Drum Technology: The Influence of Imaging Surface Geometry on Image Quality

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Abstract: Five aspects of platesetter architecture affect the quality of images produced by high resolution, raster platesetters: image surface geometry, slow scan positioning system, writing beam configuration, vacuum system , and material docking system. Image surface geometry may be internal drum, external drum, or flatbed. Mechanical runout and variations in drum cylindricity significantly affect image quality, as do variations in slow scan positioning system parallelism. Writing beam configuration has four components: resolution, number of writing beams, external drum rotation speed or internal drum writing beam spinner/deflector speed, and material length or drum depth. Multi-beam configurations are susceptible to non-uniformity of beam intensity, beam-to-beam spacing, and cluster-to cluster spacing, all of which cause visible artifacts. Multi-beam configurations also have a shorter depth of focus, which causes all drum surface variations to magnify errors resulting from runout and cylindricity variations. Image artifacts measured in millionths of an inch will be visible to the human eye. An external drum is also more susceptible than the internal drum to errors accruing from the vacuum system. The best image quality is achieved using an internal drum with a single writing beam.

Introduction

Imaging surface geometry -- whether the surface is a flat bed or an external or internal drum -- significantly affects the quality of images output from today's platesetter systems. Other aspects of platesetter architecture also affect image quality: writing beam configuration, beam positioning system, vacuum holddown system, and material docking system. All aspects are prone to specific types of errors that cause artifacts in the image visible to the human eye. What's more, these various aspects of architecture can interact in such way as to magnify certain errors. Drum geometry and writing beam configuration interact strongly.

This paper surveys the imaging surface geometries currently in use in the graphic arts industry -- flatbed, internal drum and external drum -- and assesses the advantages and disadvantages of employing one technology as opposed to another. It discusses the technology in terms understandable by the end users of the technology for imaging materials in the graphic arts market.

At this time, the prevalent geometries in use in the graphic arts industry are the internal and external drum geometries. Each geometry has advantages and disadvantages, which this paper will delineate in a comparative sense and at a system level. Because drum geometry interacts with other contributors to image quality, such as writing beam configuration, drum geometry must be considered in conjunction with other contributors to image quality.

Background

Three general drum geometries are currently in use in today's world of imaging: flatbed, internal drum, and external drum. All three geometries make use of three axes of motion to create an image: X, Y, and Z. Typically, the X axis is arbitrarily assigned to the "slow scan axis". On many systems, the slow scan axis runs along the long dimension of the imaging surface, or of the material being imaged . The Y axis is assigned to the "fast scan axis", often representing the rapid sweep of the writing beam or the rotation of the drum. The Z axis represents the modulation of the data or the on/off information. When all three axes are put into motion, an image is formed. See Figure 1.

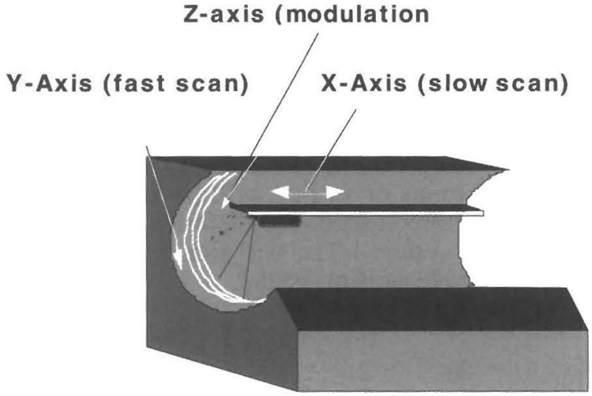

Figure 1. Axis assignments.

Geometry Overview

In flatbed imagers, the slow scan axis of motion is typically the motion of the material under the writing beam assembly, rather than the motion of the writing beam over the material. Flatbed imagers use one of two methods to move the material. Figures 2 and 3 illustrate these two flatbed formats. In Figure 2, the plate or film and the surface on which it is mounted move together along the slow scan axis while a rotating mirror or mirrors deflect the modulated beam. In Figure 3, a capstan motion system moves the plate or film while a rotating mirror or mirrors deflect the modulated beam.

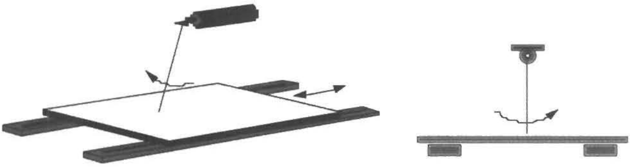

Figure 2. Flatbed geometry with movable imaging surface.

