Measurement of the cell volume of Anilox rolls

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Keywords

Flexo, Measurement, Cell volume

Abstract

The volume and shape of the cells in an anilox roll have a significant effect on the ink transferred to the flexographic plate. There is a need to accurately characterise the cells both immediately after manufacture for quality assurance purposes and during production to evaluate the effect of wear.

As part of a study into ink transfer in the flexographic printing process, a new methodology for the characterisation of the cells in anilox rolls has been developed based on single cell analysis using white light interferometry. This allows for the inherent surface roughness caused by the manufacturing process. This method has been found to give accurate and repeatable results. This study also highlights key parameters that are necessary to define the cell characteristics.

Comparisons have been made of measurements of the same anilox roll with other techniques including microscopy, volumetric and deformable tape. These offered advantages in terms of speed and cost, but generally at the expense of accuracy. However, they may be viable for use in monitoring wear.

Introduction

Although the anilox has a key roll in the control of ink flow in the flexographic printing process, there is as yet no agreement on the best practise in terms of measurement and the critical aspects of the cell dimensions that have to be controlled. This is crucial for the specification of anilox rolls, as this is the basis of communication between the printer and the supplier. It is also essential to be able to measure the rate of wear of the anilox during production. The prediction

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of the effect of cell attributes such as volume, depth, open area and internal surface on ink transfer requires these to be accurately quantified. The advent of white light inteferometry has enabled major advances in the measurement of engraved surfaces and cells.

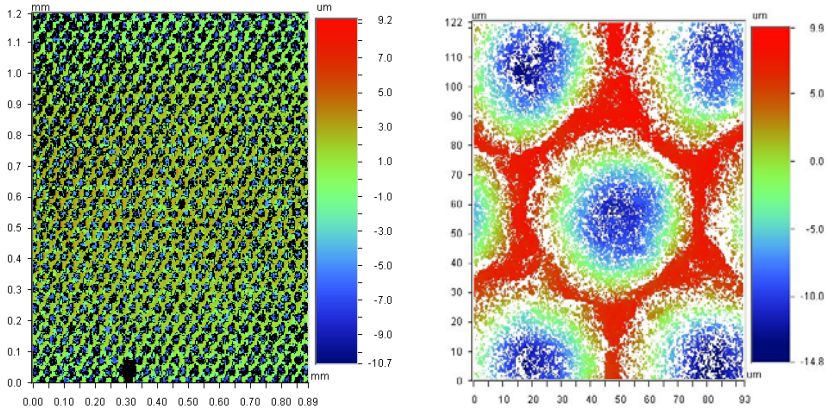
The paper describes the development of an improved method for the use of white light inteferometry for the measurement and analysis of the engraved cells on anilox rolls. The new methodology is then compared with Replica tape, Microscopic analysis and Volumetric method to highlight variations in both performance and usability between the techniques. The methods were used to make comparative measurements on a banded anilox roll with engraving patterns that cover a wide range of cell geometries currently used in flexographic printing.

White Light Inteferometry

White light interferometry [Lippol] is a non-contact profile measurement system. It works on the phenomenon that when two or more wave motions interact and combine, they produce a resulting wave of larger or smaller amplitude, depending on the recombining phase. The interference of white light results in spectral coloured fringes of lighter or darker colour, depending on the phase of the recombining light. There are two different types of interferometry available, Phase shifting interferometry (PSI) and vertical scanning interferometry(VSI). Both techniques use the same basic interferometric principles, but in PSI, not only is the light filtered, but the system measures the phase of the interference fringes rather than the degree of fringe modulation or coherence as with VSI. PSI is the older of the two techniques and although well suited to the measurement of smooth continuous surfaces with great precision, it has a limited dynamic range [Wyant] and is only reliable when the fringe pattern is sufficiently sampled. This means that if the distance between adjacent measurements points is greater than ¼ of the wavelength of the light, height errors will be introduced of multiples of ½ wavelength. With VSI on the other hand, the interferometric objective scans the surface vertically at varying heights, so the focus varies at each position. This combined with the short coherence length of white light, means the fringes are only visible over very shallow depths for each focus position. As the sample is scanned at the varying heights, the fringe contrast or modulation increases as the sample is brought into focus and decrease as it falls out of focus. The fringe modulation is recorded at each plane of focus, from which the signals are processed to produce the subsequent surface parameters and profile. The Rollscope is a handheld white light interferometer using VSI developed specifically for measurement of anilox rolls and gravure cylinders in situe.

