

Part III

Blob Analysis

This section describes conceptual information about blob analysis, including thresholding, morphology, and particle measurements.

Part III, *Blob Analysis*, contains the following chapters:

Chapter 8, *Thresholding*, contains information about thresholding and color thresholding.

Chapter 9, *Binary Morphology*, contains information about structuring elements, connectivity, and primary and advanced morphological transformations.

Chapter 10, *Particle Measurements*, contains information about areas, lengths, coordinates, chords and axes, shape equivalence, shape features, and diverse measurements of particles.

Introduction

Blobs are areas of touching pixels within an image, in which all pixels have the same logical state. All pixels in an image that belong to a blob are in a foreground state. All other pixels are in a background state. In a binary image, pixels in the background have values equal to zero while every non-zero pixel is part of a binary object.

You can use blob analysis to detect connected regions or groupings of pixels in an image and then make selected measurements of those regions. These regions are commonly referred to as *blobs* (*binary large objects*).

Blob analysis consists of a series of processing operations and analysis functions that produce information about blobs in an image. Using blob

analysis you can detect and analyze any two-dimensional shape in an image.

When to Use

Use blob analysis when you are interested in finding blobs whose spatial characteristics satisfy certain criteria. In many applications where computation is time-consuming, you can use blob analysis to eliminate blobs that are of no interest based on their spatial characteristics, and keep only the relevant blobs for further analysis.

You can use blob analysis to find statistical information—such as the size of the blobs or the number, location, and the presence of blob regions. This information allows you to perform many machine vision inspection tasks—such as detecting flaws on silicon wafers, detecting soldering defects on electronic boards, or web inspection applications such as finding structural defects on wood planks or detecting cracks on plastics sheets. You can also locate objects in motion control applications when there is significant variance in part shape or orientation.

In applications where there is a significant variance in the shape or orientation of an object, blob analysis is a powerful and flexible way to search for the object. You can use a combination of the measurements obtained through blob analysis to define a feature set that uniquely defines the shape of the object.

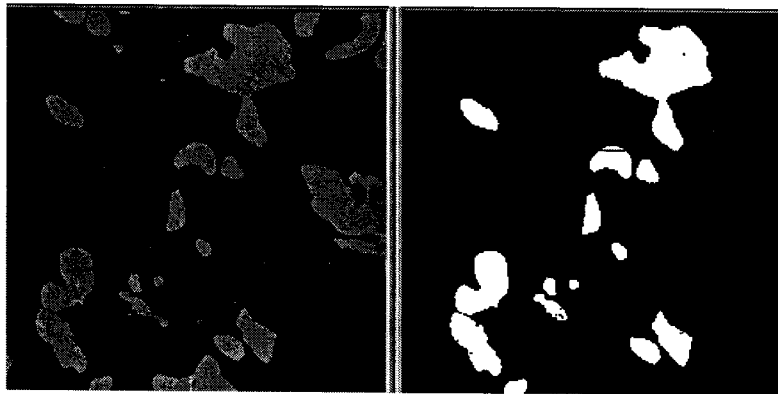
Blob Analysis Concepts

A typical blob analysis process scans through an entire image and detects all the particles, or blobs, in the image and builds a detailed report on each particle. This report usually contains approximately 50 pieces of information about the blob, including the blob's location in the image, size, shape, orientation to other blobs, longest segment, and moment of inertia.

You can use multiple parameters such as perimeter, angle, area, and center of mass to identify and classify these blobs. Using multiple parameters can be faster and more effective than pattern matching in many applications.

Also, by using different sets of parameters, you can uniquely identify a feature in an image. For example, you could use the size of the template blob as a criterion for removing all blobs that do not match it within some tolerance. You can then perform a more refined search on the remaining particles using another list of parameter tolerances. These include the longest segment in each blob and compactness factor (the ratio of the area of the blob to the area of the smallest rectangle that encloses the blob).