Figure 3. Flatbed geometry with capstan motion system.

Figure 4 illustrates internal drum geometry. An internal drum consists of a stationary, concave surface on which a plate or film is mounted and over which a rotating mirror (a spinner) moves while deflecting the modulating beam.

Figure 5 illustrates external drum geometry. An external drum consists of a rotating, convex surface on which a plate or film is mounted. Multiple writing beams are modulated as they spiral or index along the drum.

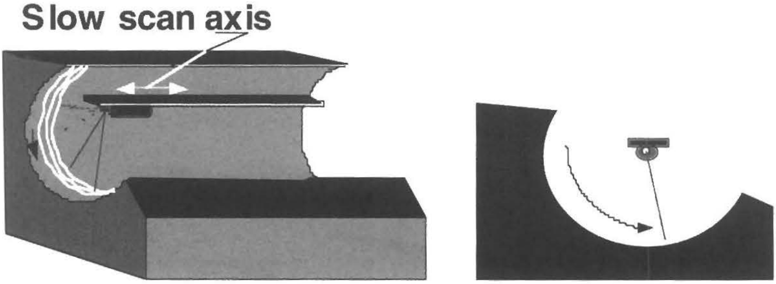

Figure 4. Internal drum geometry.

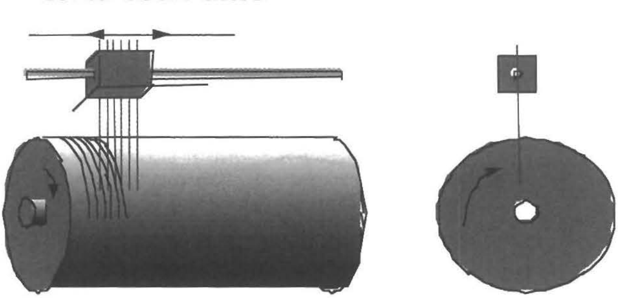

Figure 5. External drum geometry.

Flatbed Geometry Considerations

Flatbed is probably the most mature of the imaging surface geometries. It was very popular in most of the typesetting systems and in early imagesetters. This geometry has been challenged, however, by wide-format imagesetting and recently by wide plate formats.

The optical system used with flatbed architecture represents the single gating factor in the application of flatbed technology. The spinning mirror or mirrors deflect the beam into an *arc* of information on the flat imaging surface. The focal length of the beam is therefore constantly changing as the distance from the mirror to the plate or film changes. This variation can be corrected or compensated for in the optics or electronics, but only to within a practical limit. When wider format materials are used, the required components make the technology prohibitively expensive.

In a practical sense, flatbed geometry lends itself best to narrow format work such as newspapers. When imaging at low resolutions (i.e., less than 1270 dpi), flatbed architecture can be highly productive and difficult to match in total throughput.

Cylindricity and Runout

Two critical components of both internal and external drum geometry that affect image quality are *runout* and *cylindricity*. Runout is the measure of positional error relative to a defined center of axis of motion. Runout causes a drum to wobble and interacts directly with the writing beam depth of focus to create artifacts.

Cylindricity is the condition of a surface of revolution in which all points on the surface are equidistant from a common axis. It is a measure of roundness. Variations in cylindricity of the drum surface also directly interact with the writing beam depth of focus. See Figure 6.

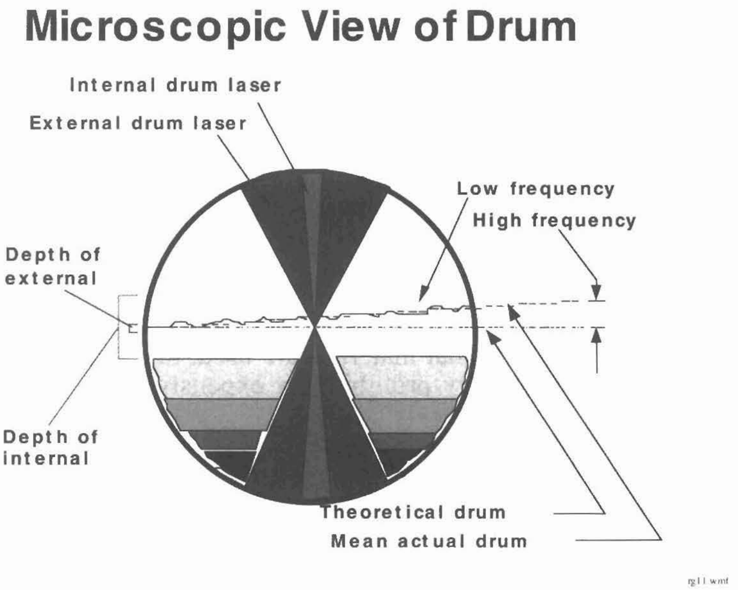

Figure 6. Cylindricity errors.

