Drive Power Requirement for Winder & Reel Section of Finishing House

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ABSTRACT

The power requirement of winder drives depends on many variables such as type of winder, critical speed of roll, deflection of roll, running time of winder, dimensions of the winder rolls, tension and speed of web and basis weight of paper. In this present paper an algorithm is developed taking into account of all the above parameters. This will provide an efficient tool to estimate the different output winders parameters to practicing engineer on shop floor. The algorithm can be used fully or partially depending on one's individual needs. The case studies of an Indian mill and mill operating abroad have been shown to facilitate the use of the algorithm derived.

INTRODUCTION

Papermaking is a continuous process and involves many processes and physical operations. The final step in manufacturing operations of saleable grade paper which is to be marketed for customer requirements is usually termed as "Finishing and Converting". This is located at the end of paper machine calendar. It consists of the operations like reeling, slitting and winding the paper to the roll or reel specified by the customers. For higher efficiencies, it is necessary that production cost should be minimized. A significant percentage of cost of producing pulp and paper is associated with the cost of electrical energy

Thus proper selection of winder drive, motors, and power control equipments is very necessary. The motors both squirrel cage A.C and D.C are basically used for the drive of machine and winders, though A.C motors are more widely used than D.C motors. Hence much attention is focused on premium efficiency designs of electrical equipment such as A.C. motors. There are two methods to estimate power consumption: Unit constant method and component value method. The traditional "Unit Constant" method uses a single constant or group of constants to represent a typical section. The component value method of determining the drive constants is far more accurate than the traditional unit constant method. This method sums the power value of each component in the section to determine the total power required.

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For the development of drive train, the basic consideration is the connection between the motor and the unwind or rewind mandrel drive system i.e. whether to use direct connection or to use gear system.

The gear reduction between the motor and load offers two benefits.

1. The speed reducer represents rather a cost effective torque multiplier between the motor and load.

2. A gear reducer lowers the load inertia checked at the motor shaft.

Both of these factors can be helpful to the designer when the particular system is being configured.

The choice of high performance or normal performance drive system depends on overall understanding of the performance. The high performance drives can be defined as those whose bandwidth exceeds approximately 30Hzs. Today these high performance packages can be either DC or AC power converters. DC high performance drives are configured around a pulse width modulated chopper, while high performance AC systems can either be brushless type servo or the controlled vector pulse width modulated AC drive. Once a determination for the need for high performance has been established the choice between AC or DC can be made based on the factors such as motor size, its complexity and acceptance of commutators and brushes.

To configure a drive system consistent with a mechanical design, a review and definition of some items should be utilized. These are direct coupled or gear- in- shaft design, load inertia, friction load, minimum and maximum diameters, roll weights, minimum and maximum operating speeds, splice sequence, tension ranges and material characteristics associated with thickness, modulus of elasticity and width variations.

POWER REQUIREMENTS FOR WINDER DRIVES

Winder is an important section in web processing and it is usually the quality of the design of this section that determines the quality of the rolls being generated by the overall machine and the ease with which they may be further processed. Winders can be basically classed in two types: (i) Surface winders and (ii) Center winders. The basic difference between them is that a winding force (drive) is applied to the surface of the winding roll of a surface winder and to the center core of the winder of the center winder. To provide constant tension in the web a surface winder drive must impart constant torque to the surface of the web at whatever line speed the machine is operating and this is accomplished by designing a current regulated drive system which develops approximately constant torque.

Surface winders can be employed wherever driving against the face of the winding roll does not harm the material. This type of winder is usually used on large, high-speed machines or on some low speed heavy web processing machines. Since tension in the web is being constant and the speed of the web is also constant the product of these two

Table 1

Reel power requirements Current and past TAPPI recommendations

Basis weight (gsm)	1969 TIS		1967 TIS		1965 & 1958 TIS 1963 TIS	
	NRL	RDC	NRL	RDC	NRL	RDC
Upto 203.6	0.008	0.0138 0.526 kN/m	0.008	0.012 0.562kN/m	0.008	0.012 0.562kN/m
Above 203.6 except kraft	0.008	0.0230 0.877 kN/m	0.008	0.020 0.877 kN/m	0.008	0.020 1.05kN/m
Kraft paper	0.008	0.0230 0.877kN/m	0.008	0.020 0.877kN/m	0.0008	0.020 1.05kN/m
Kraft board	0.008	0.0345 1.578kN/m	0.0008	0.030 1.578kN/m	—	—