The first optical geometry used with the “Rollscope” white light inteferometer measured a number of cells over a large area. While this allowed a statistically

significant number of cells in one measurement and negated the need only to measure a whole number of cells, this was at the expense of detailed data from the cells. The wide angle of the scattered light from the wall of the cells led to much of the light not returning to the optics and the amount of actual measured area was reduced. No data was gathered from the area shown in black (Fig. 1a). There is virtually no data from the cell walls and some depth information is missing. It is possible to use an algorithm to restore the data and fill in the gaps in the image, but with large areas where no data is recorded such interpolation tends to introduce significant errors. However, by increasing the magnification, then approximately 97% of the individual cell geometry is measured (Fig. 1b). This can now be used to make an accurate evaluation of volumetric, geometric and roughness.



a. Original Optical Geometry b. geometry for Single cell analysis

Figure 1. Cell contours

Once a successful measurement of an engraved cell has been made then it is necessary to analysis the image to obtain the cell parameters. In order to optimise the methodology, different algorithms were compared by taking six measurements on three rolls of different nominal engraving. The effect of magnification was accessed at this stage of the investigation. The following three methods were considered:

Rollscope proprietary software
Entire area analysis
Single cell analysis

The Rollscope proprietary software was fast and easy to use. It corrects for roll diameter. However, the method of volume calculation was not known and it appeared to make assumptions with regard to cell geometry, probably assuming a standard cell shape.

Entire area analysis utilises the histogram of spot heights to isolate the cell from the land area (A) between the cells (Fig. 2). A masking function is applied to the cell walls (B) and the base of cells (C). The volume of land area is calculated and subtracted from total measurement volume. To obtain the volume / area, the mask is removed and the total area based on the number of valid pixels x pixel area to obtain the volume in cm^3 m^{-2}.

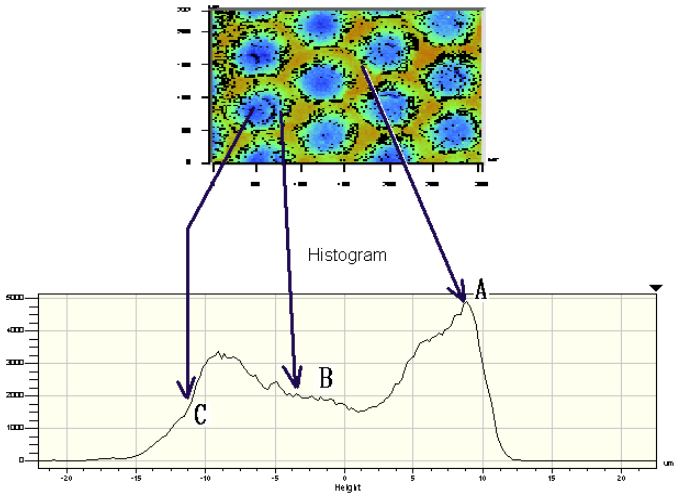
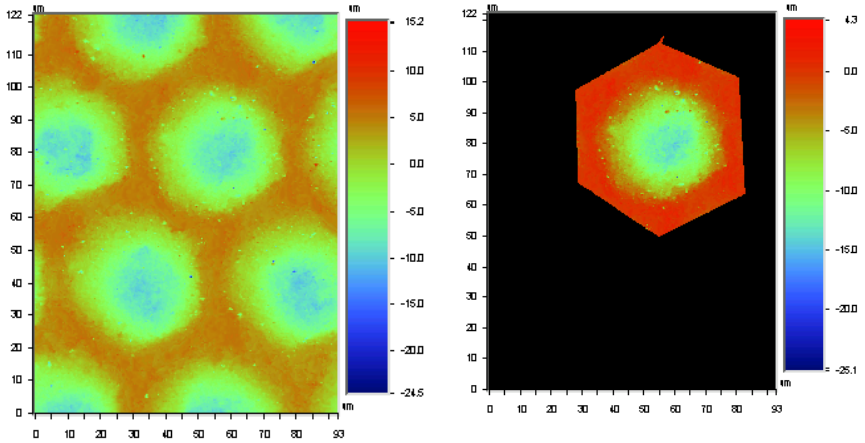