The depth of focus is determined by writing beam configuration. The smaller the depth of the focus, the greater the magnitude of the error created by surface variations. See Figure 7. This topic will be discussed in greater detail later.

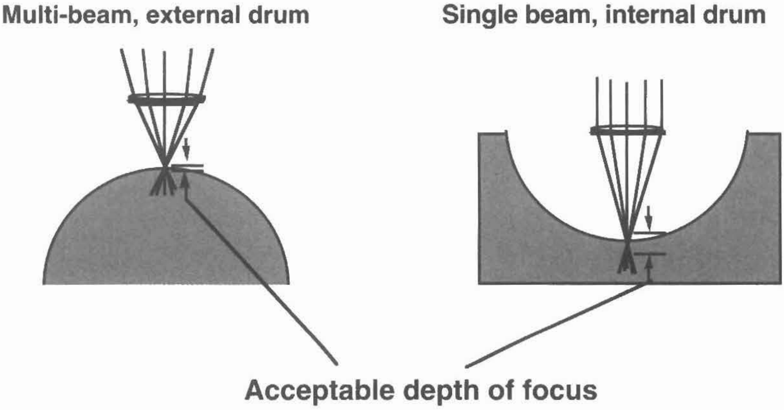

Figure 7. Depth of focus.

External Drum Considerations

As illustrated in Figure 5, an external drum consists of a rotating drum mounted on precision bearings. Drum rotation is the fast scan axis of motion. Typically, a multiple writing beam image generator traverses the length of the drum to form the slow scan axis. A single writing beam could theoretically be used, although it would be impractical as will be shown later. The modulation (Z axis) can be accomplished in several ways, ranging from direct modulation of laser diodes to the use of multiple acousto-optical modulators (AOMs) in conjunction with a laser source.

Most external drums begin as a casting or an extrusion which are spun or "turned" to form the outer surface. The cylindricity of the external drum is influenced by the equipment used in its fabrication. No matter how precisely the fabrication process is controlled, mechanical runout will be present. The turning or manufacturing fixture has a finite error built in that will be transmitted to the drum.

Another source of runout in an external drum can be size of the plate or film mounted on its surface. The rotational speed of external drums typically varies from 60 to 2000 RPM. At higher speeds, a small plate or film can throw the drum out of balance, much like a poorly balanced automobile tire. An out-of-balance condition also disrupts beam focus. During imaging, the large external drum wobbles slightly due to runout as it rotates, which moves the surface out of focus. As the beam encounters cylindricity variations, the surface also moves out of focus.

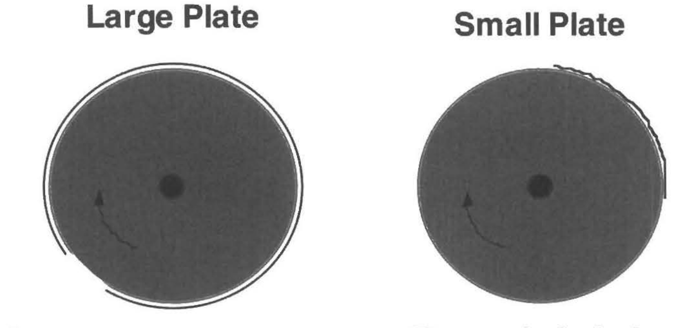

Figure 8. Plate size-related out of balance condition.

Any disruption in focus can cause visible artifacts. The errors can be categorized as low and high frequency components. The instant variation results in the high frequency component, while the slower variations as the machining tool moves down the drum form the low frequency components. See Figure 6.

Internal Drum Considerations

In contrast to the external drum, the internal drum has fewer moving parts and, in a dynamic sense, is considerably more passive. What's more, the material being imaged is not in motion during imaging and so is not subject to centrifugal forces.

Most internal drums are castings that require a post-casting machining process. A large tool spinning inside the drum forms a precise imaging surface on the inside of the drum. As a result of the turning or boring process, mechanical runout and cylindricity errors may be introduced similar to an external drum. Also like an internal drum, these errors have low and high frequency components.

A number of techniques have been used to reduce these introduced errors in internal drum technology, although some are patented or proprietary. Gerber Systems Corporation, for example, uses a patented process to avoid many error contributors. Gerber uses a unique tool to which the inner skin of the drum is mounted to form a precise cylindrical surface. Both skin and tool are inserted into the drum casting and precisely bonded together. After curing, the tool is removed, leaving behind a precise, dimensionally accurate internal drum surface.