The following figure shows a sample list of parameters that you can obtain in a blob analysis application. The binary image in this example was obtained by thresholding the source image and removing particles that touch the border of the image. You can use these parameters to identify and classify particles. The following table shows the values obtained for the blob enclosed in a rectangle, shown in the figure below:



Global rectangle:	
x1Left	125
y2Top	7
x2Right	198
y2Bottom	85
Area (pixels)	2456
Number of holes	1
Area (calibrated)	2456.00
Hole's area (pixels)	2
Sum X	406482.00
Sum XX	67885136.00
Sum Y	89909.00
Sum YY	4158045.00
Sum XY	14856285.00
Projection <i>x</i>	99
Projection <i>y</i>	94

Perimeter	289.02
Hole's perimeter	5.01
Longest segment coordinates (x and y)	x = 125 y = 36
Longest segment length	72

To use blob analysis, first create a binary image using a thresholding process. You can then improve the binary image using morphological transformations and make measurements on the particles in the image.

Make Particle Measurements

After you create a binary image and improve it, you can make particle measurements. With these measurements you can determine the location of blobs and their shape features. Use the following VIs to perform particle measurements:



- **IMAQ BasicParticle (Image Processing»Analysis)**—This VI returns the number of blobs in an image and a report containing the pixel area, real-world area, and bounding rectangle of the blobs. You can use the bounding rectangle to determine the location of the blob in the image.



- **IMAQ ComplexParticle (Image Processing»Analysis)**—This VI returns the number of blobs in an image and a report containing 16 of the most commonly used measurements, including the area, bounding rectangle, and perimeter of blobs.



- **IMAQ ChooseMeasurements (Image Processing»Analysis)**—This VI selects information about blobs from the reports generated by IMAQ BasicParticle or IMAQ ComplexParticle. Blobs that do not meet the criteria you set are filtered from the reports.



- **IMAQ ComplexMeasure (Image Processing»Analysis)**—This VI uses the reports from IMAQ ComplexParticle or IMAQ ChooseMeasurements to calculate 50 particle measurements.

Table 4-1 lists all of the measurements that the IMAQ ComplexMeasure VI returns.

Table 4-1. Particle Measurements

Measurement	Description
Area (pixels)	area of the particle in pixels
Area (calibrated)	area of the particle in user-defined units
Number of holes	number of holes within the particle
Holes area (pixels)	total area of the particle holes in pixels
Total area	area of the particle and its holes
Scanned area	area of the entire image in real-world units
Ratio area/Scanned area (%)	percentage of the surface area of a particle in relation to the scanned area

Table 4-1. Particle Measurements (Continued)

Measurement	Description
Ratio area / Total area (%)	percentage of a particle's surface area in relation to the total area
Center of mass (X)	x-coordinate of the center of mass
Center of mass (Y)	y-coordinate of the center of mass
Left column (X)	left x-coordinate of the bounding rectangle
Upper row (Y)	top y-coordinate of the bounding rectangle
Right column (X)	right x-coordinate of the bounding rectangle
Lower row (Y)	bottom y-coordinate of bounding rectangle
Width	width of bounding rectangle in user-defined units
Height	height of bounding rectangle in user-defined units
Longest segment length	length of longest horizontal line segment in a particle
Longest segment left column (X)	leftmost x-coordinate of longest horizontal line segment in a particle
Longest segment top row (Y)	y-coordinate of longest horizontal line segment
Perimeter	length of the outer contour of the particle in user-defined units
Hole's perimeter	perimeter of all holes in user-defined units
SumX	sum of the x-coordinates for each pixel of the particle
SumY	sum of the y-coordinates for each pixel of the particle

Table 4-1. Particle Measurements (Continued)

