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Guide to Selecting the Best Winding Process

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Introduction

There is a lot of Science that goes into winding. The TNT winding principles are well established and have been proven and modeled at the Web Handling Research Center at OSU in Stillwater, OK. Yet determining which of these principles, or the proportional amount of each of these to use for proper winding of different types of materials under a specific set of conditions, is still considered an Art. This article is a guide for selecting the best type of winder to use in order to consistently produce quality, defect-free rolls of web material. We will discuss the winding principles, how they are used on different types of winders, and present product parameters that each type of Winder is best suited for.

Winding Principles

Roll hardness is developed in different ways on different types of winders but the basic principles of how to build roll hardness are always the same.
To remember these principles, just remember that to consistently wind "Dynamite Rolls" you need TNT:

T ension - The Winding Web Tension
N ip - The Nip of the Pressure Roll or Drum
T orque - From the Center Drive or Torque Drum

Web Tension Principle of Winding

When winding elastic films, web tension is the dominant principle of winding used to control roll hardness. The more tension pulled and the more stretch put on the web before winding, the harder the wound rolls will ultimately be. The winding web tension is often determined empirically. However, the maximum amount of web tension can also be determined by using 10-25% of the material's elastic limit. When only relying on tension to control roll density, it is important that the winding tension is tapered smoothly as the roll diameter increases. The tension taper should be between 0 and 50%. A tension taper of 25% at full roll is common.

Nip Principle of Winding

When winding inelastic webs, nip is the dominant principle of winding used to control roll hardness. Web tension is controlled to optimize the slitting and spreading operations. The nip controls the roll hardness by removing the boundary layer of air following the web into the winding roll. The rolling nip also induces in-wound tension into the roll. The harder the nip, the harder the winding roll will be. The challenge for winding is to have sufficient nip to remove the air and wind hard, straight rolls without winding in too much in-wound tension in order to prevent roll blocking or deformation of the web over the high caliper areas.

The important considerations in applying the nip principle of winding are:

- The nip must be applied where the web enters the winding roll.
- The winding film's weight and the lay-on roll's weight, as well as web tension, should not affect the nip loading.
- The nip pressure should be tapered as the roll winds to prevent "starring" and "telescoping".
- The larger the winding roll's diameter, the more air is introduced to the nip. Also, as the roll builds in diameter, the "footprint" area between the pressure roll and the winding roll becomes larger.
  These produce a tapered nip pressure with a constant nip loading.
- On wide and fast applications, the nip loading may have to be increased as the diameter builds to prevent the hydraulic pressure of the air following the web and winding roll from opening the nip.

Torque Principle of Winding

Torque winding is the force induced through the center of the winding roll which is transmitted through the web layers & tightens the inner wraps. This torque is used to produce the web tension when center winding. Therefore, "tension" and "torque" are the same winding principle. However, when the pressure roll is driven to control the web's tension, then the torque induced through the center of the roll can be independently controlled to control the winding roll's hardness profile.

Winding of film is often referred to as an "Art". This is because the setting and programming of the **T**ension, **N**ip and **T**orque will vary depending on:

- The type and design of the winder
- The type of web material being wound
  - Thick / Thin
  - Extensible / Non-Extensible
  - Slippery / Sticky
- The width of the rolls being wound
- The speed of the winding operation

Winding Process

There are three basic winding processes used for winding of webs materials. These are center winding, surface winding and combination center-surface winding. Each process uses one or more of the TNT winding principles to build roll hardness.

Center Winding

A center winder could be a gap winder where only **T**ension is used to control the roll's hardness. A center winder could also incorporate a lay-on or pressure roll. This winder would use both **T**ension and **N**ip to control the roll's hardness. With a center winding process, the spindle torque through the center of the roll provides the web tension.

Photo #1 - Center Winder with Pressure Roll Nip Control

An advantage of center winding is that this process can wind softer rolls. This type of turret winder can provide quick indexing and fast cycle times. The disadvantage of center winding is the limitation of maximum roll diameter due to the torque applied through the layers of slippery webs. In addition, center winders have a higher probability of generating scrap during roll changes.

Turret center winders are:

- Best for winding soft rolls (i.e. webs with gauge bands)
- Best for winding film with high tack
- Best for winding small diameter rolls
- Easily designed for dual direction winding
- Able to provide adhesiveless transfers

Surface Winding

When surface winding elastic materials, web tension is the dominant winding principle. When surface winding inelastic materials, nip is the dominant winding principle. Surface type film winders use a driven winding drum. The winding rolls are loaded against the drum and are surface wound.