Slow Scan Positioning System Considerations

In both internal and external drum geometries, the writing beam moves over the material surface in the fast scan axis, either by beam deflection or by drum rotation. See Figures 4 and 5. At the same time it moves down the drum along the slow scan axis of motion and is modulated to form an image.

In an internal drum, the slow scan axis is located precisely in the center of the drum. In an external drum, the slow scan axis is located outside the drum. In both drum geometries, the slow scan axis must be precisely parallel to the center of the drum. In fact, in an internal drum machine, it is the center. Positional errors in this axis are extremely critical and are accentuated when multiple writing beams are used because multiple writing beams are subject to variations in beam-to-beam spacing or intensity variations between the last beam in one scan and the first beam of the next scan. It should be emphasized that even a very small error -- measured in millionths of an inch -- will be visible to the human eye.

Image Generator Configuration Considerations

The image generator, which is the assembly that delivers the writing beam to the imaging surface, is the most critical contributor to image quality. All of the previously discussed tolerances -- mechanical runout, cylindricity, and slow scan parallelism -- come into play, more or less critically depending on the drum geometry and image generator configuration. Image generator configuration consists of imaging resolution, number of writing beams, rotational speed of the drum or of the beam spinner/deflector, and either material length or drum depth.

Imaging Time as a Function of Image Generator Configuration

Imaging time is the time it takes to expose a plate or film of a specified length at a specified resolution. It is **not** *throughput*, which includes many other factors such as RIP time, communications overhead, start/stop repositioning, etc. These two terms have been used interchangeably, and incorrectly, in specifications for computer-to-plate technology, which can be misleading.

Imaging time may be expressed as in equation (1):

$$\text{Imaging time} = \frac{(\text{length of the plate or film}) \text{ X } (\text{resolution})}{(\text{rotational speed- RPM}) \text{ X } (\text{\# of writing beams})} \qquad (1)$$

The cases below illustrate imaging time calculations.

Case A: Imaging Time for an External Drum with Multiple Writing Beams

Case A is an external drum imaging at 2400 dpi, rotating at 60 RPM, on a 44-inch plate, using 480 writing beams. The calculation is shown in equation (2):

$$\text{Imaging time} = (44 \text{ X } 2400)/(60 \text{ X } 480) = 3.67 \text{ minutes} \qquad (2)$$

Case B: Imaging Time for an External Drum with a Single Writing Beam

Case B is identical to Case A except a single writing beam is used. The calculation is shown in equation (3):

$$\text{Imaging time} = (44 \text{ X } 2400)/(60 \text{ X } 1) = 1{,}760 \text{ minutes} \qquad (3)$$

Clearly, an external drum requires multiple writing beams to achieve a practical imaging time.

Case C: Imaging time for an Internal Drum at 18,000 RPM

Case C is an internal drum imaging at 2540 dpi with a spinner/deflector rotating at 1,8000 RPM, on a 42-inch plate, using one beam. The calculation is shown in equation (4):

Imaging time = (42 X 2540)/(18,000 X 1) = 5.92 minutes
(4)

Case D: Imaging time for an Internal Drum at 30,000 RPM

Case D is the same as Case C but with a spinner/deflector rotating at 30,000 RPM. The calculation is shown in equation (5):

Imaging time = (42 X 2540)/(30,000 X 1) = 3.55 minutes
(5)

Discussion of Calculations

Based on the calculations shown above, an external drum must utilize multiple writing beams to operate in a practical fashion. Use of a single beam illustrates an extreme condition for an external drum that would prove entirely unacceptable. Even so, the multi-beam scheme is approaching practical limits, assuming we are able to ignore image quality degradation. Of course our customers cannot do this.

Incidentally, AOM technology used in multi-beam configurations is extremely sensitive to temperature variations in the room. Multi-beam configurations are also less efficient in the use of laser power, which affects cost, life, and reliability.

More importantly, it becomes apparent that only a single writing beam configuration can achieve high quality and high resolution imaging. Acceptable imaging times with a single beam can only be accomplished by an internal drum. The reasons for this are discussed below.

Quality Degradation Factors

The quality degradation associated with multi-beam imaging is due to several factors: non-uniformity of beam intensity, beam-to-beam spacing, and cluster-to-cluster spacing. Depending on the technology applied, the intensity of each beam may be difficult to maintain as well as to manufacture. What's more, as the individual devices age, the intensity or brightness of the beams may vary. See Figure 9.