Measurement	Description
SumXX	sum of the squared x-coordinates for each pixel of the particle
SumYY	sum of the squared y-coordinates for each pixel of the particle
SumXY	sum of the product of the x-coordinate and y-coordinate for each pixel of the particle
Corrected projection X	sum of the horizontal segments that do not superimpose any other vertical segment
Corrected projection Y	sum of the vertical segments that do not superimpose any other horizontal segment
Moment of inertia Ixx	inertia matrix coefficient in XX
Moment of inertia Iyy	inertia matrix coefficient in YY
Moment of inertia Ixy	inertia matrix coefficient in XY
Mean chord X	mean length of horizontal segments
Mean chord Y	mean length of vertical segments
Max intercept	length of the longest segment in the convex hull of the particle
Mean intercept perpendicular	mean length of the chords in a particle perpendicular to its max intercept
Particle orientation	direction of the longest segment
Equivalent ellipse minor axis	total length of the axis of the ellipse having the same area as the particle and a major axis equal to half the max intercept
Ellipse major axis	total length of the major axis of the ellipse having the same area and perimeter as the particle in user-defined units

Table 4-1. Particle Measurements (Continued)

Measurement	Description
Ellipse minor axis	total length of the minor axis of the ellipse having the same area and perimeter as the particle in user-defined units
Ratio of equivalent ellipse axis	fraction of the length of the major axis to the length of the minor axis
Rectangle big side	length of the large side of a rectangle having the same area and perimeter as the particle in user-defined units
Rectangle small side	length of the small side of a rectangle having the same area and perimeter as the particle in user-defined units
Ratio of equivalent rectangle sides	ratio of rectangle big side to rectangle small side
Elongation factor	max intercept / mean perpendicular intercept
Compactness factor	particle area / (breadth × width)
Heywood circularity factor	particle perimeter / perimeter of circle having same area as the particle
Type factor	complex factor relating the surface area to the moment of inertia
Hydraulic radius	particle area / particle perimeter
Waddel disk diameter	diameter of the disk having the same area as the particle in user-defined units
Diagonal	diagonal of an equivalent rectangle in user-defined units

Convert Pixel Coordinates to Real-World Coordinates



The particle measurement functions return only the area of blobs in pixel coordinates. If you need to find the location of the center of mass or the bounding rectangle of the blobs in real-world units, use the IMAQ Convert Pixel to Real World VI (**Vision Utilities**»**Calibration**).

10

Particle Measurements

This chapter contains information about the areas, lengths, coordinates, chords and axes, shape equivalence, shape features, and diverse measurements of particles.

Digital Particles

You can characterize a digital particle by a set of morphological and intensity parameters described in the *Areas, Lengths, Coordinates, Chords and Axes, Shape Equivalence, Shape Features, and Diverse Measurements* sections.

When to Use

Use particle measurements when you want to make shape measurements on particles in a binary image.

Digital Particle Concepts

Areas

This section describes the following area parameters:

- **Number of pixels**—Area of a particle, without holes, in pixel units
- **Particle area**—Area of a particle expressed in real units (based on image spatial calibration). This value is equal to **Number of pixels** when the spatial calibration is such that 1 pixel represents 1 square unit.
- **Scanned area**—Area of the entire image expressed in real units. This value is equal to the product (**Resolution X × X Step**) (**Resolution Y × Y Step**).
- **Ratio**—Ratio of the particle area to the entire image area. The percentage of the image occupied by all particles.

$$\text{Ratio} = \frac{\text{particle area}}{\text{scanned area}}$$

- **Number of holes**—Number of holes inside a particle. The software detects holes inside a particle as small as 1 pixel.
- **Holes' area**—Total area of the holes within a particle
- **Total area**—Area of a particle including the area of its holes. This value is equal to **Particle area + Holes' area**.



Note A particle located inside a hole of a bigger particle is identified as a separate particle. The area of a hole that contains a particle includes the area covered by the particle.

