Understanding Roll Length

The Calculation

For many persons in flexible packaging, the length of film on a roll seems a mystery to calculate; many people fear the calculation is sophisticated, possibly even requiring differential or integral calculus. While determining the length of film on a roll of film or lamination can be complicated, the arithmetic is relatively simple. Most of us can remember the formula for the area of a circle and the formula for the area for a rectangle; if you know these you can calculate the length of film or lamination on a roll.

Area of a circle = $\pi * r^2$ Area of a rectangle = $l * w$

Where "π" is pi and equals 3.14159…, "r" is the radius of the circle, "l" is the length of the rectangle, and "w" is the width of the rectangle (but for this purpose let's think of the width as equivalent to the film or laminate thickness).

First: calculate how much film there is by using the formula for the area of a circle. Begin by calculating the area of the circle that is defined by the outside diameter of the roll of film (DOD) . . .

Area of the Big Circle = $3.14159 * (D_{OD}/2)^2$

Then calculate the area of the circle defined by the outside diameter of the core (D_{CORE}) . . .

Area of the Small Circle = $3.14159 * (D_{CORE}/2)^2$

Since there is no film in the area occupied by the core, the "amount of film" is . . .

Area of Film = Big Circle - Small Circle

or

Area of Film = $3.14159 * [(D_{OD}/2)^2 - (D_{CORE}/2)^2]$

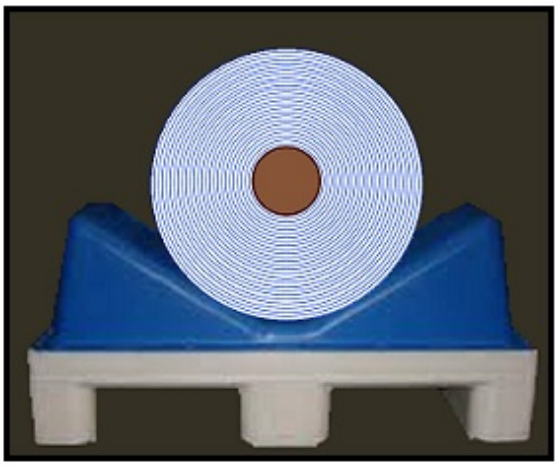

Figure 1

Second: calculate the length of film. In a roll of film, the edge of the roll looks like a very long rectangle of "film" that is continuously overlapped on top of its self as it is wound around and around and around the core. If you can visualize that the film wound on the roll is an incredibly long rectangle that is incredibly thin, then you can see how to apply the formula for the area of a rectangle to determine the length of film . . .

Length of Film = Area of Film / Film Thickness

The important thing at this point is to be sure the units for measuring the outside diameter of the roll, the outside diameter of the core, and the film thickness are the same; otherwise the calculated length will not make sense.

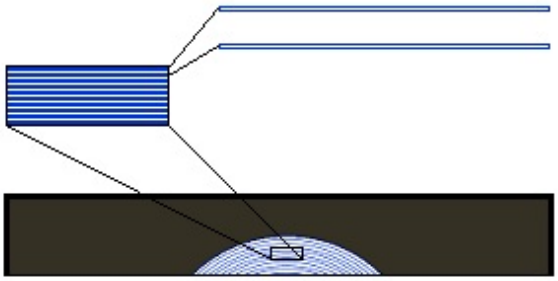

Figure 2

Example calculation:	measured	feet
Outside diameter of film roll	28 in	2.333
Outside diameter of a 6-in core	6.652 in	0.5543
Film thickness	100 ga	0.00008333

Area of the Big Circle = 3.14159 * 1.166666667² = 4.276053058 ft²

Area of the Small Circle = 3.14159 * 0.277166667² = 0.24134122 ft²

Area of Film = 4.276053058- 0.24134122 = 4.034711838 ft²

Length of Film = 4.034711838 / 0. 00008333 = 48,418.4788 ft

$$\text{Length of Film} = \frac{3.14159 * (1.166666667^2 - 0.277166667^2)}{0.00008333} = 48{,}418 \text{ ft } (0.4788 \text{ ft} < 6 \text{ in})$$

Errors?

If you tell a production person that this is the roll length, he will probably check the film length recorded by the winder that made the roll. Conclusion: what is actually on the roll will almost always be less than the calculated length using the above formula. Why?

Film thickness: The first cause for the actual roll length to be somewhat less than the calculated roll length is management of the film making process. Film makers make film to a target yield (in²/lb); moreover, they guarantee the yield. This means that the "target" thickness of a film is actually somewhat less than the nominal or published thickness.

