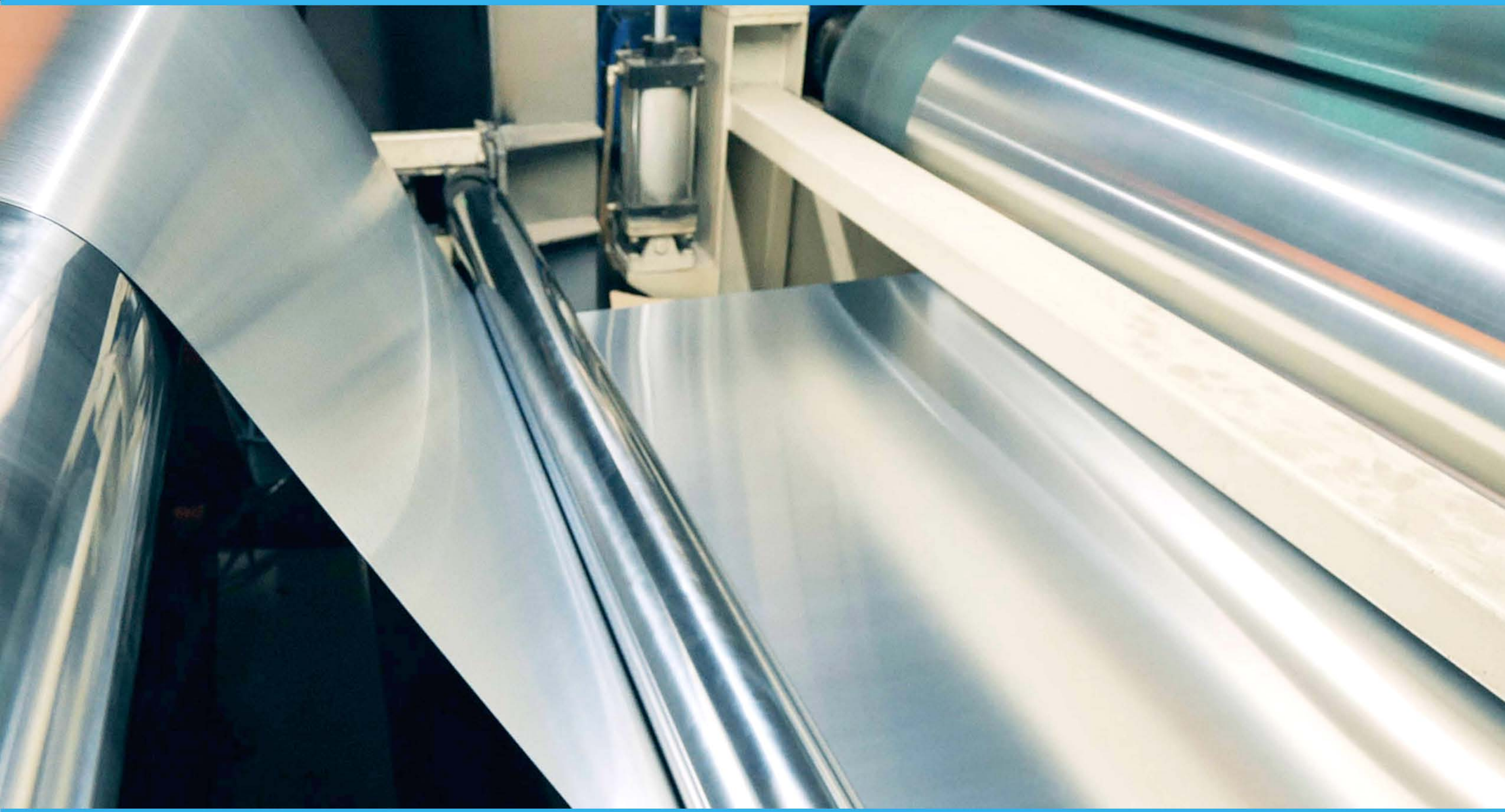
Web Handling

Testing Best Practices

Version 1.0



Created & Maintained by the Web Handling Committee
of the Association for Roll-to-Roll Converters

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Introduction

All tests useful to web handling are not assembled into a single location. When tests are described in the literature, such as those commonly found in test labs, web handling context and application are seldom mentioned. Those web-handling specific tests that are published have not been consistently described nor curated by a team of experts. This collection of web handling best practices is intended to bring together a curated group of test methods, with specific application to web handling.

Disclaimer

While this document brings together many of what the ARC Web Handling Committee deems to be important best testing practices, it is by no means a complete collection of tests that can be used in the web handling context. Additionally, no guarantees are stated or implied relative to the best practices included herein. The choice of test and the implementation thereof are the sole responsibility of the individual user of this document.

Credits

This document is created and maintained by the Web Handling Committee for the Association to Roll-to-Roll Converters (ARC). It is a living document with sections that are still under development (denoted with an asterisk). Contact us here if you would like to contribute to this work or be a part of the Web Handling Committee.

Thanks to the following contributors for offering this resource to our association and the broader converting industry:

Joe Kotwis, Steve Lange, Neal Michal, Andy Palmer, Amol Patil, David Roisum, Aravind Seshadri, Ben Tremblay and Shane VanHorn.

Means and Methodology

Each test is primarily the responsibility of a single author. As such, the *Web Handling Best Practices* function as a living monograph. The test author may be on the committee or in the community at large. The test author is to write up a proposal for a single test, then submit it to the wider committee for review during a short commentary period, and then incorporate those comments as they see fit. New tests and updates to a test will proceed similarly. If the author abandons a test, it may be picked up by another author or by the committee at large. Author and version dates are included at the top of each test.

For ease of use, tests will have a **standard format**, very much like Smith's *Roll and Web Defect Troubleshootin*g. For ease of use, the test writeups will be very brief: one page is the target, three is the maximum. When a suitable writeup exists, such as exemplified by *Web Test 101 – Basis Weight*, references may be all that are needed. When more than one option might be used, they will be grouped under the main test and numbered as exemplified by *Web Test 801 – Wound Roll Diameter* 801.1, 801.2, 801.3 etc. When too many variations might exist, only an outline of how the test might be designed and performed is given as exemplified by *Web Test 301 – Dancer Calibration* and all details would then be left to the service engineer. This overview approach rather than spelling out details will avoid difficulties for the author and user alike. This is especially true for situations where industry variation is large, such as for machine components such as dancers and nips. This is also true for certain tests like curl where some test variations, in common use in industry, are not currently detailed in the literature.

Profile and Testing

Webs are neither perfect, nor perfectly uniform. The word 'profile' is shorthand for a variation of 'x' across the width of the web where 'x' can be any measurable or observable property. Two common examples are thickness profile, a variation of thickness (see Test 102) across the web, and basis weight profile, a variation of areal basis weight (see Test 101). It is not uncommon for the edges to be thicker or thinner than the rest of the web. Instead of requiring graphs or even measurements, we can describe those profiles as 'frown' or 'smile' shaped respectively. Other common profiles include ridges, valleys, and tapers. Why this is important for any test, including those for web handling, is that you would get different values, answers if you will, depending on where on the web the sample and/or measurement was taken. More about sampling next.