Particle #	Particle Area	Holes' Area	Total Area
Particle 1	A	B + C	A + B + C
Particle 2	D	0	D
Particle 3	E	F + G	E + F + G
Particle 4	G	0	G

Lengths

This section describes the following length parameters:

- **Particle perimeter**—Length of the outer contour of a particle.
- **Holes' perimeter**—Sum of the perimeters of the holes within a particle. Holes' measurements becomes valuable data when studying constituents A and B such that B is occluded in A. If the image can be processed so that the B regions appear as holes in A regions after a threshold, the ratio (**Holes' area / Total area**) gives the percentage of B in A. **Holes' perimeter** gives the length of the boundary between A and B.

- **Breadth**—Distance between the left-most and right-most pixels in a particle, or $\max(X_i) - \min(X_i)$. Breadth is also equal to the horizontal side of the smallest horizontal rectangle containing the particle, or the difference $\max X - \min X$.
- **Height**—Distance between the upper-most and lower-most pixels in a particle, or $\max(Y_i) - \min(Y_i)$. It is also equal to the vertical side of the smallest horizontal rectangle containing the particle, or the difference $\max Y - \min Y$.

Coordinates

Coordinates are expressed with respect to an origin (0, 0), located at the upper-left corner of the image. This section describes the following coordinate parameters:

- **Center of Mass (X, Y)**—Coordinates of the center of gravity of a particle. The center of gravity of a particle composed of N pixels, P_i , is defined as the point G such that

$$\overline{OG} = \frac{1}{N} \sum_{i=1}^{i=N} \overline{OP}_i \text{ and}$$

$$\text{the center of mass } X_G = \frac{1}{N} \sum_{i=1}^{i=N} X_i$$

X_G gives the average location of the central points of horizontal segments in a particle.

$$\text{The center of mass } Y_G = \frac{1}{N} \sum_{i=1}^{i=N} Y_i$$

Y_G gives the average location of the central points of vertical segments in a particle.



Note G can be located outside a particle if the particle has a non-convex shape.

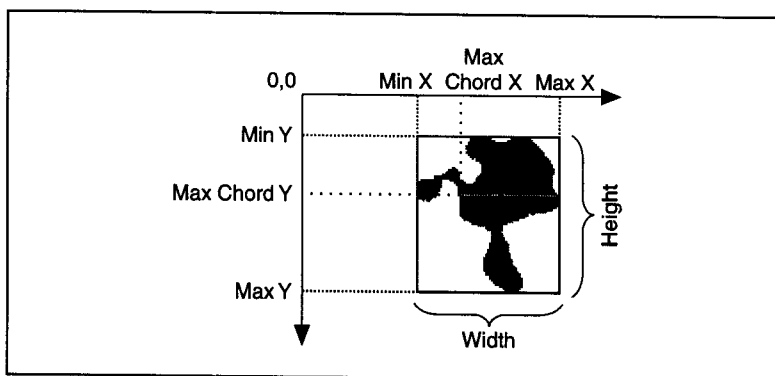
- **Min X, Min Y**—Coordinates of the upper-left and lower-right corners of the smallest horizontal rectangle containing a particle.

The origin (0, 0) has two pixels that have the coordinates (minX, minY) and (maxX, maxY) such that

$$\begin{aligned} \text{min}X &= \text{min}(X_i) \\ \text{min}Y &= \text{min}(Y_i) \\ \text{max}X &= \text{max}(X_i) \\ \text{max}Y &= \text{max}(Y_i) \end{aligned}$$

where X_i and Y_i are the coordinates of the pixels P_i in a particle.

