Polygon Size Calculation

Polygon size determination is a critical first step in the selection of a motorized scanner. The selection of the proper polygon for a given application requires some knowledge of the system parameters. In all cases a few key parameters must be known: scan angle, beam feed angle, wavelength, and desired duty cycle.

θ - is the full extent of the active scan measured in degrees as illustrated in figure 1. This value is usually in the range of 5 to 70 degrees.

α - is the beam feed angle measured in degrees between the input beam to the polygon and the center of the scan exiting the polygon. It will be cost effective to keep this angle as small as possible in order to reduce polygon size. In certain scanner applications the beam feed angle is zero. The beam is brought in through a beamsplitter in the center of scan or at a slight angle relative to the exiting scanned beam.

λ - is the wavelength expressed in microns and will be used in the calculation of the beam size on the polygon with a known desired spot size in the scan plane.

C - is the duty cycle which is the ratio of active scan time to total time. Duty cycles in the range of 40 to 80 percent are common. However, the greater the duty cycle, the larger and more costly the polygon. With all conventional polygonal systems with the exception of drum scanners some portion of the time will be spent transitioning from one facet to the next. We will assume that the design being considered is under filled. This means that only one facet is being used to scan the image plane at any given time. Overfilled designs allow more than one facet to be actively scanning the image or allow for extremely high duty cycles because the time crossing from one facet to the next is not lost. This design approach results in a loss of optical efficiency, variations in scan plane power and scatter from the facet tips.

Calculate Number of Facets

The number of facets to be used is a tradeoff that now needs to be addressed. The formula for the number of facets is given by:

$$n = 720C / \theta$$

where θ is the active optical scan angle and C is the duty cycle

If this equation produces a non integer answer this means that there is no exact solution to provide the duty cycle desired at the same time as the optical scan angle requirement is satisfied. A next logical step is to fix the number of facets to an integer value near the result from the previous calculation and fix either the scan angle or the duty cycle and solve for the remaining variable.

$$C = n\theta / 720$$

Calculate the Beam Diameter Incident to the Facet

The following figures 1 and 2 illustrate two common design layouts. One with a scan lens and one without. The equations used to size the polygon depend on which design approach is used.

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The following two formulas work regardless of the use of a scan lens:

$$D(mm) = .00127(\lambda)/(\beta(.017453))$$

where β is the angular resolution in degrees which is defined as the full optical angle of active scan divided by the number of resolvable points and λ is the wavelength in microns.

$$D(mm) = .00127(\lambda)(N)/(\theta(.017453))$$

where N is the number of resolvable points
and λ is the wavelength in microns
and θ is the optical scan angle in degrees

Recall that N = scan length / d if N is not provided directly

The polygon can be sized without a scan lens by using the following formula:

$$D(mm) = 1.270(\lambda)T/ (d)$$

where T is the distance from the polygon to the scan plane in mm and d is the 1/e2 beam diameter in the scan plane in microns

If a scan lens has been selected then you can use the following formula:

$$D(mm) = 1.270(\lambda)(F)/d$$

where F is the focal length of the scan lens in mm
and λ is the wavelength in microns
and d is the 1/e2 beam diameter in the scan plane in microns

One final design decision that is required before continuing the sizing is the amount of intensity variation during the scan that is allowable. The calculations assume a TEM00 gaussian beam that is truncated at either the 1/e2 or 1.5 x 1/e2 diameter. If the polygon is sized for a beam that is not truncated then using the 1/e2 diameter for D in the calculations will result in a 6.25% intensity drop off at the beginning and end of scan. If the polygon is sized for a 1.5x1/e2 diameter truncated beam then the intensity drop off will be approximately 0.5%.

Calculate the Beam Footprint on the Facet

The value D' now needs to be determined. This is the projected footprint on the polygon facet. It takes into account the truncation diameter and the cosine growth of the beam on the facet due to the beam feed angle. The formula for calculating the beam footprint is:

$$D' = 1.5D/\cos(\alpha/2)$$

This equation assumes nearly perfect intensity across the scan. If more drop off is allowed the 1.5 value can be lowered or eliminated completely.

Calculate the Length of the Facet

The length of the facet can be determined from the beam footprint using the following:

$$L(mm) = (D'+1)/(1-C)$$

The value of 1mm in the numerator has been added to allow for facet 'roll off' at the edges.

Calculate the Polygon Diameter

The polygon diameter can now be calculated as follows:

$$Diam_{inscribed} = L / (\tan(180/n))$$

This result is the inscribed polygon diameter in mm.

If the polygon diameter is too large then you have three options. The first is to reduce the duty cycle and suffer a higher speed and data burst rate. The second is to reduce the beam feed angle. The third is to allow more intensity variation across the scan by reducing the 1.5 multiplier which will reduce the facet length. After any of these changes go back and recalculate the polygon diameter and see if you have achieved your desired diameter.

