of 1-cm per second to a total compression of 20-mm. The force of compression was measured by the compression apparatus at a 10-Hz. rate. The size of the "print contact patch" of the dot top with the compression surface was measured using a Fuji pressure sensitive paper, allowing accurate quantification of a dot's contact area during compression.

The force vs. compression curves for the dots are shown in *Figure 1* below. It is interesting to note the curves were non-linear, indicating that the force rose faster than the compression distance. The degree of non-linearity, as well as the overall level of force exerted during compression, was clearly dependent upon shoulder angle, with the force curve being higher for lower shoulder angles (i.e., broader dots). It is also noteworthy that the dot with the steepest shoulder angle showed a hiccup in its compression curve, although its force vs. compression progression was the flattest of all the dots tested.

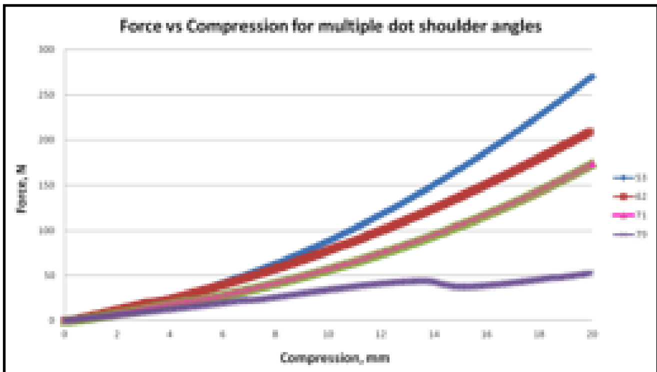

Figure 1

The contact patch vs. compression curves (*Figure 2*) were also non-linear and again showed clear relation of the contact patch behavior to the shoulder angle. As with the force generation, contact patch, growth was inversely proportional to dot shoulder and the contact surface of broader dots increased more rapidly than that of narrower dots. The steepest shouldered dot once again showed a deviation about halfway through the compression distance, with the contact patch growing rather suddenly in the middle of its compression.

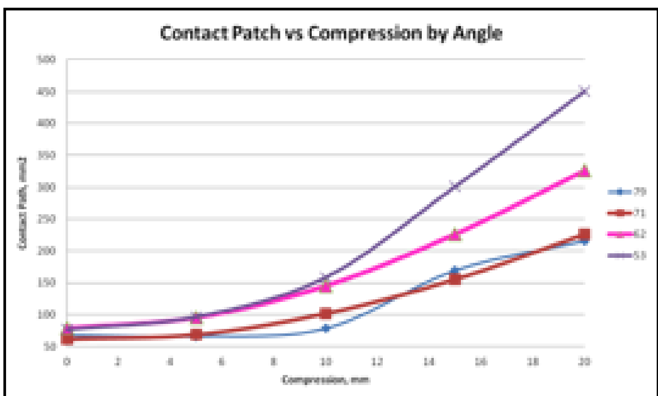

Figure 2

Image 3, taken from the compression test of the steepest shouldered dot, explains the hiccup seen in both curves. It is due to the tip of the dot folding over onto its side, which both reduces the force it can exert and drastically increases its contact surface, which is now oblong instead of round. This observation corresponds directly to a phenomenon well known and much disliked in flexo, where the smallest dots start to print like dashes instead of dots. This typically happens at the lowest end of the tone scale and intensifies the dreaded "hard edge" of vignettes.

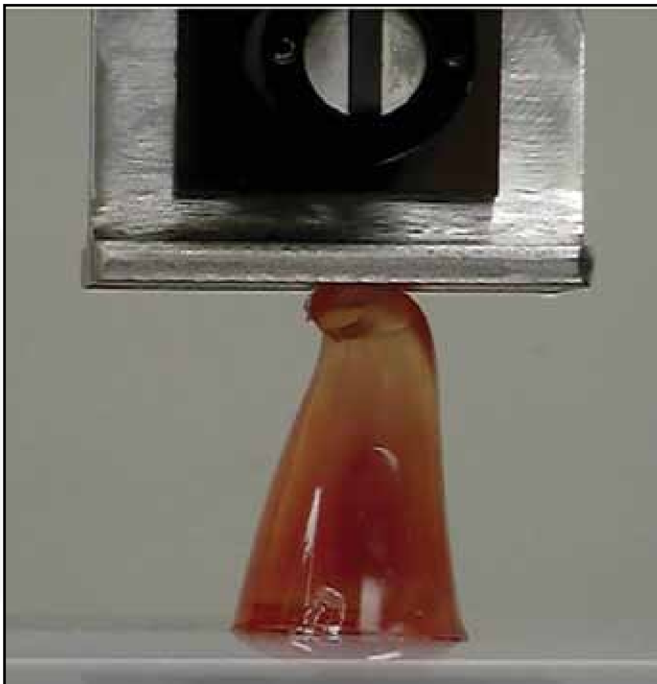

Image 3

SHOULDER ANGLE

After quantifying the effects of dot shoulder angle on dot deformation and observing the phenomenon of dot failure directly, the team directed its attention to more closely studying the effect of shoulder angle on highlight dot failure. A second set of macrodots was fabricated, but this time with a more closely spaced set of shoulder angles (2-degree increments from 70 degrees to 80 degrees, shown in *Image 4*) that would allow it to more accurately seek the "critical angle" at which the dots would begin to fail under compression.