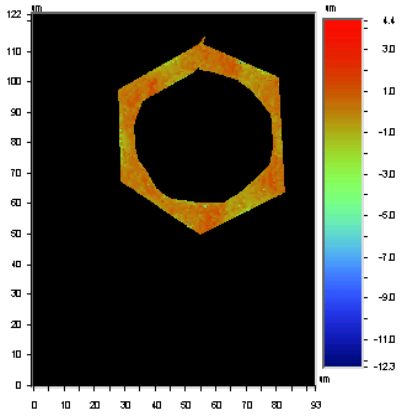
Figure 2. Entire Area Analysis

It is possible to isolate a single cell using an analysis mask (Fig. 3). The analysis mask allows the perimeter of the cell to be outlined after which all the other data can be removed. A terms mask is applied to ensure that when removing the cylinder or tilt, it is only the land area that is taken into consideration and not the cell itself. After the terms mask has been applied, the terms of cylinder and tilt can then be removed, allowing the edges of the cell to be level. The histogram filter is used to remove the land area from around the isolated cell, allowing any calculations to be calculated purely from the cell.

To assess the correct mask height, the roughness of the land area surrounding the cell in question needs to be attained. Apply an analysis mask to remove the internal area of the cell, thus leaving the land area. Once the land area has been isolated, it is possible to identify the height over which the majority of the data points have been recorded and remove those that are affecting the measured parameters but are not common. Once this has completed, the Rz value attained should be noted. The mask height is then assumed to be half Rz for subsequent masking of the cell in order to remove the land area. Having isolated then cell, it is then possible to calculate the cell volume using the volumetric analysis function.



a. Measurement b. Isolated Cell



c. Land Area

Figure 3 Single Cell Analysis

The total cell volume is the combination of two volumes (Fig. 4). Therefore, to calculate the total cell volume V1, the volumes V2 and V3 must be calculated. The volume V2 is taken as the volume below the cell roughness and is the volume calculated for the filtered isolated cell. The volume V3 is added as when the filter is applied, some of the cell volume is lost with the removal of the land area. Therefore to find V3, the lateral surface area of the cell is found, which is then multiplied by the mask coefficient to give the volume V3. This then gives the total volume V1 as:

V1 = (Cell volume V2 + (lateral surface area x mask coefficient))

The cell depth is calculated using the RZ value and the mask coefficient as follows:

Cell Depth = RZ + mask coefficient

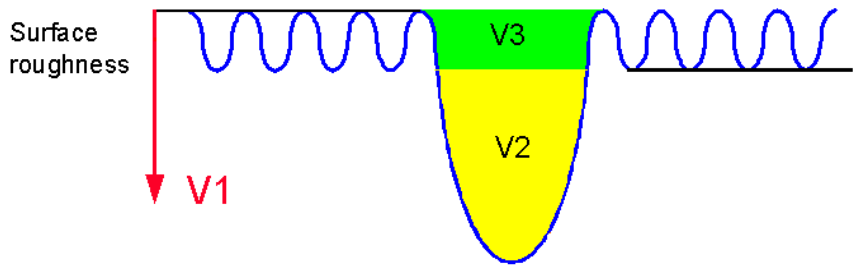


Figure 4. Calculation of cell Volume

A comparison of the three methods of analyses the data from the white light interferometer is shown in Figure 5. The nominal (specified) volumes in each case are higher than the measured volumes. The proprietary (Roll scope) software even with increased magnification produces the next largest volume. Entire area analysis produces the next lowest value. All of these methods are quicker as they analyse an area with each measurement. The single cell analysis is based on the average of several discrete measurements. While more time consuming it makes less assumptions and has more valid data points per cell measured. Thus, it tends to be more reliable, although sufficient cells have to be measured to ensure the sample is statistically valid. As each measurement with single cell analysis takes as long as one entire area analysis, then this is a much longer process. However, as it has no systematic errors, and provided the sample size is large enough to allow for the natural variation in production of the cell geometries, then it gives the most reliable result and has been used for the comparison with other techniques.