> *Caution*: avoid the temptation to arbitrarily "adjust" the nominal film thickness down. Manufacturers have different tolerances to paying claims to customers for missing the basis weight guarantee.

Film flatness: while a major goal of film manufacturers is continuous improvement to uniform film flatness, flatness variation remains an issue that will cause the calculated roll length to be somewhat less than the measured roll length.

Note: While this variation is intermittent and infinitesimally small, the cumulative effect can be huge because any variation is compounded (additive) as layer upon layer is successively wound onto the roll. For example: if an 70 ga film is wound onto a 6-in core to a roll diameter of 28 inches, the effects of gauge variation will be multiplied by 15,250 (there are approximately that many layers of film wound on top of each other).

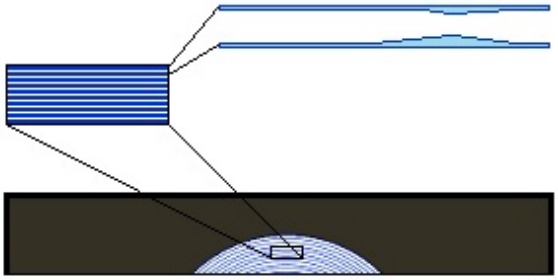

Figure 3

Hardness of the wind: No winding theory here, just the practical implications of how different film types, as well as different roll geometries, will impact how closely the calculated roll length will be to the measured roll length.

High slip (low COF) films have to be wound harder than low slip (high COF) films to avoid telescoping. Manufacturers should wind rolls as soft as possible, while still avoiding telescoping, to avoid exaggerations in poor film flatness due to thicker sections as well as to avoid roll blocking. That said, roll hardness can affect actual roll length to the positive (more) or to the negative (less). This is origin of the concept of wound-in-air: softer wound rolls will have more wound-in air than harder wound rolls.

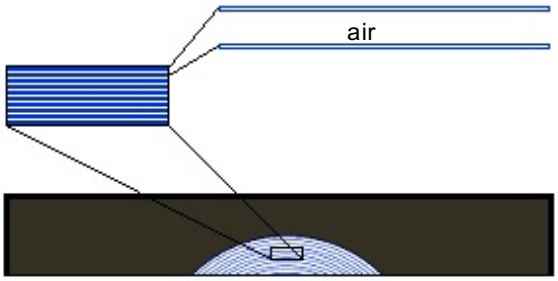

Figure 4

Voided film: Films with voided cores are much more crushable [1] than non-voided films. So, hard winding a roll of a voided film has the added consequence reducing the film's thickness thereby rendering a roll with more length than might be calculated.

What might the cumulative effect of these [2] be?

This example calculation gives a roll length of 48,418 ft. But the actual (measured) roll length will likely be closer to 46,480 ft, a not insignificant difference of almost 2000 ft!

So why bother calculating roll length if it is always wrong? If you cannot come up with an answer, then this is the end of the article for you. If being able to calculate roll length has a value to you, then there are two options:

Many years ago I took a study of a wide range of non-voided films to determine just how

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1 Another consequence of the "crushability" of voided film is the difficulty of measuring the thickness. While not impossible, it is not straight forward, extremely difficult, and not easily accomplished in a production environment.

2 i.e. film thickness, film flatness, roll hardness, and possibly voided film.

far off the measured roll length was from the calculated length using this approach. By film type the differences ranged from 1% to 7%. This is the source for selecting the default setting of 4% wound-in air I used in “MATH in Flexible Packaging” [3] (KMath); 4% will usually get the probable "error" down to less than 3% for most rolls of film.

You might want to undertake the same kind of in-house study of the different types of films and/or structures and develop the typical "wound-in air" factors to apply to the calculations you most frequently need to make. You will need to produce the following table:

	Roll Number	- - - - - - Roll Lengths - - - - - - Measured	Calculated	Percent Difference
1.	_____	_____	_____	_____
2.	_____	_____	_____	_____
3.	_____	_____	_____	_____
4.	_____	_____	_____	_____
5.	_____	_____	_____	_____
6.	_____	_____	_____	_____
7.	_____	_____	_____	_____
	Average	_____	_____	_____

Statistically, based on the multipliers in the Student’s t-distribution, the least number of rolls for this average should be 7. I recommend this be done for each film or structure type and for each slitter/winder unit in the plant.

Leighton K. Derr

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3 A software program, with more than 65 sub-programs, I sold to flexible packaging professionals world-wide from 1990 to 2011.