Determine Polygon Thickness

The thickness of the polygon is not critical in most applications. If you are using an optical design that produces a line focus on the facet then the facet thickness is determined by what our housings can accommodate and staying below a 12:1 diameter to thickness ratio. If the design has a round beam incident to the facet then the minimum facet thickness is the beam diameter plus .120 inches for facet 'roll off' plus any alignment tolerance required. In most cases if you can minimize the polygon thickness the cost will be lower.

If you have any questions regarding this calculation please consult with our Applications Engineers.

EXAMPLE 1

Given:

θ = 60 degrees
α = 45 degrees
λ = 633nm
duty cycle = 70 percent

Additional info:

desired spot size = 20 microns
scan length = 250 mm

Calculation:

n = 720(.7)/60
= 8.4

set n to 8 facets, let the duty cycle vary slightly

C = 8(60)/720
= .6666667

N = 250mm/20microns
= 250/.02
= 12,500 points

D = .00127(.633)(12,500)/(60(.017453))
= 9.596mm

D' = 1.5(9.596)/cos(45/2)
= 15.5799mm

L = (15.5799 + 1) / (1 - .666667)
= 49.7397mm

$Diam_{insc}$ = 49.7397 / Tan(180/8)
= 120.08mm

EXAMPLE 2

Given:

no scan lens
3mm collimated output beam
θ = 15 degrees α = 90 degrees
C = 55%
λ = 820nm

Calculation:

n = 720(.55) / 15

= 26.4

choose n = 26 facets, let duty cycle vary slightly

C = 26(15) / 720

= .542 D = 3mm

D' = 1.5(3) / cos(90/2)

= 6.364mm

L = (6.364 + 1) / (1 - .542)

= 16.07mm

$Diam_{insc}$ = 16.07 / Tan(180/26)

= 132.35mm

EXAMPLE 3

Given:
θ = 60 degrees
d = 42 microns
α = 40 degrees
C = 75% λ = 635nm
Scan lens with F = 300mm

Calculation:

n = 720(.75) / 50

= 10.8

choose 10 facets and allow duty cycle to vary slightly

C = 10(50) / 720 = .694

D = 1.270 (.635)(300) / 42

= 5.7603mm

D' = 1.5(5.7603) / cos(40/2)

= 9.1949mm

L = (9.1949 + 1) / (1 - .694)

= 33.323mm

$Diam_{insc}$ = 33.323 / Tan(180/10)

= 102.558mm

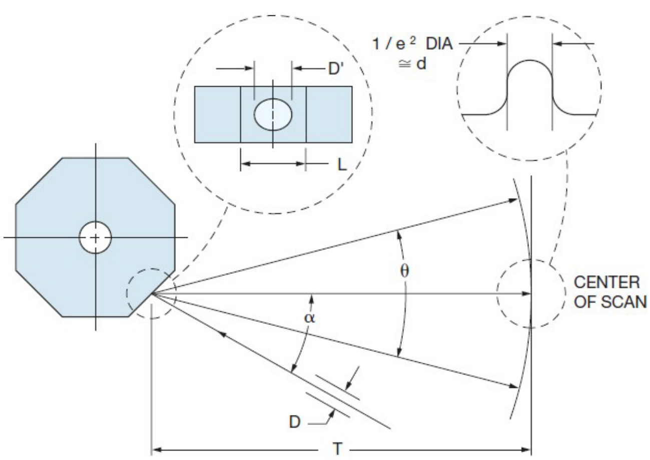

FIGURE 1: SCAN SYSTEM WITHOUT SCAN LENS

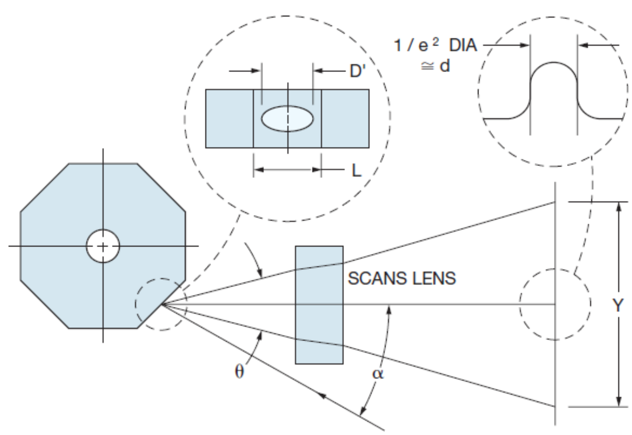

FIGURE 2: SCAN SYSTEM WITH SCAN LENS