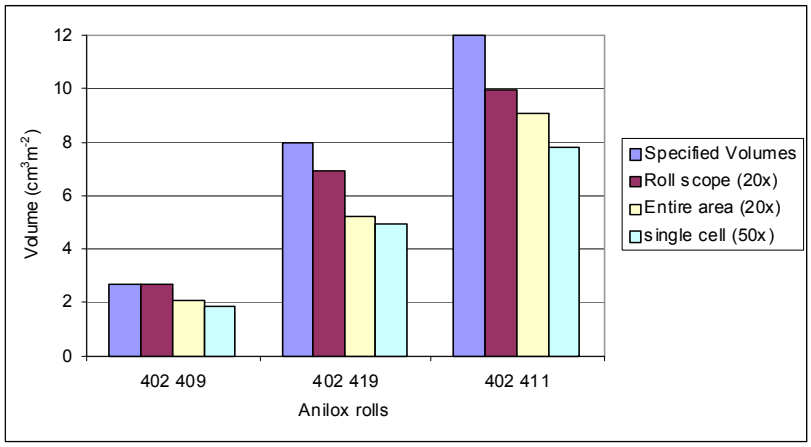


Figure 5. Comparison of different analysis techniques

Comparison with other characterisation techniques

In order to compare the different measurement techniques in detail, each was applied in turn to banded anilox roll. The Anilox was a CO2 engraved ceramic roll incorporating 11 differently engraved bands. These bands varied from low screen rulings (200 lpi) and high cell volumes to very high screen rulings (1200 lpi) and low cell volumes, thus the majority of engravings were covered. To provide a reference, eight measurements were taken using the Rollscope for each of the eleven bands, using either the 25X or 50X magnification depending on the size of each cell. The magnification was optimised to produced the most detailed image of an individual cells as is possible, thus maximising the amount of data recorded. Single cell analysis was then performed.

Replica Tape

Replica tape was originally intended for the measurement of steel surfaces that have been blasted to ensure a suitably rough surface prior to painting. However, it has been used as an in-direct contact method of measurement for anilox rolls. The replica tape consists of a layer of crushable plastic microfoam coated onto polyester film of uniform thickness. The microfoam is compressed by way of applying a suitable pressure, therefore collapsing into the cells (Fig. 6). This gives an impression of the surface. It is intended primarily for profile height measurement, not volumes. Manufacturers of similar products claim to be able to calculate the volume to within 10% accuracy.