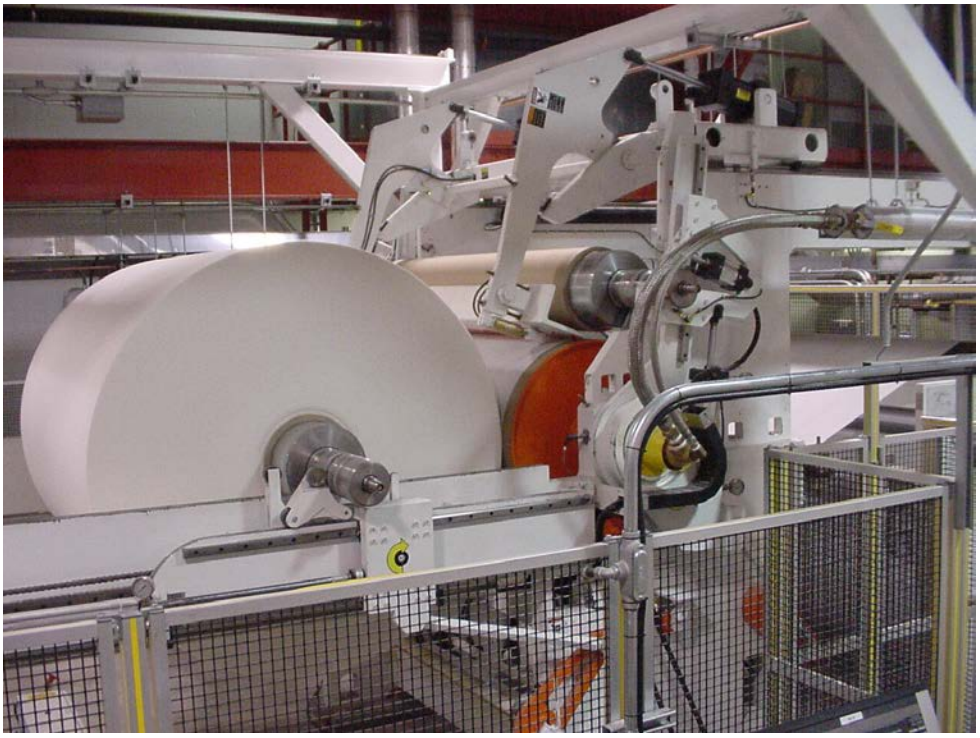

Photo #2 - Surface Winder with Stationary Knife Transfer System

The advantage of surface winding is that the web tension is not supplied from torque being applied through the layers of film wrapped into the roll. The disadvantage of surface winding is that air cannot be wound into the roll to minimize gauge bands and roll blocking problems.

Drum Surface Winders are:

- Best for winding hard rolls (i.e. protective films)
- Best utilization of space and horsepower
- Best for winding very large diameter rolls
- Best for minimizing waste during transfers
- Single & smaller winding drive

Center-Surface Winding

A center-surface winder uses both center winding and surface winding processes. (See Figure #1) Center-surface winding uses all three of the **T.N.T.** winding principles. The web **T**ension is controlled by the surface drive connected to the lay-on or pressure roll to optimize the slitting and web spreading processes. The feedback from the tension load cells trims this drive to control constant web tension. The lay-on roll loading applied to the winding roll controls the **N**ip. The **T**orque from the center drive is programmed to produce the desired in-wound tension for the roll hardness profile desired.

The advantage of center-surface winding is that the winding tension can be independently controlled from the web tension. For high tension applications, center-surface winders can share the tension horsepower requirements to allow small center drives. The disadvantage of center-surface winding is that the winding equipment is more expensive and more complex to operate.