Note: Multiply HP/inch @ 100 fpm by 0.09634 to obtain kW/m @ 1m/min.

constant values the work being done on the web to impart the tension, which is also constant. The work and horsepower can be calculated as under:

Work (m-kg/min) = Tension (kg.) × line speed (mpm)

Hence the winding kW requirement can be given by:

kW = Tension (kg) x line speed (mpm) x 0.00981

The size of winding motor is determined by two factors

1. The web horse power requirements and

2. The full roll to empty core ratio

The total winder power requirement (neglecting friction and other losses) can be expressed as:

Winder, KW=[Tension (kg) x web speed (mpm) x full roll diameter(m) x 0.00981]/Empty core diameter(m)]

The sizing of electrical drive equipment for a winder drive requires two basic considerations. Equipment ratings required for continuous operation at production speed and equipment ratings required for satisfactory acceleration and deceleration performances.

The recommendations for reel power requirements as given by TAPPI in TIS published at different years are given in the Table I

WHAT TENSION IS REQUIRED?

How much tension is required to wind the roll is very important as it directly correlates with motor power and roll built up. In general, the more elastic a material, the less winding tension is required to produce a satisfactory roll. The heavier the paper, higher the tension required pulling the sheet into the flat uniform surface that will produce a good roll. The amount of air trapped between the successive layers of paper determines how soft a roll will be. There are two obvious ways of reducing the air cushion

(a) Stretch the material into a flat uniform surface and press out the air cushion

(b) Use an ironing roll that presses the air out just as the material is laid on the roll.

As such the surface winders always provide an ironing nip resulting in hard rolls. On the other hand a pure center wind produces roll as soft as desired.

The factors governing the tension requirements vary from one process to another. The thumb rules to determine the maximum tension required to wind normal rolls are as under:
For the ream of 500 sheets of most commonly used size of 0.6 x 0.9, which represents a total area of 278.7 m^2 of paper (500 x 0.6m x0.9m), rule of thumb have been drive as normal required winding tension will usually not exceed basis weight divided by 20, expressed in lbs./inch of width.

Tension (kN/m) = 0.08 x Basis weight (gsm)

In other words, 13.3 kg basis weight newsprint will normally be wound with a maximum tension of about 26.7 kg/m of width. Similarly a 36.2 kg Kraft paper will usually be wound with approximately 71.3 kg/m maximum tension

DEVELOPMENT OF ALGORITHM FOR WINDER POWER REQUIREMENT

The step-by-step calculations can be written as follows

Step I.Calculate the critical speed of a roll
Critical speed $= 4.12 \times 10^6 \times (R_0/L^2)(R_o^2 + R_1^2)^{1/2} = (55.37\, D_o (0.9))/d_o^{1/2}$

Step II. Find out the deflection of a roll
$Dq = WF^3 (12B - 7F)/384EI$

Step III. Calculate the Torque
Torque = Force ×Radius

Step IV. Calculate Horsepower
Winding kW = T (kg) x max. speed (mpm)/ 6119.8 kg. mpm/kW
Tension (kg) = 0.45 kg/m x W (m)

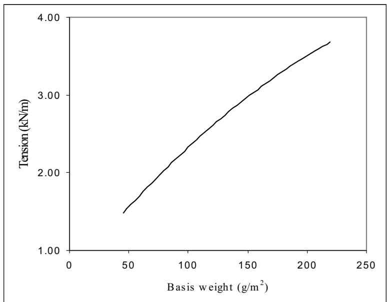
Step V. Calculate inertia WR^2 (kg-m^2) of the roll
$WR^2 = 0.000682\,(W)(L)(D_0^4 - D_1^4)$

Step VI. Calculate tension T,

Kraft paper:

$T = (0.3 \times BW)^{0.60}$,

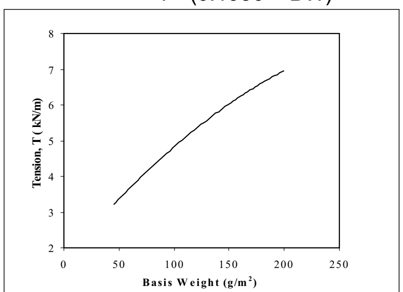
where, BW = Basis weight in g/m^2



Effect of basis weight on tension

For Light Weighed Coated, bond, tablets, CRS and similar grade:

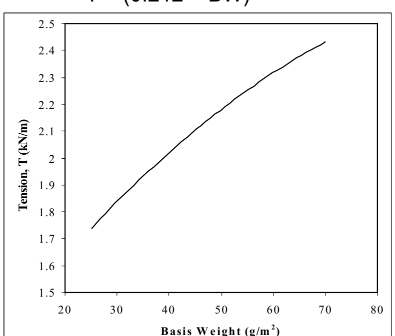
$T = (0.1956 \times BW)^{0.53}$



Effect of basis weigth on tension

For Newsprint, groundwood and directory grade:

$T = (0.212 \times BW)^{0.33}$



Effect of basis weight on tension

which is dependent on sheet basis weight and grade. It can be calculated as follows-

where, BW = Basis weight in g/m^{2}For

Kraft paper:

$T = (0.3 \times BW)^{0.60}$,

where, BW = Basis weight in g/m^2

The recommended RDC/NRL ratio is 1.25. Typically 150% torque, 60 s drives are applied a part roll, a 200% torque may be required.

Step VII. Calculate the winder running time from the following equation

$$\text{Run time} = \frac{19.78 \times (\text{density of paper}) \times (\text{Min. reel dia.})^2}{(\text{Speed mpm}) \times (\text{Max. basis weight})} - \frac{\text{acc. time + dec. time}}{2}$$

Acceleration time to max. speed = 60 sec

Deceleration time = 60 sec

Application with acceleration/deceler - -ation times in excess of 60 seconds may require the derating of the standard 60-second rating. i.e. derating on electric drive systems for constant I^2t value

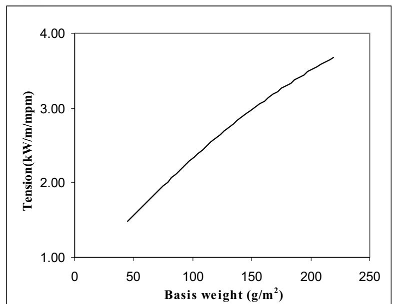
$$T_{pu} = [(I^2_{pu} \times 60)/t_a]^{1/2}$$

$$\text{or,} T_{pu} = 15.49\,(t_a)^{-0.5}$$

Step VIII. Calculate the maximum tension depending upon the type of paper and basis weight.

For Kraft paper:

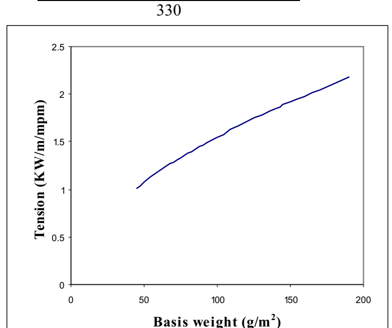
$$T = \frac{0.09634\,(0.340 \times \text{Basis weight})^{0.59}}{330} \text{ kW/m/1mpm}$$



Effect of basis weight on tension

For coated boards, bonds etc.

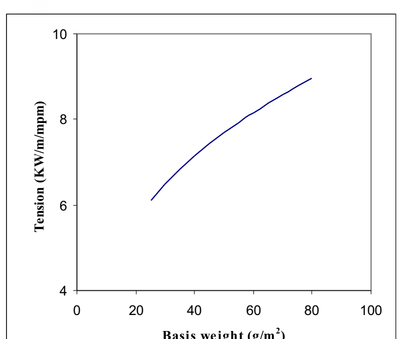
$$T = \frac{0.09634(0.375 \times \text{Basis weight})^{0.33}}{330} \text{ kW/m/1mpm}$$