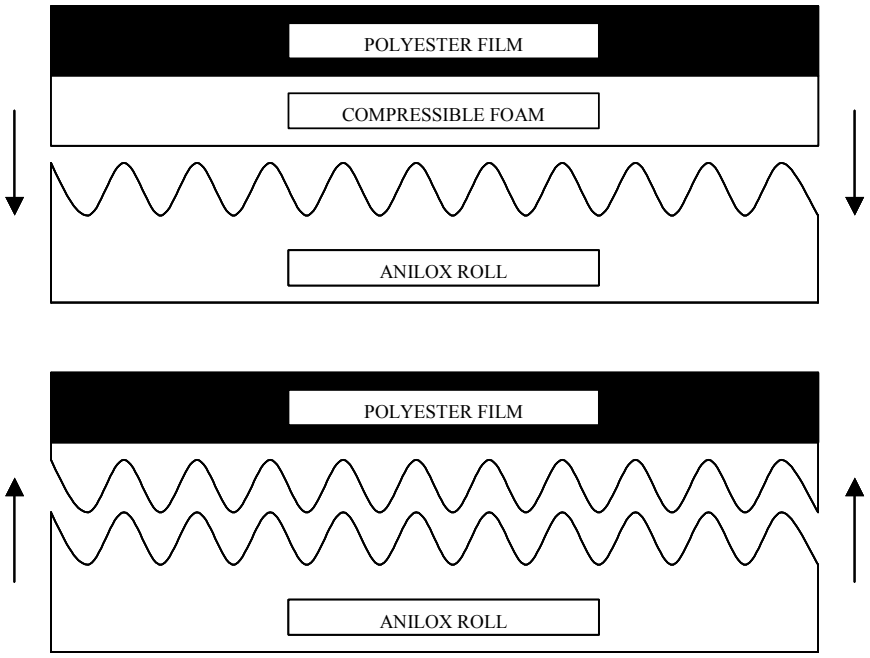


Figure 6. Schematic of profile measurement with replica tape

The thickness of the microfoam contained in the tape varies depending on the tape grade, as different grades are required to cover different ranges of depth measurement. Three tape grades were evaluated; X-coarse plus, X-coarse and coarse. There is also a fine-medium grade, but this was found to be inappropriate. Eight measurements were taken per band, four per replica impression. The replicas were measured using the NT2000 white light interferometer, using the optimum magnification. Initially, each of the three tape grades (coarse, x-coarse and x-coarse +) were assessed to highlight the performance of each grade when used for measurement of anilox rolls. The optimised tape grade was then used for all subsequent measurements. Single cell analysis was carried out for all measurements. The results were compared to those achieved using the rollscope, thus highlighting which of the tape grades performs best over the range of cell sizes.

The results gained from each type of tape are similar and confirm the consistency of the method used to obtain the geometry of the cells (Figure 7). However the different tape types have their limits depending on the cell depth, etc. This is especially noticeable for bands 1 through 3. The x-coarse plus tape gives consistently the highest readings for both volume and depth throughout all 11 bands.

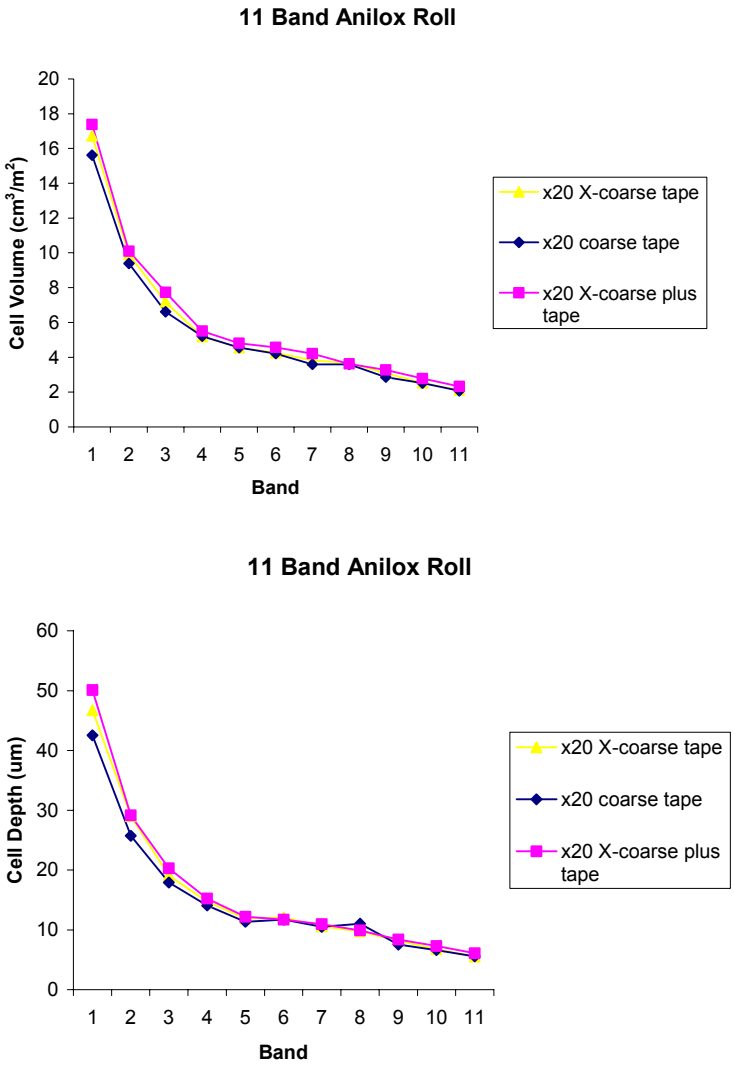


Figure 7. Comparison of the cell volume and depth measured with different tape grades