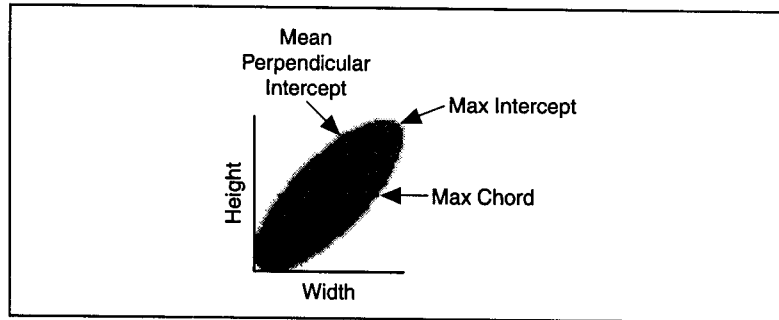
- **Max X, Max Y**—Lower-right corner of the smallest horizontal rectangle containing the particle
- **Max chord X and Y**—Coordinates of the left-most pixel along the longest horizontal chord in a particle



Chords and Axes

This section describes the following chord and axis parameters:

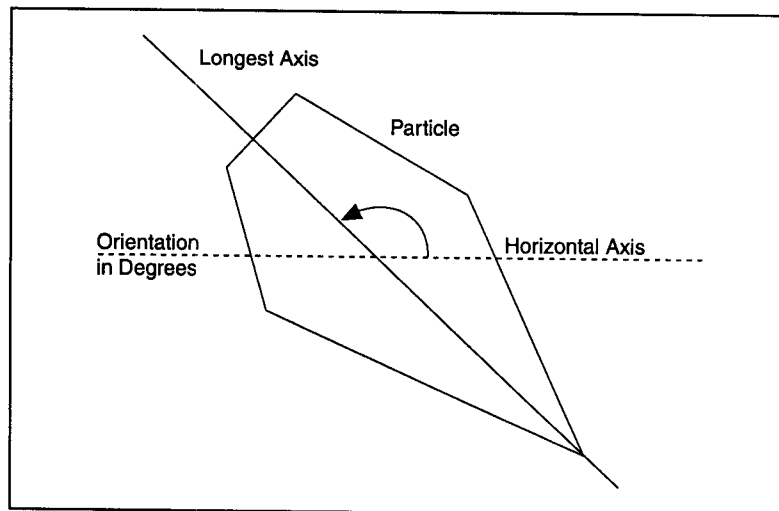
- **Max chord length**—Length of the longest horizontal chord in a particle.
- **Mean chord X**—Mean length of horizontal segments in a particle.
- **Mean chord Y**—Mean length of vertical segments in a particle.



- **Max intercept**—Length of the longest segment in the convex hull of a particle (in all possible directions of projection).
- **Mean intercept perpendicular**—Mean length of the segments in a particle perpendicular to the max intercept.

$$\text{Mean intercept perpendicular} = \frac{\text{area of the convex hull of the particle}}{\text{max intercept}}$$

- **Particle orientation**—The angle of the longest axis with respect to the horizontal axis. The value can range from 0° to 180°. Notice that this value does not provide information regarding the symmetry of the particle. Therefore, an angle of 190° is considered the same as an angle of 10°.



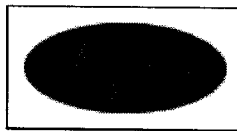
Shape Equivalence

This section describes the following shape-equivalence parameters:

- **Equivalent ellipse minor axis**—Minor axis of the ellipse that has the same area as the particle and a major axis equal to half the max intercept of the particle

This definition gives the following set of equations:

$$\begin{aligned} \text{particle area} &= \pi ab \text{ and} \\ \text{max intercept} &= 2a \end{aligned}$$



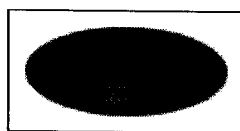
The equivalent ellipse minor axis is defined as

$$2b = \frac{4 \times \text{particle area}}{\pi \times \text{max intercept}}$$

- **Ellipse major axis**—Total length of the major axis of the ellipse that has the same area and same perimeter as a particle. This length is equal to $2a$.

This definition gives the following set of equations:

$$\begin{aligned} \text{Area} &= \pi ab \\ \text{Perimeter} &= \pi \sqrt{2(a^2 + b^2)} \end{aligned}$$



This set of equations can be expressed so that the sum $a + b$ and the product ab become functions of the parameters **Particle area** and **Particle perimeter**. a and b then become the two solutions of the polynomial equation $X^2 - (a + b)X + ab = 0$.