The height and size (70-mm. tall, 10-mm. top diameter) of the second set of dots were identical to the first set, and they were subjected to the same compression tests (20-mm. maxi-

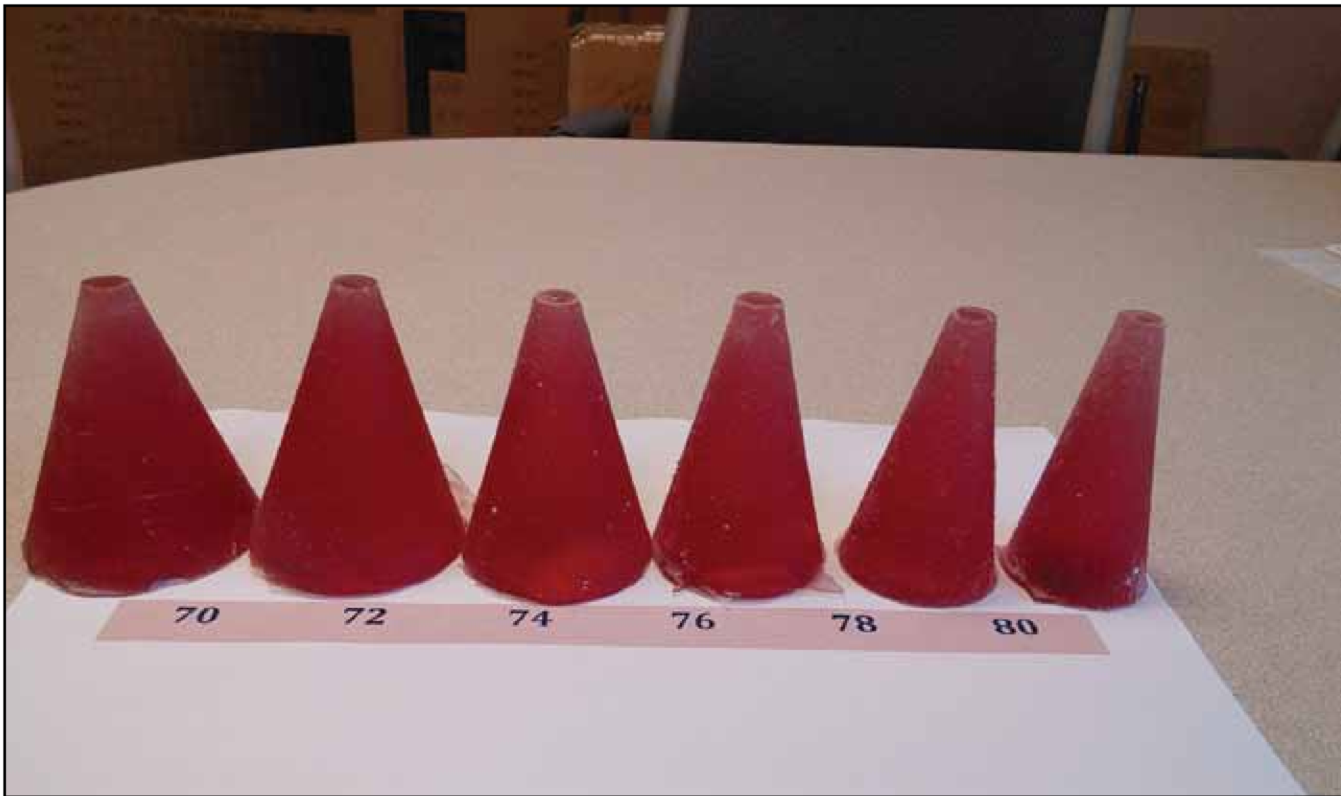

Image 4

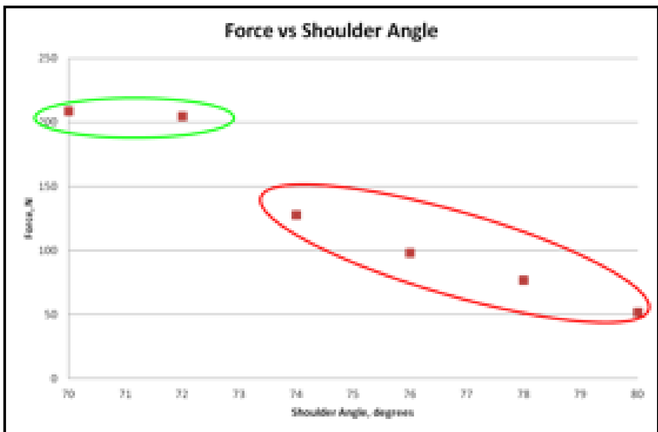

Figure 3

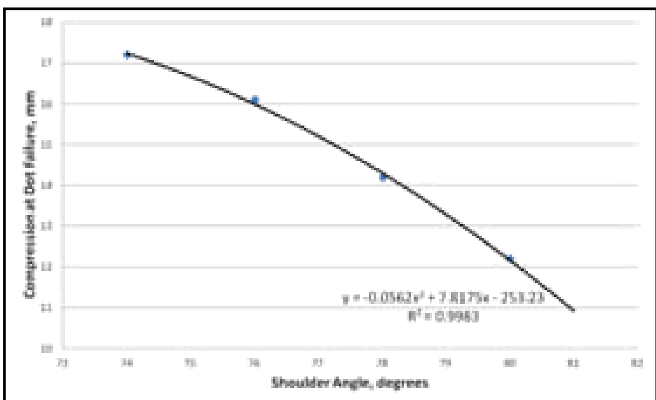

Figure 4

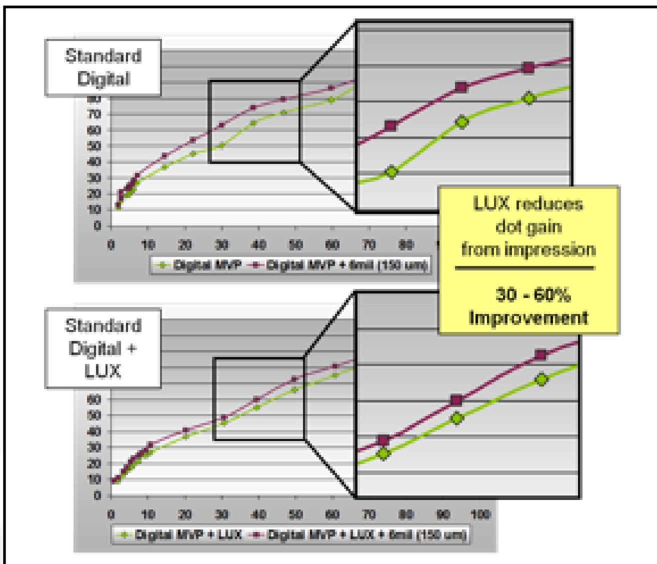

Figure 5

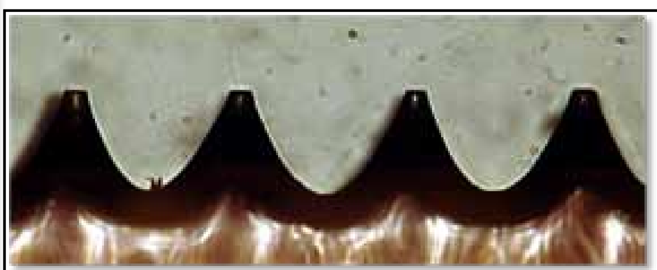

Image 5

mum compression, 1-mm. per second, 10-Hz. data collection rate).

The critical angle was found to lie between 72 degree and 74 degree shoulder angles (See *Figure 3*). The 72 degree angle dot did not fail at all, whereas the 74 degree dot and all those with steeper shoulder angles always failed.

Among the group of dots that failed under compression, there was a clear relationship between the onset of failure and the shoulder angle (See *Figure 4*). The steepest shouldered dots failed at the lowest compression levels, with decreases in shoulder angle allowing the dot to absorb progressively more compression before failing. While this trend is in itself not surprising, this is the first instance we have seen where dot compression response behavior has been quantified in a coherent manner.

ANALYZING RESULTS

Although this model system is simplistic in many ways, it has given researchers the ability to visualize and quantify phenomena that are directly relevant to flexographic printing. We have quantified the significant impact of shoulder angle on dot deformation and force generation, both of which are major contributors to print gain. Studies indicate that steeper dot shoulders reduce the rate of print surface increase with compression, which obviously causes gain through mechanical means. All other things being equal, this should mean that steeper shoulders are a highly desirable trait.

However, there is a limit to how far this logic can be extended, because at some point the dot simply becomes unstable to compression and fails to behave as a dot, ruining its ability to create the desired halftone image. In their model system, researchers found this "critical angle" to be between 72 degrees and 74 degrees, and that beyond this critical angle, the onset of dot failure occurs at lower compression levels with increasing shoulder angle.

Dot compression studies have also helped explain the favorable print behavior of plates made with LUX platemaking technology. A print characteristic of plates made by LUX is an increase in "impression latitude" on press, such that changes in dot compression have less effect on dot gain (See *Figure 5*).

These model compression studies suggest that this favorable print behavior is due to the steep shoulder angle of the LUX-produced dots (shown in *Image 5*), which causes a decrease in the rate of gain with compression.

Perhaps more importantly, the model dot system has yielded insight that enhances plate and platemaking technology development, suggesting design targets for even better gain performance and highlight dot stability in future generations of products. ■

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