The measurements gained from the x-coarse plus tape were compared with those from rollscope to highlight the effectiveness of the tape to accurately replicate the anilox cells (Figure 8). The replica tape and the rollscope, produce almost identical for cell volume for the first three line rulings (up to 400 lpi). However, as the line rulings become finer, then there is less agreement between the two measurement methods. There are differences in the cell depth measured by the replica tape, except for bands 3, 4 and 5 which display almost identical results

for depths. The other bands display a reduction in cell depth for those taken with the tape, especially bands 1, 2, 6, 8 and 10. This generally coincides with a reduction in the cell volume, indicating that perhaps the tape is not fully reaching the base of these particular cells, or as the tape is removed form the cylinder, the tape is displaying some elastic reformation. However, it could also indicate that the volume achieved using the tape may be the same although the replicated cell shape is different to that measured using the rollscope. This may also be the reason for the slight increase in volume gained with the replica tape for many of the bands.

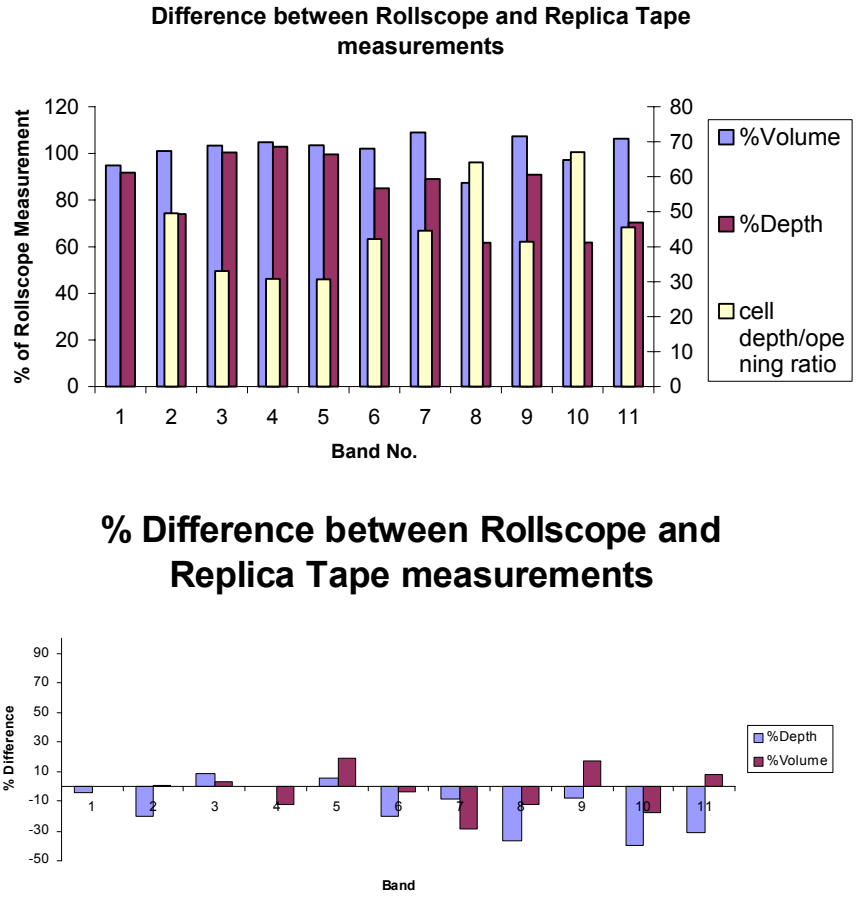


Figure 8. Comparison of the replica tape with rollscope

This is not a function of line ruling, but would appear to be related to the cell depth-to-opening ratio. As the cell depth-to-opening ratio increases, so the

variation between the Rollscope and tape also increases. This would suggest the tape has difficulties in replicating cells, which have high wall angles or are thin but deep in profile. As cell depth/opening ratio increases so does angle of cell wall. There is also more opportunity for elastic reformation of the material. Therefore, it is recommended when using replica tape to characterise anilox that the cell not be more than half as deep as it is wide and the slope not greater than 45º.