Of course, properties can vary down the length, machine direction (MD), or with time as well. It is not uncommon for webs to be quite different in the first many minutes after startup. Even if quality assurance (QA) 'blesses' the material at a certain time after startup, it is still likely to have more variability over the next hour than it will later in the run. MD or time-dependent variability is often less or even far less than cross-machine direction (CD) variability. The fingerprint CD profile 'shape' of a web may be stable for hours, days or even for the life of a machine.

Concepts like where in the web a measurement is made are not trivial, especially when the product proceeds to the next machine, such as a rewinder, which may remove material at the top and bottom of a master roll as well as cut master roll into daughter rolls from different CD locations as well as possibly of different individual widths. Those who want to learn more about traceability can view a series of YouTube clips on traceability with titles beginning with Web401.21a-g. Those wanting a bit more about sampling and documentation may wish to view Appendix S in The Web Handling Handbook.

Sampling and Testing

The tester must make two choices about sampling. The first is *where* across the width, CD position, of the web the sample is taken, or the measurement is made. The second is the *number of samples* at any given CD location which is the subject of the next section. This, of course, is a judgment that needs to be made by the tester if it is not already spelled out by local testing protocols. Common sampling for QA is 3 or 5 measurements equally spaced or 7 or more measurements equally spaced on wider webs. For example, 5 samples would be at the front edge, front quarter point, middle, back quarter point and back edge. However, a choice must be made as to where the 'edge' sample is taken. Typically, it is inside the saleable width a bit, but there are cases where you might measure outside the saleable width or much further inside due to edge effects of the sensor itself. Examples of sensors affected by edge include many online scanners as well as roll hardness measurements.

Statistics

Describing statistics is, for the most part, far beyond the intent of this brief guide on testing. However, a few generalities should be mentioned regarding **how many samples are needed** to be confident in both the logical and statistical sense.

1. Always **retain individual test values** rather than compute and average and discard the original values for two reasons. First, there is information in the individual values that can't be reconstructed from the aggregate. The second reason is that data storage is super cheap. An example of poor protocol would be to sample 5 places across the width, compute the average, and discard the individual values. Questions about CD profile could not be answered without those individual values should that need ever arise.
2. **Some tests are inherently noisy.** Examples include web-web (see test 115) or web-roller (see test 206) COFs. Here it can be very difficult to tell where the variation is coming from. It could be the web material or the test itself. One can't simply take the same web sample and repeat the friction test (to check for test variation) because every time you touch the sample you may well change its surface characteristics, perhaps

noticeably. Increasing sample size will help both reduce and characterize variation, though at a cost.

3. The **number of samples required to be confident** can vary enormously, well beyond the differences individuals might have in setting confidence levels. An extreme example is that a web break during a brief acceleration period may be sufficient to say that the tension control may be brutish during that challenging portion of a minute. That is because the web presumably runs for hundreds or thousands of minutes during steady state without a web break. At the other extreme, it can take the running of as many as 10,000 wound rolls to conclude that one paper supplier provides a less break-prone material than another. [Page, D.H. and Seth, R.S. The Problem of Pressroom Runnability. Tappi J., vol 65, no 8, pp 92-95, Aug 1982]
4. Paul Frost has looked at sampling and testing and MD/CD variability in great depth with some quite statistically shocking conclusions. For example, the **sampling protocol** in some test labs is insufficient to make some of the conclusions that might be useful, such as whether one roll is better than another. Even the online scanners that take thousands of measurements per roll are not immune because those measurements are often exceedingly noisy. [The Application of Statistical Process Control to Web Products. TAPPI Polymers Conf. Proc, Sept 1989 and a self-published book by Paul Frost Associates].
5. Testing, like everything else, is subject to **economics**. The quality of the instrument and the number of samples is, at best, a judgement call that tries to balance consumer and producer risk.

Environmental Conditions and Time

While web handling tests may not always be as rigorous as those performed in a dedicated quality test lab, there are a few things to consider. 'Standard' test conditions are often specified as 20C and 50% RH. Conditioning and pre-conditioning may also be required to give time for the sample to equilibrate. TAPPI has as much or more to say about this subject as any. For example, TAPPI/ANSI 402 sp-21 defines environmental conditions for preconditioning (which is required for paper that is wetter than standard conditions), conditioning (as well as the time required) and testing. This is especially important for cellulosic materials, such as paper, because most material properties are sensitive or extremely sensitive to moisture content, thus RH and time.

There are other environmental conditions that may apply. In-situ testing may be preferred because it is the environment in which the web behavior takes place, AND because it is simpler. Behaviors taking place in hot ovens are much more challenging for testing. Finally, some material properties and thus behaviors can be noticeably time dependent. An example is that the web-web COF (see Test 115) of some films can get lower with time due to migration of slip agents. Similar behavior is seen on some paper grades for unknown reasons.

Units and Unit Conversions

Almost all test values have units. Common exceptions include COF, 'draw' and web strain, all of which are unitless. All test values should include units when written and often when spoken. For example, web speed could be measured as 500 m/min. Only if there were no ambiguity, such as when speaking informally with an operator of a European built machine, could one perhaps safely omit the units. In the US, there can be much ambiguity and inconsistency of units among machines and even on different sections of the same machine. Sometimes the displayed units are improper machine units, such as bar or psi of pressure on a dancer or nip, instead of PLI (pounds per lineal inch) or kN/m (kilo-Newtons per meter). Units can be no less confusing for test lab equipment. Often, a test instrument might not display units, and/or the units recorded may not be listed on a data recording sheet. Units should be in the machine's or instrument's instruction manual or in the original test writeup, if they can be found. If there were any doubt remaining, one could calibrate or check calibration of the instrument – a best practice for other reasons as well.

Sometimes when the units are known, they may not be in the desired form or system. An example is if you were vacationing in the US and looked at the day's weather forecast, you would likely see them displayed in degrees Fahrenheit, rather than in your familiar degrees centigrade. The conversion factor is well known and easy enough. The formula can be readily found on the internet or as a convenient internet calculator.

$$C = 5/9(F - 32)$$

Other times the conversion will not be as easy to find, and you may need to figure out the conversion factor yourself. Here is an example for converting one odd basis weight, OZY (ounces per square yard) used only in nonwovens and textiles in the US, to a more universal GSM (grams per square meter). While this can be found on the internet, we will do this here as a simple illustration.

$$\left(\frac{g}{m^2}\right) = OZY\ \left(\frac{oz}{yd^2}\right)\left(\frac{28.35g}{oz}\right)\left(\frac{yd}{0.9144\ m}\right)^2$$

The user must first find the individual conversion factors, such as 28.35 g/oz and yd/0.9144m. Then one must check to make sure all units 'cancel' except the ones that one wishes to remain, g/m^2). Finally, you can do the calculations to get conversion formula. As an extra check, you could go to a conversion utility (that may or may not always list the formula and certainly not the derivation).

g/m2 = 33.9 X OZY

The purpose of this example is not to teach unit conversion. Rather it is that if you can't readily perform this type of operation yourself, perhaps because you never learned or since forgot, then it could be risky to use *any* conversion formulas or internet calculators.

Because there are so many tests given here and so many possible conversions one might want to do between one set of units and another and in either of two directions, we will not provide them in the body of this text.

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100 – Web Material Properties

Overview

In addition to quality control, certain web material properties are useful for design and troubleshooting. Some of these tests and sample web handling applications are given below. Most of these tests are common lab tests, others are custom made for web handling.