Effect of basis weight on tension

For mechanical grade,

$$T = \frac{0.09634(0.234 \times \text{Basis weight})^{0.53}}{330} \text{ kW/m/1mpm}$$



Effect of basis weight on tension

Step IX. Calculate drive horsepower

P (kW) = Tension (KW/m/1mpm) × Trim width (m) × Max. speed (mpm)

Step X. Calculate the stored energy in the steel roll

$$\text{Stored energy (kW.sec/m)} = 1.659 \times 10^{-09} \times d \;\; \delta \times \frac{D_0^4 - D_i^4}{D_0^2} \times (\text{mpm})^2$$

where, d = density of steel = 6360 kg/m^3

D_0 = outside diameter of roll (m)

D_i = Inside diameter of roll (m)

Step XI. Calculate the stored energy in the roll of paper

$$\text{Stored energy (kW.sec/m)} = 1.659 \times 10^{-09} \times d \times \frac{D_0^4 - D_i^4}{D_0^2} \times (\text{mpm})^2$$

where, d = density of steel = kg/m^3

D_0 = outside diameter of roll (m) \

D_i = Inside diameter of roll (m)

IMPORTANCE OF ALGORITHM DEVELOPED IN ENERGY CONSERVATION AT WINDER SECTION

The algorithm developed above is a very useful tool for shop floor practicing engineers. The algorithm can be used fully or partially in calculating the various winder parameters which is otherwise not possible to measure in real practices. It establishes the relationship between power required by winder drive with other parameters like web tension, speed of web, basis weight of paper, acceleration/deacceleration time etc. It helps in finding out the variation in energy consumption at winder section with change in paper grade, basis weight of paper, web tension, jumbo roll condition etc, thus routing the way for energy conservation measure at winder section (e.g. installation of variable speed drive at winder drives).

CASE STUDY

The above algorithm is now applied for the cases as given in Table II to compare the drive power requirement for reel and winder in finishing house and has been under taken for both Indian and foreign mills. The results are given in Table III.

CONCLUSION

The gear reduction method is still preferable to direct coupling method. Regarding drive selection, both AC and

Table II: Comparison between the operating parameters of winders
Winder Specifications.

Parameters	Mill abroad	Indian Mill
Web speed, m/min	2286	760
Machine balance speed, m/min	2438	800
Web tension, kg/m	54 – 178	36 – 125
Web width, m	7.165	4.8
Drum face, m	4.27	5.08
Product	Kraft	Kraft,writing/printing
Basis weight, gsm	42 –65 (Avg. 54 gsm)	120
Drum diameter, m	0.762	0.3048
Max. rewound roll dia, m	1.524	1.00
Max unwind roll dia, m	2.79	1.80
Outer steel roll diameter, m	0.381	0.304
Inner steel roll diameter, m	0.254	0.254
Normal accle/dece time, s	90	120
Max unwind E – stop time, s	35	50
Slitters	10 max	6 max
Braking generator motor, kW	260	112
Drum motors, kW	186 (each)	56
Rider roll motors, kW	5 (each)	5
% Torque	78	–
Doctor load, kg/m	35.72	35.72

Table III:Different parameters as calculated based on algorithms

Parameters	Mills abroad	Indian Mills
Power constant (K_m)	13120	4712
Web tension at reel, kg	1.34	2.19
Winder run time, s	411.39	298
Max. tension at winder kW/m @1m/min	0.00395	0.00197
Drive horse power , kW	123.5	72
Stored energy in steel roll, kW-sec/m.	6.422	0.293
Stored energy in roll of paper, kW sec/m.	87.69	4.026

DC squirrel cage motors are in use. It is necessary to configure a drive system consistent with a mechanical design to get proper function of winder. The power requirement or winder drives depends on type of winder, tension in web, speed of the web, and basis weight of paper. The motor selection for the drive is based on number of factors. The important one is amount of tension required. The algorithm developed provides an easy route to calculate the different winders parameters by a practicing engineer on shop floor. The algorithm can be used fully or partially depending on needs. The case study of an Indian mill and mill operating abroad is to facilitate the use of algorithm derived.

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