Notice that for a given area and perimeter, only one solution (a, b) exists.

- **Ellipse minor axis**—Total length of the minor axis of the ellipse that has the same area and same perimeter as a particle. This length is equal to $2b$

- **Ellipse Ratio**—Ratio of the major axis of the equivalent ellipse to its minor axis

It is defined as $\frac{\text{ellipse major axis}}{\text{ellipse minor axis}} = \frac{a}{b}$

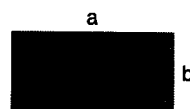
The more elongated the equivalent ellipse, the higher the ellipse ratio. The closer the equivalent ellipse is to a circle, the closer to 1 the ellipse ratio.

- **Rectangle big side**—Length of the big side (a) of the rectangle that has the same area and same perimeter as a particle

This definition gives the following set of equations:

$$\text{Area} = ab$$

$$\text{Perimeter} = 2(a + b)$$



This set of equations can be expressed so that the sum $a + b$ and the product ab become functions of the parameters **Particle Area** and **Particle Perimeter**. a and b then become the two solutions of the following polynomial equation:

$$X^2 - (a + b)X + ab = 0$$

Notice that for a given area and perimeter, only one solution (a, b) exists.

- **Rectangle small side**—Length of the small side of the rectangle that has the same area and same perimeter as a particle. This length is equal to b .
- **Rectangle ratio**—Ratio of the big side of the equivalent rectangle to its small side

It is defined as $\frac{\text{rectangle big side}}{\text{rectangle small side}} = \frac{a}{b}$

The more elongated the equivalent rectangle, the higher the rectangle ratio.

The closer the equivalent rectangle is to a square, the closer to 1 the rectangle ratio.

Shape Features

This section describes the following shape-feature parameters:

- **Moments of inertia** I_{xx} , I_{yy} , I_{xy} —Gives a representation of the distribution of the pixels in a particle with respect to its center of gravity
- **Elongation factor**—Ratio of the longest segment within a particle to the mean length of the perpendicular segments. It is defined as

$$\frac{\text{max intercept}}{\text{mean perpendicular intercept}}$$

The more elongated the shape of a particle, the higher its elongation factor.

- **Compactness factor**—Ratio of a particle area to the area of the smallest rectangle containing the particle. It is defined as

$$\frac{\text{particle area}}{\text{breadth} \times \text{width}}$$

The compactness factor belongs to the interval [0, 1]. The closer the shape of a particle is to a rectangle, the closer to 1 the compactness factor.

- **Heywood circularity factor**—Ratio of a particle perimeter to the perimeter of the circle with the same area. It is defined as

$$\frac{\text{particle perimeter}}{\text{perimeter of circle with same area as particle}} = \frac{\text{particle perimeter}}{2\sqrt{\pi \times \text{particle area}}}$$

The closer the shape of a particle is to a disk, the closer the Heywood circularity factor to 1.

- **Hydraulic radius**—Ratio of a particle area to its perimeter. It is defined as

$$\frac{\text{particle area}}{\text{particle perimeter}}$$

If a particle is a disk with a radius R , its hydraulic radius is equal to

$$\frac{\pi R^2}{2\pi R} = \frac{R}{2}$$

The hydraulic radius is equal to half the radius R of the circle such that

$$\frac{\text{circle area}}{\text{circle perimeter}} = \frac{\text{particle area}}{\text{particle perimeter}}$$

- **Waddel disk diameter**—Diameter of the disk with the same area as the particle. It is defined as

$$\frac{2\sqrt{\text{particle area}}}{\sqrt{\pi}}$$

The following tables list the definition of the primary measurements and the measurements that are derived from them.