100 Web Material Properties
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Preparation

The outer layers of the roll may not always be best for testing and thus may be removed and discarded. Sampling intervals across the width, often 3-5, should be selected. For completeness, samples should also be selected at different diameters of the roll. Documentation would include the time/date of testing, time/date of roll manufacture, web grade (SKU, part number etc) and roll ID# [101, 102]. Statistics should be considered to assess variability with respect to MD position, CD position, sampling strategy, test machine and tester.

References

101 Roisum, Walker and Jones. *The Web Handling Handbook*, Destech, 2020. Appendix S – Best Practices for Taking a Sample, pp 660-661.
102 Web401.21c -Traceability - Roll ID. AllWebHandling channel of YouTube.

101 – Basis Weight

V 2021.10.25 – DR Roisum

Overview

Basis weight is the weight per unit area of a web. It is a common commercial and quality control specification. It can also be used to troubleshoot certain web problems (such as poor profile by comparing weights across the width of a web). Be aware of units and list them explicitly for every test value. Common unit examples include gsm (grams per square meter), ozy (ounces per square yard for nonwovens and textiles) and lb/3000 ft^2 (for paper, though there are many other 'ream' sizes).

Methods

There is seldom a need to invent, innovate, or modify basis weight measurement methods because the standards listed below are well-described and well-trusted. ISO 536 / TAPPI T410 is the most common. Manual sample die cutters, in rectangular or circular shapes, that give standard basis weight areas are commercially available and are preferable to measuring with a ruler and cutting specimens by hand (or guillotine cutter). The scale used for weight measurement should be able to resolve far less than 1% of the sample weight. Weighing 10 specimens and dividing by 10 will improve resolution.

- ISO 536—TAPPI T410 Grammage of paper and paperboard (weight per unit area)
- TAPPI T545—Grammage profile measurement (gravimetric method)
- TAPPI T546—Machine direction grammage variation measurement (gravimetric method)
- TAPPI T844—Determining construction (nominal basis weight) of corrugated board
- TAPPI T1011—Fiber glass mats

102.1 – Thickness, Single Ply

V 2023.11.14– DR Roisum

Overview

Thickness is one of the most useful of the web properties for both QA and web handling. In web handling, non-dimensionalized strength (and thus recommended web and winding tensions), spring rate and other properties are nearly proportional to thickness. Thickness is also the largest factor, along with length, for determining wound roll diameters (see Test 102.3). There are many other uses.

But first we must establish an important concept. That is, there is no such thing as thickness independent of measurement technique as there are with say the speed of light or temperature, where all techniques would deliver quite similar values. That is because most techniques define thickness as the distance between a moving probe (or platen) and a stationary platen under load. Because the load and probe size vary between various methods, the pressure on the specimens varies. Thus for materials, especially low density materials such as nonwovens, textiles, and tissue, that are noticeably compressible, a test that loads at 100 will give a different value than a test that loads at 10. Even stiff materials are not immune. Bending around the probe and flatness will affect the spring rate of the material and thus affect the value slightly. See Test 102.2 for higher order effects when measuring as a stack.

Methods

Some thickness measurements are not codified by standards. Examples would be using a handheld or stationary micrometer or caliper. While cheap and convenient, these methods do not usually have anywhere near the resolution of the much pricier purpose-built lab test instruments that conform to a test standard. The most common thickness test standards are the following. Other organizations and companies either use these directly, but with their own naming designations, or are derived from them.

- *ISO 534 TAPPI T411 Paper, paperboard, and combined board*
- *TAPPI T500 Book bulk and bulking number of paper*
- *TAPPI T516 Envelope seal, seam, and window patch testing*
- *TAPPI T551 Paper and paperboard (soft platen method)*
- *TAPPI T580 Towel, tissue, napkin and facial products*
- *ISO 12625-3 Soft tissue*
- *TAPPI T1006 Testing of fiber glass mats*

102.2 – Thickness, Stack

V 2023.11.27– DR Roisum

Overview

Stack thickness can be more useful than single ply measurements and may be more desirable despite the extra work of cutting and assembling several specimens instead of one. The first reason is simply to improve test resolution by increasing sample size. However, there are more fundamental reasons for end-use products such as a book, a ream (stack of paper), box of tissue or ALL wound rolls. That is because all of these products are inherently stacks.

Stack thickness will not be the same as single ply thickness. For webs with rough surfaces, such as nonwovens, textiles and tissue, the nesting of adjacent surfaces means that the stack thickness is likely less than single ply thickness. For materials with smooth surfaces, such as film, foil and rubber, the inevitable air between the layers means that stack thickness is likely greater than single ply thickness. Note that the pressure between the layers of a stack in a lab test is unlikely to be the same as in a book or ream, which will be near zero, a box of tissue and especially wound rolls. Even so, the stack versus single ply will be an improvement in prediction of effective product thickness.

Methods

Most test lab methods, such as listed in Test 102.1, that can measure *single* ply thickness can also be adapted to measure *stack* thickness. One need only cut say 10 plies, assemble them into a stack and then use the chosen thickness measurement method and finally divide the results by 10.

An interesting method is *TAPPI T500 Book bulk which utilizes a large stack of plies under a specified pressure.*

102.3 - Average In-Roll Caliper (AIRC)

V2024.01.16 Neal Michal

Equipment/Materials Required

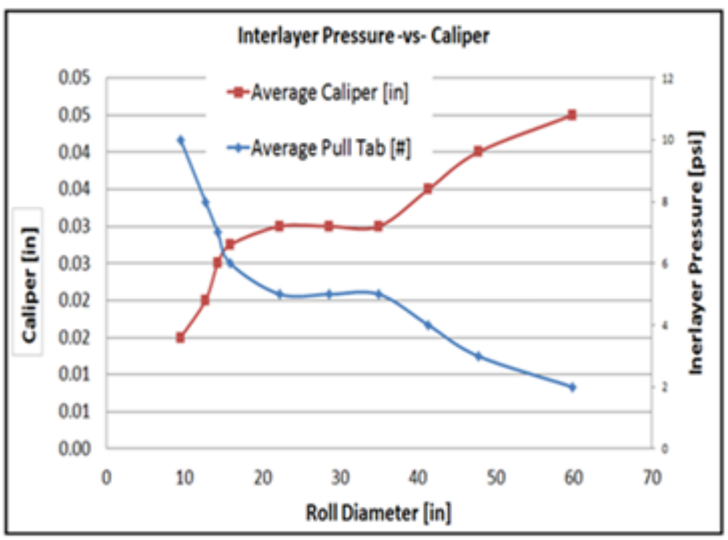
1. Pi tape or flexible tape measure
2. Wound roll

Figure 102.3.01 – Pi Tape, Flexible Tape

Discussion

The stored caliper of the web after it has been wound into a roll will vary as a function of local interlayer pressure and the compression modulus (ZD) of the web. For tissues and many high loft nonwovens, it is common to see 20% compression through the middle "plateau" and 40% or more close to the core. Loss of caliper is a serious concern for some customers.