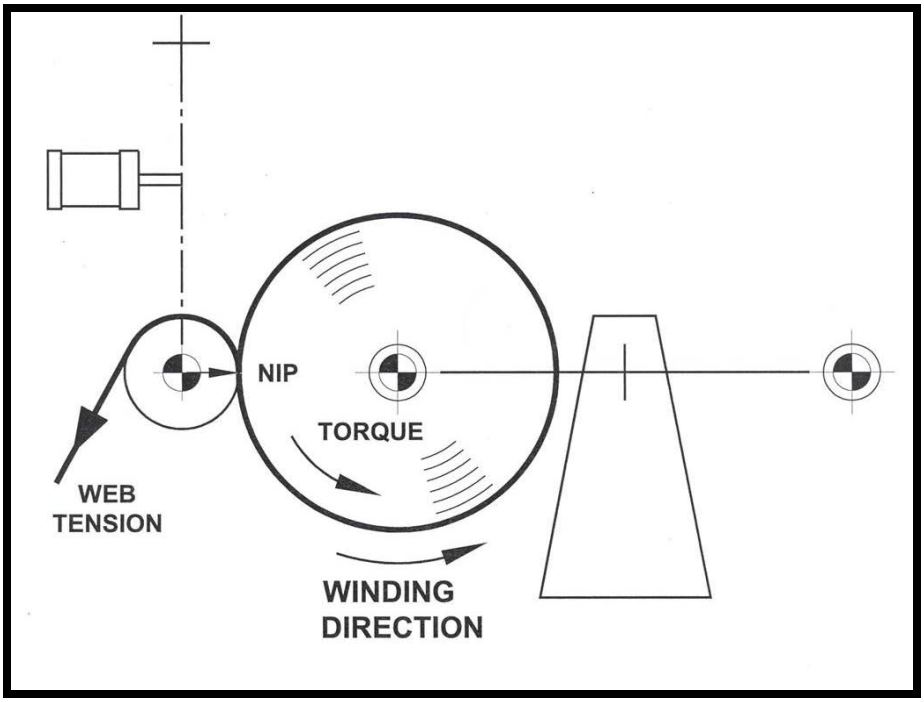

Figure 1: Tension-Nip-Torque Principles on a Center-Surface Turret Winder

Center-Surface Winders are:

- Best for winding high slip films to larger diameters
- Best for slitting and winding extensible films to larger diameters
- Best for ability to significantly taper in-wound tension without affecting the width of the film
- Able to supply in-wound tension without stretching the web over caliper bands

The suggested winding processes for different general material characteristic are summarized in the table below.

Suggested Winding Process

1 – Center Winding Process with Lay-on Roller in Gap or Contact Mode

2 – Surface Winding Process

3 – Combination Center / Surface Winding Process

Material Characteristics	Suggested Winding Process
Thin Webs processed at High Speeds	1 Contact Mode
Thin Non-Extensible Webs - Small Dia.	1 Gap or Contact Mode
High Coefficient “sticky” Materials	1 Gap Mode
Extensible “stretchy” Webs - Small Dia.	1 Gap or Contact Mode
Extensible “stretchy” Webs - Large Dia.	2, 3
Thick Webs wound to Large Diameters	2, 3
Inline Slitting of Multiple Webs	2, 3
Thin Non-Extensible Webs - Large Dia.	3
Low Coefficient “slippery” Materials	3

Conclusion

Selecting the type of winding process for the materials to be produced on web processing line is extremely important for consistently production of high quality rolls wound without defects. This paper presented some guidelines to assist in the selection of the winding process best suited for the material characteristics and the requirements for the wound rolls. These are just guidelines but hopefully, with the understanding of the winding principles and how they are used on the difference classes of winders, you can select the best type of winder to consistently produce high quality, defect rolls of your high value added products.

BIOGRAPHY OF R. DUANE SMITH

R. Duane Smith is Process Manager of Web Handling and Specialty Winding at Davis-Standard LLC. Duane is widely known throughout the Paper, Film and Nonwoven Industries for his technical knowledge on web handling and winding with over 43 years of experience working in this area.
He has two patents in the winding area. Duane has made over 85 technical presentations and published over 30 articles in major international trade journals and magazines. He has been an instructor at 18 TAPPI short courses and has published three books through TAPPI Press. He is the editor of TAPPI Press' first e-book, *The Ultimate Roll and Web Defect Troubleshooting Guide*.
Duane is the author of the winding chapter of the TAPPI Film Extrusion Manual and the author of the Unwinding and Splicing chapter and co-author of the winding chapter of the TAPPI Extrusion Manual. Duane has been honored by the TAPPI Board of Directors naming him a TAPPI Fellow and by the Society of Plastic Engineers by awarding him the SPE Certificate of Recognition for his "Significant Contributions made to the Society and the Plastic Industry. He can be reached at dsmith@davis-standard.com