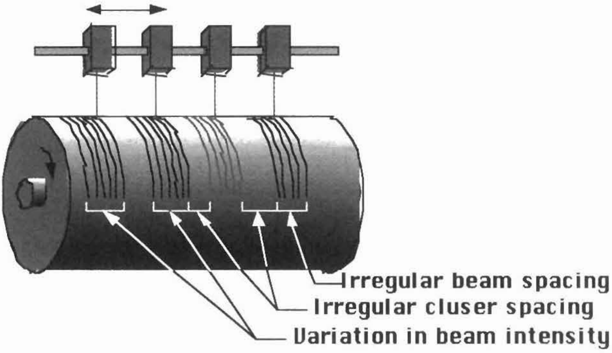

Figure 9. Multiple writing beam non-uniformity.

The beam to beam spacing is very critical. The human eye is highly sensitive to spatial frequency variations. This is quite apparent when large clusters of beams are used. The resulting phenomena is referred to as "stitching", which may be thought of in general terms as misregistration. The same effect can occur when a large cluster of beams vary in intensity, especially between the leading and trailing beams of the cluster.

The slow scan positioning system can also contribute to the stitching (misregistration) artifact, which is accentuated in multiple beam configurations due to the spatial frequency effects. While a slow scan positioning system error can also be present in a single-beam configuration, it is much less visible. This is because any given mechanical error due to the slow scan positional system is distributed over the fast scan motion. In a 480-beam system, for example, the error would be distributed over only five revolutions of the drum. In a single-beam system, the error would be distributed over 2400 revolutions of the spinner/deflector.
A single beam does not vary in intensity as do many separate light sources. These problems are quite evident when higher line screens are used with high resolution imaging. The artifacts are far less visible at lower line screens.

The most critical parameters of any light source are its spot size and depth of focus. In a multi-beam environment, both of these parameters are far more critical than in a single-beam system. There are several ways of forming multiple-beam arrays, each one having characteristics slightly different from the others. In each of the methods, the depth of focus is extremely small.
A typical depth of focus for an external drum is typically less than 0.5 mil.
A small depth of focus is a function of the optical system. The numerical aperture of the optics is directly affected by the number of beams used. A rule of thumb is that the greater the number of beams, the greater the numerical aperture and, therefore, the shallower the depth of focus.

A typical internal drum, single-beam system can have several mils depth of focus. See Figure 7. In a system environment, all the parameters come into play. The net result is that an internal drum system can maintain more consistency in the critical parameters such as spot size and focus. Spot size and focus variations can have ill effects such as banding and color shifts at high resolution, especially at high percentage tints, such as in shadows and degradés.

The Vacuum System

In both imaging geometries, the film or plate is held in place by vacuum. Since the internal drum is stationary, the vacuum system can be selectively channeled to support various plate or film sizes, as in the Gerber-patented, zoned vacuum system. This feature is far more difficult to implement in an external drum. In the case of the external drum, the vacuum system performs an active function of protecting the plate from deforming due to centrifugal forces. The faster the rotation, the greater the force. This force can be yet another contributor in the depth of focus error that is already present in the external drum.

Another concern is vacuum failure during rotation. The mechanism for coupling a vacuum pump to an external drum is more complex than to an internal drum, increasing concerns about reliability and downtime. The external drum requires a bearing system that will allow the air to flow while in motion, whereas the internal drum is static.

The Docking System

Both external drum and internal drums have some form of material docking systems. The use of electronic docking feedback is possible in an internal drum as evidenced by the Gerber internal drum. Electronic docking feedback can seriously reduce the make-ready time on press, resulting in more jobs per shift and reduced waste going to the land fill, significant cost reductions for the printer and the end user.

Conclusion

A simplistic method of differentiating one geometry from the other is to segment them by performance and image quality. The flatbed is limited in its format size but extremely fast imaging speed at lower resolutions. The external drum is able to support larger format sizes but is limited in image quality. Stitching (or misregistration), color shifting, and other spatial artifacts are real and impact high quality, high resolution work. External drum imagers claim faster imaging speeds, but total system throughput may be less than with internal drum imagers.

The ultimate in imaging quality is the internal drum system, as embodied by the Crescent PlateSetter™ family. Multi-beam schemes have reached their practical limits, whereas the internal drum technologies have yet room to expand. Rotational speed increases are not the only means of improving imaging speed. Internal drum efficiencies can be improved as well, leaving Gerber the opportunity to continue enhancing its products.

The absolute bottom line is image quality, which can be best achieved using an internal drum.

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