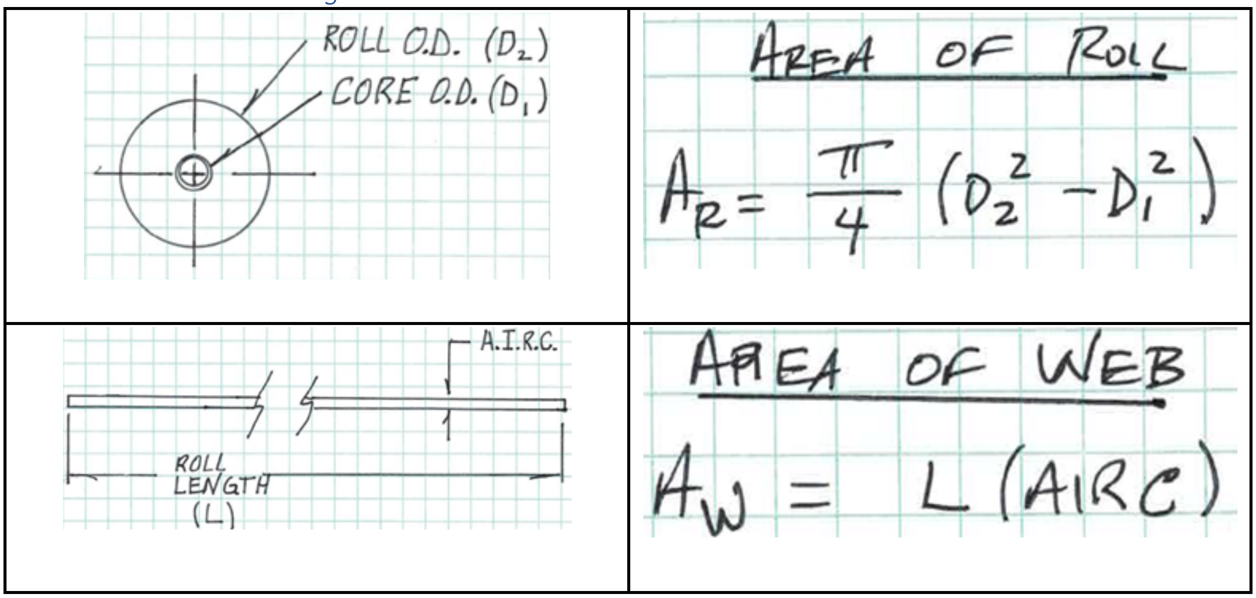
Figure 102.3.02 – Interlayer Pressure vs AIRC



One common metric to assess a wound roll that was just doffed is average in-roll caliper, "AIRC". This may be referred to as "In-Roll Effective Thickness" as well.

Calculating AIRC is simple once one understands the relationship between cross sectional areas. Calculate the cross-sectional area of the wound roll. Remember to subtract the cross-sectional area of the core OD. The cross-sectional area for the web if it was laid out end to end must be the same as the area of the wound roll.

Figure 102.3.03 – Cross-Sectional Area: Roll & Web



If you know the roll OD, core OD and the length of the web, solve for the caliper of the web. This is an average. Different more tedious tests are required to document actual caliper through roll. One will find that AIRC will be inversely proportional to Average Wound Roll Density for compressible webs.

Method

<u>Identify Target Roll</u>

- Identify roll to be documented.
- Move roll to a safe place.

<u>Measure Roll Outside Diameter</u>

- Measured roll OD using a Pi Tape.
- If using a flexible tape, measure the circumference. Divide circumference by pi to obtain diameter.
- Do not rely on roll OD info from the production system or from the winder display.

<u>Document Roll Length</u>

- Obtain the length of the wound roll.
- This is normally on the roll ticket.
- If not, look in the production data system to find the length.

<u>Calculate Average In-Roll Caliper</u>

- Pay attention to your units.
- Calculate AIRC using the following equation.

Figure 102.3.04 – AIRC Equation

$$AIRC = \frac{\pi}{4L}\left(D_2^{\,2} - D_1^{\,2}\right)$$

Sample Calculation

Roll OD	58.8”
Core OD	7.4”
Roll Length	34,000 yd = 1,224,000 in

AIRC = [Pi/(4L)]x(Roll OD^2 – Core OD^2)
AIRC = [Pi/(4*1,224,000 in)]x(58.8in^2 – 7.4in^2)
<u>AIRC = 0.002 in</u>

103 – Width

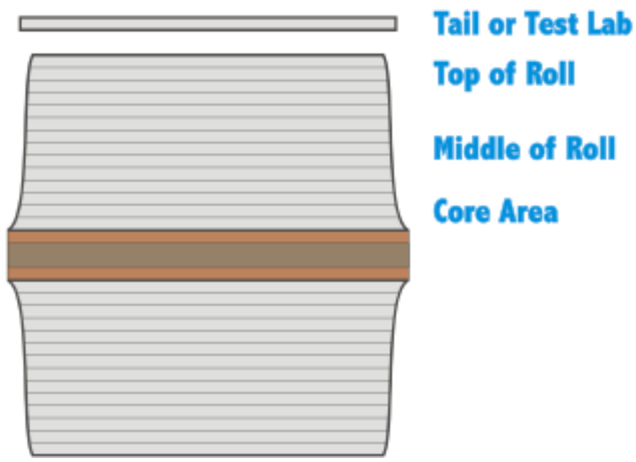
V 2023.11.27– DR Roisum

Overview

The width of a slit or unslit web is a very important commercial specification. However, as with thickness, there is no such thing as width that is independent of measurement method.

If the web is measured under tension while running in a machine, such as via edge sensors, the value will be different than when measured under no tension, such as a test lab. This is due to Poisson 'necking.' Correlating the two measurements can be done using Hooke's law if tension, thickness, modulus, and Poisson's ratio are all known. While Poisson's ratios for almost all materials are around 0.3, nonwovens and other structures can be quite different with ratios approaching 3 in some cases.

Web width inside a wound roll is even more complicated because the load case is more complicated. Instead of depending on a single value of tension (which is zero in the test lab), both MD tension and ZD compression inside a roll are radius dependent. Most materials will 'creep' such that some of that width variation will be irrecoverable even when the web is released from wound roll pressures. The figure below illustrates these roll width complications.



Methods

1. Ruler applied to the web or top of a wound roll.
2. Edge sensors for a tensioned web running through a machine
3. Optical comparator for better resolution