Optical Microscope Measurement

Microscopic analysis employs a high magnification microscope to capture images of the anilox roll. The captured images can then be examined using image analysis software. The microscopes have interchangeable lenses and therefore allow high magnification and detail of the anilox cells to be observed. It is important that the surface of the anilox is illuminated to allow the reflected light from the cylinder to be observed through the microscope. Many of the microscope systems allow the microscope to be attached to a computer, which allows the 2-dimensional image to the captured for further analysis. The instrument is calibrating by placing a calibration tile incorporating a metric scale under the microscope and an image is captured for use with the image analysis software. Although, it is only possible to measure in a two-dimensional plane using image analysis software, it is possible to gain some information regarding the cell depth. The measurement of cell depth is achieved by using the focus of the microscope and a micrometer. Once focus on the top of the cell is achieved, the micrometer can be reset, the microscope can then be refocused on the bottom of the cell and the distance travelled is the measurement of the cell depth. The width and area of the cell derived from the image processing is then combined with the measurement of the cell depth and assumed cell geometry to calculate the cell volume. A typical image with the calibration length displayed can be seen in figure 9.

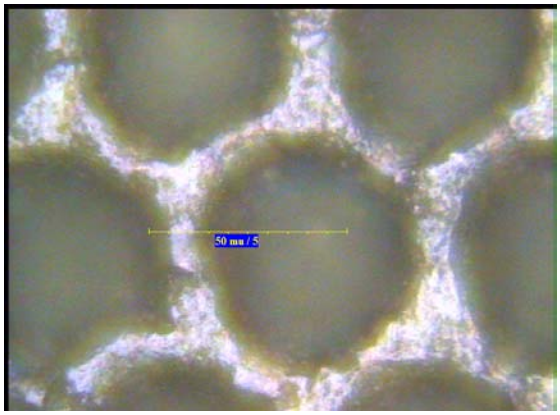


Figure 9. Typical image from Microscope measurement

Four measurements from each band were measured, using the M-Service Cellcheck microscope. The exception was that of band one, where problems with the magnification meant that it was impossble to measure a complete cell. Image analysis was carried out using the Metric 7.1 PE Plus software. The cell volume was calculated using the measured base area and depth, 1/3(base area x depth).

The microscope system has significant differences in the measured cell depth (Figure 10). The difference in the measured volume is far less, yet still well over ±10% and as high as 30%. The accuracy of the system depends on the assumptions of the formula used for determining the shape of the cell, as well the accuracy of the depth measurement. This would suggest the simplistic pyramid approach does not allow for the more rounded based of the manufactured cell.