Diverse Measurements

These primary coefficients are used in the computation of measurements such as moments of inertia and center of gravity. IMAQ Vision contains the following diverse-measurement parameters:

- **SumX**—Sum of the x coordinates of each pixel in a particle
- **SumY**—Sum of the y coordinates of each pixel in a particle
- **SumXX, SumYY, SumXY**—Sum of x coordinates squared, sum of y coordinates squared, and sum of xy coordinates for each pixel in a particle
- **Corrected Projection X**—Sum of the horizontal segments that do not superimpose any other horizontal segment
- **Corrected Projection Y**—Sum of the vertical segments that do not superimpose any other horizontal segment

In-Depth Discussion

Definitions of Primary Measurements

A	Area
p	Perimeter
Left	Leftmost point
Top	Topmost point
Right	Rightmost point
Bottom	Bottommost point

P_x Projection onto the x-axis
 P_y Projection onto the y-axis

Derived Measurements

Table 10-1 describes derived measurements in IMAQ Vision.

Table 10-1. Derived Measurements

Symbol	Derived Measurement	Primary Measurement
l	Width	Right – Left
h	Height	Bottom – Top
d	Diagonal	$\sqrt{l^2 + h^2}$
M_x	Center of Mass X	$(\Sigma x)/A$
M_y	Center of Mass Y	$(\Sigma y)/A$
I_{xx}	Inertia XX	$(\Sigma x^2) - A \times M_x^2$
I_{yy}	Inertia YY	$(\Sigma y^2) - A \times M_y^2$
I_{xy}	Inertia XY	$(\Sigma xy) - A \times M_x \times M_y$
C_x	Mean Chord X	A/P_y
C_y	Mean Chord Y	A/P_x
C	Mean Perpendicular Intercept	Area of convex hull / Max intercept
A_{2b}	Equivalent Ellipse Minor Axis	$4 \times A / (\pi S_{max})$
d°	Orientation	<p>If $I_{xx} = I_{yy}$ then $d^\circ = 45$, else $d^\circ = \frac{90}{\text{atan}(2 \times I_{xy} / (I_{xx} - I_{yy}))}$</p> <p>If $I_{xx} \geq I_{yy}$ and $I_{xy} \geq 0$, then $d^\circ = 180 - d^\circ$ If $I_{xx} \geq I_{yy}$ and $I_{xy} < 0$, then $d^\circ = -d^\circ$ If $I_{xx} < I_{yy}$ then $d^\circ = 90 - d^\circ$ If $d^\circ < 0$, then $d^\circ = 0^\circ$</p>

Table 10-1. Derived Measurements (Continued)

Symbol	Derived Measurement	Primary Measurement
E_{2a}	Ellipse Major Axis (2a)	$E_{2a} = \sqrt{\frac{p^2}{2\pi^2} + \frac{2\pi}{A}} + \sqrt{\frac{p^2}{2\pi^2} - \frac{2\pi}{A}}$
E_{2b}	Ellipse Minor Axis (2b)	$E_{2b} = \sqrt{\frac{p^2}{2\pi^2} + \frac{2\pi}{A}} - \sqrt{\frac{p^2}{2\pi^2} - \frac{2\pi}{A}}$
E_{ab}	Ellipse Ratio	E_{2a} / E_{2b}
R_c	Rectangle Big Side	$\frac{1}{4}(p + t')$ where $t' = \sqrt{p^2 - 16A}$
r_c	Rectangle Small Side	$\frac{1}{4}(p - t')$ where $t' = \sqrt{p^2 - 16A}$
R_{Rr}	Rectangle Ratio	R_c / r_c
F_e	Elongation Factor	Max intercept / C
F_c	Compactness Factor	$A / (h \times l)$
F_H	Heywood Circularity Factor	$\frac{p}{2\sqrt{\pi A}}$
F_t	Type Factor	$\frac{A^2}{4\pi\sqrt{I_{xx} \times I_{yy}}}$
R_h	Hydraulic Radius	A/p
R_d	Waddel Disk Diameter	$2\sqrt{\frac{A}{\pi}}$