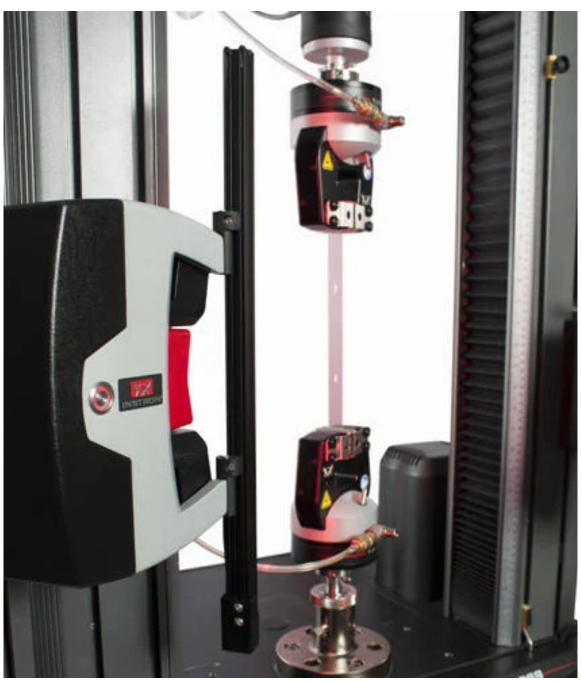
104 – MD Tensile Strength

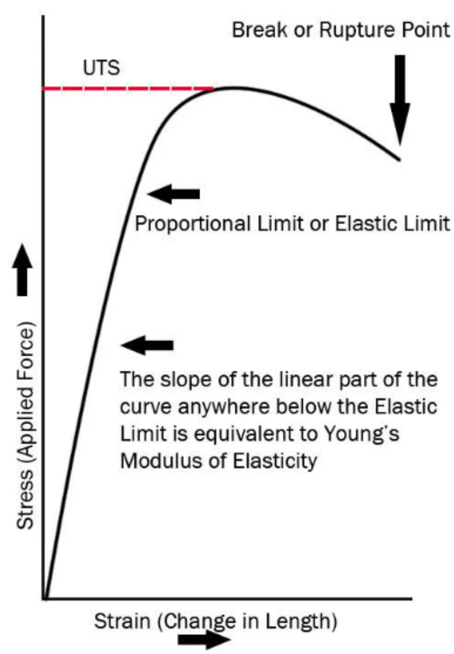
V 2023.05.03 - Benjamin Tremblay

Overview

Among several methods of obtaining the tensile strength of thin plastic films, ASTM D882 is an often-used standard for obtaining tensile strength of films under 0.010" (0.25mm) thick (and sheets under 0.040"(1mm) thick). Standard samples widths are 0.2" to 1" (5mm-25mm) wide. Gauge length (distance between the jaws on the tensile test machine) must be a minimum of 2" (50.8mm), with the sample length at least 2" (50.8mm) longer than the gauge length. Crosshead speed (the speed at which the jaws separate from each other) may vary between ½" (13mm) and 20" (500mm) per minute. The load cell used should be selected according to the nominal tensile strength of the material being tested; always use a higher-limit load cell than the nominal tensile strength of the material (e.g., use a 100 lb. load cell for a sample with a nominal tensile strength of 80 lbs., or a 500N load cell for a sample with a nominal tensile strength of 450N) Anywhere from 5-10 samples should be tested. Each of the parameters above may need to be based on the physical properties of the material being tested.

There are several tensile testing machines available on the market (Instron, Thwing-Albert, and Shimadzu among them); most of these manufacturers have background information on their websites with regards to tensile testing. Outputs of tensile testing may include tensile strength, yield strength/strain, and modulus of elasticity. Related test methods include ASTM D638 (for materials thicker than 0.040"(1mm)) and ASTM D903 (lamination strength of adhesive bonds), both of which can utilize the same equipment as used in ASTM D882 with slight component changes.





Standard Methods
Most test methods focus on the determination of strength,
the load at which some type of material failure (yield or break) occurs.

• ISO 1974 TAPPI T414 Internal tearing resistance of paper (Elmendorf-type method)
• TAPPI T456 Tensile breaking strength of water-saturated paper and paperboard
• ISO 1924/2 TAPPI T494 Tensile properties of paper and board (constant rate of elongation)
• ISO 527-3 Plastics—Determination of tensile properties—part 3: test conditions for films and sheets
• ASTM D882-10 Tensile Properties of Thin Plastic Sheeting
• TAPPI T1009 Elongation at break for fiber glass mats
• Web handling often requires knowledge of the MD Young's modulus, which requires a measurement of elongation as well as load. Methods include:
• ASTM E111—04(2010) Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
• ISO 1924-2:2008 Paper and board—Determination of tensile properties– *Part 2: Constant rate of elongation method (20 mm/min)*

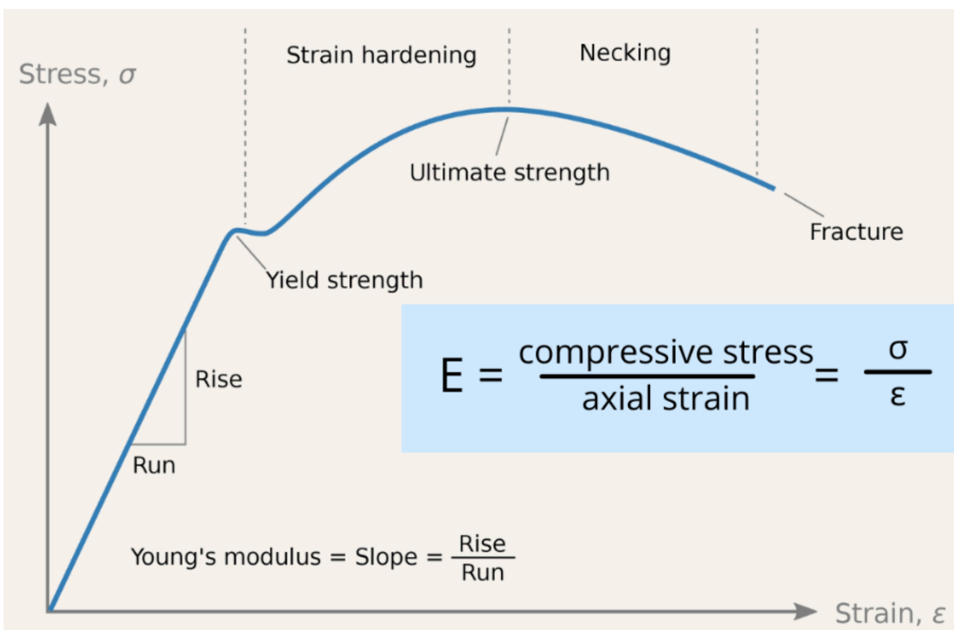
105 – MD Modulus – Industry Standards

V2023.12.26 - David Roisum

Overview

MD (Machine Direction) modulus is the stiffness of a material in the direction of web travel and tensioning. The opposite of stiffness is stretchability. MD modulus is used in many web handling models as well as all winding models. In web handling, a stiff material must usually be run in load cell or dancer tension control or torque control. A flexible material can be run in draw/speed control in addition to those modes. The range can be from rubberlike, to stiffer materials such as paper and PET film, all the way to foil metals.

Modulus, also called Young's modulus, is the local slope of the stress versus strain diagram. Note that modulus is a definition rather than a property independent of measurement method, particularly if the stress-strain curve is non-linear as it is for many materials and most structures. This is not usually an issue for web handling where materials are loaded well below yield and thus a tangent modulus at low loads is easiest to measure and serves us best. Other moduli definitions that are found in engineering include tangent modulus, chord modulus and 0.2% offset modulus (used in metals).



Modulus is often measured on the same tensile testers as is strength. In the case of modulus, the machine computer software extracts the slope from the curve instead of reporting peak load as it does with strength measurements (see Test 105 – Tensile Test). Common standards in the web industries include MD modulus tests and related flexural (bending) moduli tests. If possible, it is recommended that the raw stress-strain data be reported, so the end user of the data is able to determine the amount of nonlinearity over the range of tensions seen in running conditions.