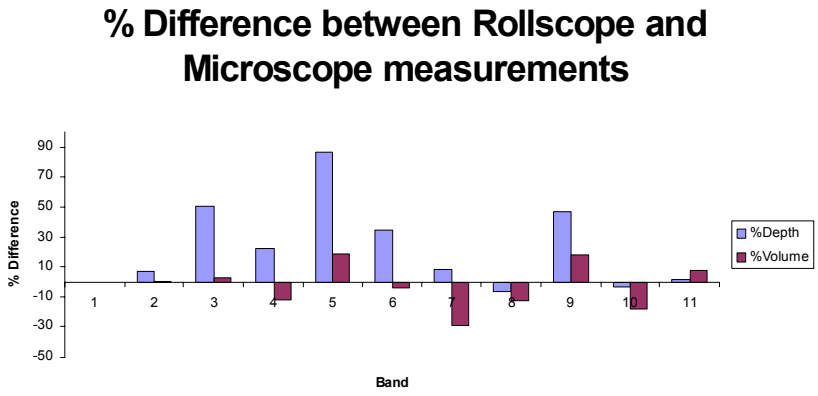


Figure 10. Comparison of Microscope and Rollscope measurments

Volumetric method

This is a direct contact method for measuring anilox volume. A pre-set volume of indicator fluid in a bubble contained within a capsule on the adhesive strip is forced out of the capsule along the anilox roll with the use of a doctor blade. As the fluid is forced out, it fills the cells until it reaches the point at which all the liquid has been exhausted. The length of fluid flow indicates cell volume. A scale on the side of the strips allows the operator to read off the result. It is assumed that the cells are completely filled. It is cheap and relatively fast, but can't evaluate geometry and surface characteristics.

For this study the "Capatch" system of volumetric measurement was used. Two test strips were used per band and the volume measured using the logarithmic scale. For bands 1 and 2, medium volume strips were used and for bands 3-11,

the low volume strips were used. The number of cells over which the volumetric method measures the volume is far higher than the other methods. However, it does assume the cells are all completely filled. Compared to the other methods, it makes a reasonable estimate at the low line rulings, but tends to significantly over estimate the volumes at high line rulings (band 5 onwards, Fig. 11).

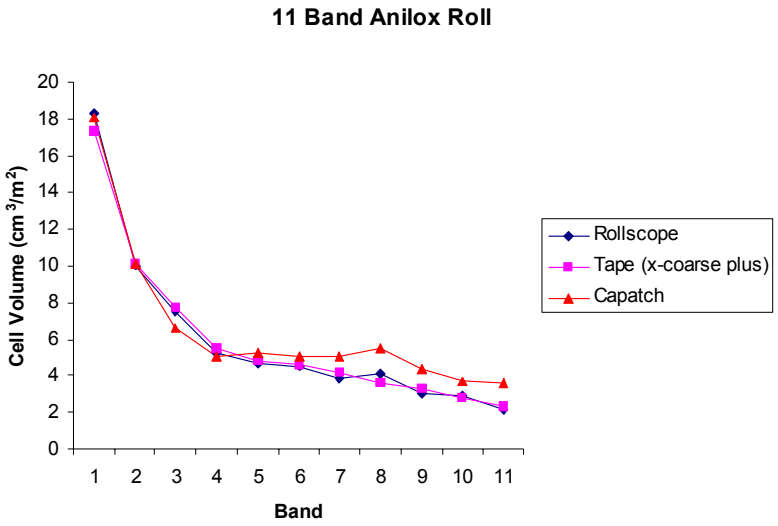


Figure 11. Comparison of Volumetric with other techniques

Conclusions

White light interferometry is potentially the most accurate of all the techniques in measuring cell geometry. However, it is also the most expensive. Great care has to be taken in measurement and analysis of the results to achieve this accuracy. Of the three analysis methods evaluated, the proprietary software was quickest and easiest to use but was least accurate. The Entire Area Analysis method tended to overestimate volume. The Single Cell Analysis technique was most accurate, but the most time consuming, as it required detailed measurements of sufficient cells to ensure statistical accuracy. In this mode, it is user independent and can measure shape.

The X-Coarse plus replica tape gave the best results across all bands. It needs off site measurement of tape profile and the overall result is operator dependent. The replica tape generally underestimates volume and depth. The variation general increases as cell becomes smaller. The performance of the replica tape is also affected by the cell depth-to-opening ratio. As the ratio increase, so the cell walls become steeper and the tape performance reduces.

While the measurement of open area of the cell is highly accurate with the microscope system, the cell depth tends to be highly subjective and the cell volume is highly dependent on the assumed geometry. The variation of volume is similar to those of replica tape. It tends to overestimate the cell depth compared to the other techniques. It produces a detailed image of cell.

The Volumetric system measures over a larger area, but is unable to measure cell depth or geometry. It generally gives higher volume and is highly user dependent and the roll has to be cleaned before it can be used.

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