MD Modulus Tests

ASTM E111—04(2010) Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

ISO 1924-2:2008 Paper and board—Determination of tensile properties– Part 2: Constant rate of elongation method (20 mm/min)

(Flexural) Stiffness

ISO 2493 TAPPI T495, T416 Paper and Board: Bending Resistance

TAPPI T451 Clarke Stiffness

ISO 178:2001 Plastics—Determination of Flexural Properties

ASTM D790-03 Flexural Properties of Plastics

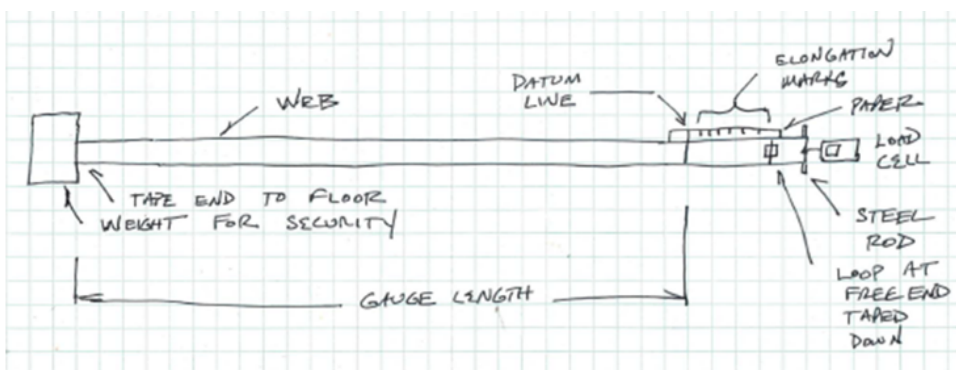
106 – MD Modulus – Using Handheld Tools

V 2022.02.23 - Neal Michal

Equipment/Materials Required

1. Long hallway with smooth surface.
2. Two people.
3. Handheld force gauge.
4. Long flexible tape measure 30m or 100ft.
5. Weight to hold down one end of the web sample. Suggest 10lb (40N) or more.
6. Steel rod – approximately ¼” (6mm) diameter
7. Masking tape.
8. Notepad, pen.
9. Fine point permanent marker.
10. Vernier calipers.

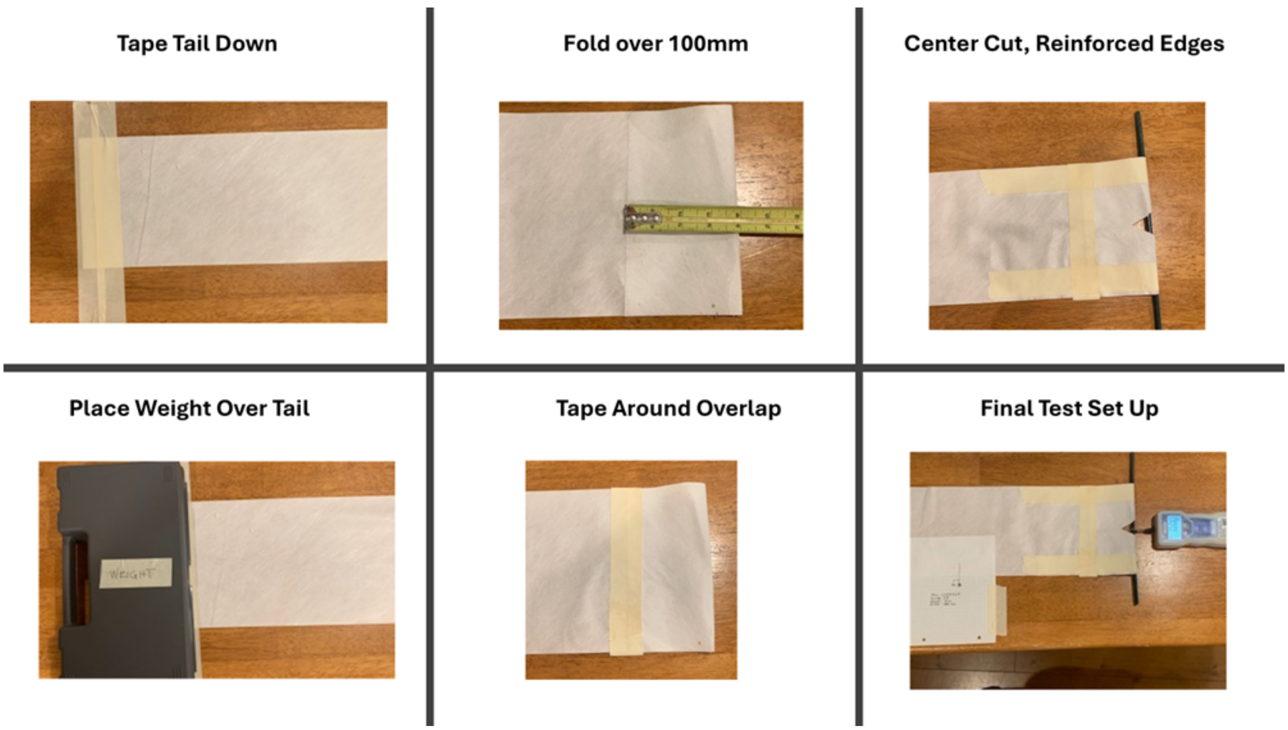
Figure 106.01 - Setup for MD Modulus Measurement



Method

<u>Prepare Sample</u>

1. Find a long hallway with a smooth floor such as polished concrete, smooth tile or linoleum.
2. Roll a 15 – 20m long web. Cut.
3. Position the web in the hallway for access to the free end
4. Tape down one end to the floor
5. Place heavy weight over the taped end to secure the fixed web.
6. Loop the free end over and attach the end to itself. Loop should be ~ 25mm.
7. Fold the web over CD. Cut a notch out of the middle.



<u>Prepare Paper for Documentation</u>

8. Layout a 1m long piece of paper. At least 4” (100mm) wide. Cut. This can be made by taping several pieces of standard size paper end to end.
9. Position the paper toward the end of the free end. Slide it under the web such that the web overlaps the paper by 20-30mm. Tape this paper into place.

<u>Prepare Web for the Test</u>

10. Pick the web up from the free end. Slowly bring it down to the floor to allow it to find its normal path.
11. Apply a small amount of force to the free end of the web to pull out any wrinkles or puckers. Slowly release the web.

Establish Gauge Length

12. Lay the flexible tape down to measure length from the taped end toward the free end.
13. Select a nominal length to set zero. Suggest whole increments of 1m each (e.g. 15, 16, 17 m).
14. Strike a line across the web and the paper.
15. Mark this line as the "Zero" point.
16. Write out details on this paper off to one side. Gage length, web ID, slit #, width, date of test, names of those who conducted the test.

Prepare Load Cell

17. Install J hook on load cell. Lay load cell down. Set Zero.
18. Place steel rod inside the free end loop
19. Attach load cell to the middle of the rod (thru the notch) with the J hook facing up.

Collect Data

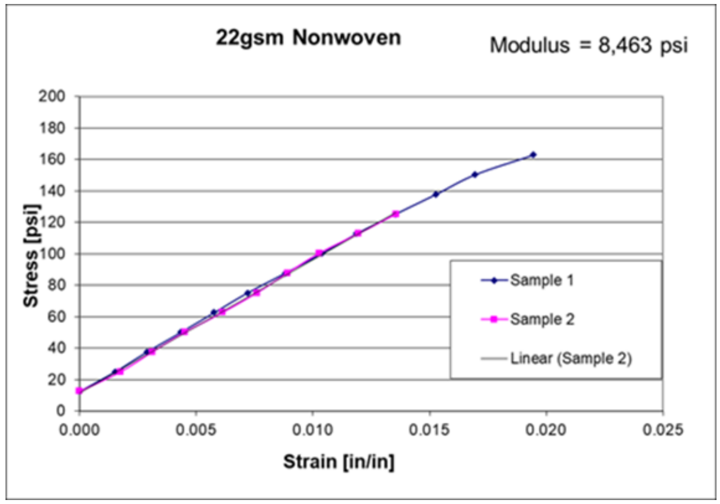
20. One person will slowly load the sample using the load cell.
21. Agree on force units (N for Si; lb for Imperial).
22. Agree on increments of force (e.g., every 1N, or 0.5 lb).
23. Agree on maximum value of force.
24. The second person will mark lines onto the paper as they follow the zero line on the web as it moves downstream. These marks will become the elongation from the gauge length.
25. It is important to use a slow extension of the web to ensure consistent results. (Note – It will take a couple of iterations to sort out your procedure.)
26. Continue pulling on the web until it breaks, slips, or the final value has been achieved.
27. Repeat Test with New Sample
28. Repeat steps 2-25 for another test.
29. Three repeats minimum are recommended. Add more if desired.

Analyze Data

30. Remove paper from the floor.
31. Lay it out on a table.
32. Measure elongation using vernier calipers.
33. Enter elongation versus load.
34. Calculate stress based on load / cross sectional area.
35. Calculate strain based on elongation / gauge length.
36. Graph stress vs strain.
37. Add linear trend line.
38. Modulus is the initial slope of the stress – strain diagram.

Sample Data

Natural Modulus Test			
Material	22 gsm Hygiene Nonwoven		
slit#	9218463		
Width	7.94	in	
Caliper	0.0052	in	
Gauge Length	603	in	
Force [lbs]	Elongation	Strain	Stress
0.0	in		psi
0.5	0.88	0.002	8347.7
1.0	1.66	0.003	8376.7
1.5	2.501	0.004	8904.3
2.0	3.321	0.006	9054.6
2.5	4.144	0.007	8795.0
3.0	5.074	0.009	8371.3
3.5	5.981	0.010	7995.6
4.0	6.833	0.012	7893.8
4.5	7.796	0.014	7776.0
5.0	8.795	0.015	7000.6
5.5	9.761	0.017	6741.6
6.0	11.201	0.019	6810.9
6.5	12.48	0.021	5919.7
7.0	13.582	0.024	5242.4
7.5	15.146	0.027	4680.5
8.0	16.505	0.030	4178.1



Standard Methods

• ASTM E111—04(2010) Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

• ISO 1924-2:2008 Paper and board—Determination of tensile properties–
Part 2: Constant rate of elongation method (20 mm/min)

107 - CD Modulus

v2023.12.27 - David Roisum

Background

CD modulus is used far less commonly than MD modulus in testing, and for web handling equations and for modeling. It is most often used for product/process design. One example from paper forming is the tensile stiffness index, which is the ratio of MD modulus / CD modulus, gives important insight into the orientation preference of wood fibers. Another example is for nonwovens where stretch in both directions may be useful as an indicator of product performance of consumer products.

Methods

The methods are identical to Tests 105 and 106 except that the long direction of the tensile specimen is cut oriented in the CD instead of MD.

109 – TEA or Toughness

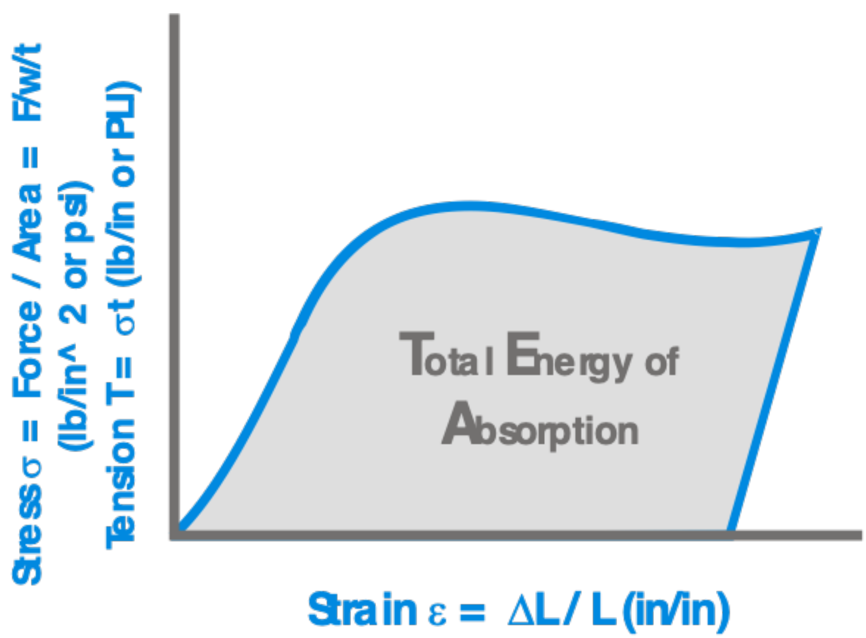
v2023.12.31 - David Roisum

Background

TEA (Total Energy Absorption) is a measure of toughness. It is a combination of desirable properties of both strength (see Test 104) and stretch. In many ways it can be a better predictor of runnability (length between web breaks) than is the much more common strength.

TEA is measured on a computer-controlled tensile tester that simultaneously measures stress (force divided by area) and stretch (elongation). TEA is defined as the area under the stress-strain curve to failure as seen in the figure below. Strictly speaking, the rightmost boundary should have a slope equal to the initial loading curve. However, for simplicity many software programs might use a vertical line as the rightmost boundary.

Figure 109.1



Methods

The following standard test methods are used for web materials.

ISO 1924/2 TAPPI T494 Tensile properties of paper and board
(constant rate of elongation)
ASTM D828 − 22 Tensile Properties of Paper and Paperboard Using Constant-Rate-of-Elongation Apparatus1

110.0 – Bagginess Intro

v2023.12.31 - David Roisum

Background

Bagginess causes many web handling issues, such as wrinkling going over rollers and especially into nips, poor path control, poor winding, and others. It also causes troubles with many processes such as laminating and printing. Finally, it is a problem with end use when the web is not flat and straight enough for customers, especially for those web products whose visuals are very important.

Wrinkling (see Tests 500) is one of the largest causes of waste, delay, and customer complaint in the collective web industries. While there are many causes of wrinkling, baggy webs are one of its top causes, hence our interest in measurement of bagginess (this section), mitigation (accommodation and prevention) and troubleshooting. Those interested in the primary literature about bagginess should query the Roisum Library Database (available free as both an MS Excel file and as the Roisum Library by AbbottApp. Those wishing to diagnose the root causes should look at the YouTube series by David Roisum, Web201.45a-r

Bagginess may go by many names including baggy edges, baggy lanes, buckles (metals industry), cross buckles, camber, layflat, lasagna edges, loose edges and so on. All are similar EXCEPT camber (see Test 110.3) which is a specific outcome or subset of bagginess. A very important concept is that bagginess is ALWAYS a tension profile (variation across the CD) issue. More can be found about profile in the introduction to this text. Another important concept is that bagginess can be either formed (as variation of MD residual stress) during manufacture or by brutish converting (stretching materials unevenly past yield). However, the most common by far is that bagginess is a thickness profile variation in disguise that is stretched into bagginess on the relatively high thickness lanes on the winding roll. In metals and plastics, this is nearly always the case and is a common case with other materials.

While there is a tremendous need for good, fast, and cheap measurements of bagginess, there are few that meet more than one of those criteria and none that meet all. Still, this is what we have to date.

110.1 - Bagginess via the Strip Test
110.2 - Bagginess via Time of Flight
110.3 - Bagginess as Camber
110.4 - Bagginess inferred from Roll Hardness

110.1 – Bagginess via the Strip Test

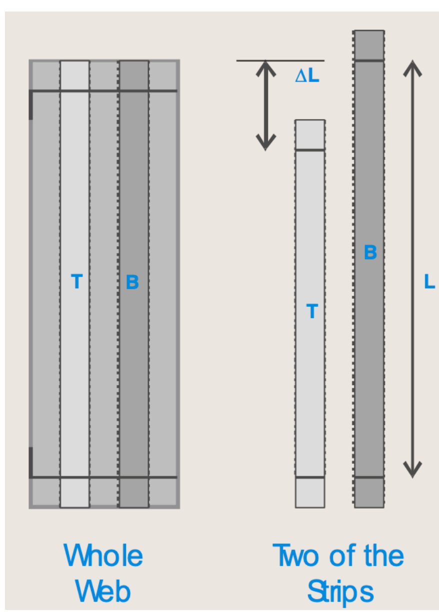
v2024.03.04 - David Roisum

Background

There are few direct measurements of bagginess and far fewer that are good, fast and cheap. The strip test is good and cheap. Good in the sense that it is sensitive. Good in the sense that it works well for a variety of materials that do not have extreme moduli such as tissue or metal. Good in that it is predictive of customer complaint. It is cheap because all it requires is a bit of waste (say 10 meters) and a pair of scissors. However, it is far from fast. Not only does it suffer from all test lab measurements in that sampling is done from the top of a roll, and thus is delayed by something like an hour after the product was made, but it also takes a fraction of an hour to complete.

Procedure

1. Scribe (2) perpendiculars to slit edge 50-100 feet apart.
2. Mark CD positions within tight band T and baggy band B
3. Strike chalk lines on each side of the tight and loose bands.
4. Cut out strips with a scissors (this procedure can also be done on a slitter rewinder with some modifications).
5. Drag strips from one edge.
6. Align perpendiculars.
7. Calculate bagginess.
8. Bag = delta L / L
9. Customer complaint tends to be on the order of 2 (e.g. wide format printed paper) to 20 (e.g. garbage bags) parts per 10,000.



110.2 – Bagginess via Time of Flight

v2024.03.04 - David Roisum

Background

Local web MD tension (as well as modulus) can be measured via time-of-flight of sound. MD tension *profile,* in other words bagginess, can thus be measured by measuring time-of-flight in more than one CD location. This procedure requires an instrument that can make a sound on a very small spot on the web, call it a 'thumper' and a receiver that is located a small MD distance away from the source. A computer is needed to separate the air pulse (which arrives later but is louder) from the web pulse (which arrives faster).

The original technique is described in

1. Vickery, C.M. and Lowery, R.L. Measurement of Web Tension Distribution by Point Source Excitation. Ph.D. Thesis 1992 and 2nd Int'l Conf. on Web Handling, Oklahoma State Univ, June 6-9 1993. https://shareok.org/bitstream/handle/11244/321678/oksd_icwh_1993_vickery.pdf?sequence=1&isAllowed=y

2. A conversion to practice had been made by Ronald Markum. https://www.angelfire.com/ma/OnPurpose/AWS.html

110.3 Bagginess as Camber

V 2024.08.08- Neal Michal

Background

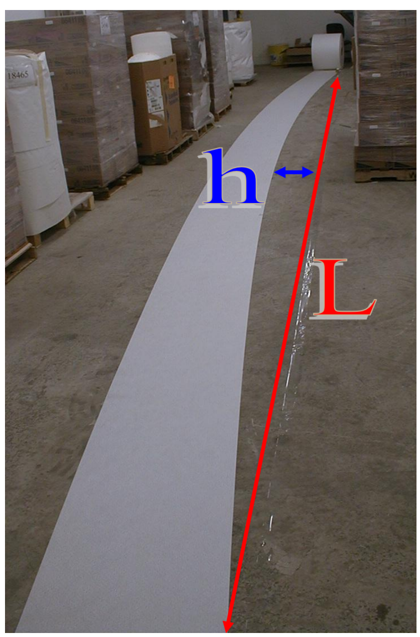
It is ideal for webs to be flat and planar when relaxed. However, there is no perfect web. Often the web will have floppy edges, baggy lanes, or camber. Camber is common on narrow webs. Poor lay flat is most often caused by a persistent cross deckle (CD) variability. This could be caliper, basis weight, moisture, etc. It is common to see the amount of camber change as a function of where the slit was obtained from the total width of the process. Camber may change directions on opposite sides of the process centerline.

In order to make improvements to a process that has poor lay flat, one needs to quantify the amount of camber. One proven method is to measure the "radius of curvature".

Purposes:

Measure web camber on a narrow web as defined by radius of curvature.

Test Set Up



R	Radius of Curvature
L	Straight Line Length of Web
h	Maximum Offset Distance

Equipment/Materials Required:

1. Roll of material or a long portion of web.
2. Tape measure.

Method:

1. Find a long hallway or a room with a smooth floor.
2. Roll out a long piece of web. The longer the better.
3. Smooth it out so it lays flat & planer to the floor.
4. One technique is to lift the web from both ends and let it float back down to the floor.
5. Ensure the web is flat on the floor, without any standing buckles on either side.
6. Measure length and the maximum amount of deflection as shown above.
7. Calculate "Radius of Curvature" using the following equation.

$$R = \frac{L^2 + 4h^2}{8h}$$

Sample Calculation

L = 40 ft = 480 in

h = 22 in

R = (L^2 + 4h^2) / 8h

R = (480in^2 + 4*22in^2) / 8*22in

R = 1,320 in

Radius of Camber = <u>1,320 in</u>

References:

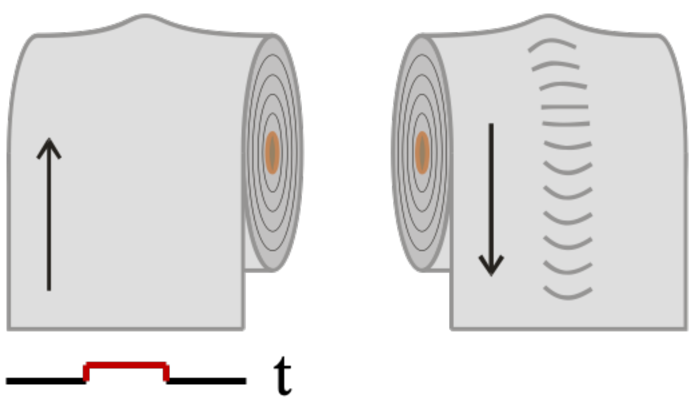
Machinery's Handbook, 25th Edition, Industrial Press. Pages 697-698. Figure 8.

110.4 – Bagginess Inferred from Wound Roll Hardness

v2024.03.04 - David Roisum

Background

The great majority of baggy webs are not *manufactured* baggy but are rather *made* baggy by the winding of webs that are *manufactured* flat, but that have excessive thickness profile variation and are thus stretched differentially and permanently into bagginess profile variation as seen in the figure below. What may be considered excessive is dependent on the specific web or product being manufactured. For materials, such as film and foil, bagginess as the outcome of winding webs with thickness variations is very likely. For more complicated materials, such as paper, thickness variation may account for perhaps only half of the cases. Moisture variation is another important cause.



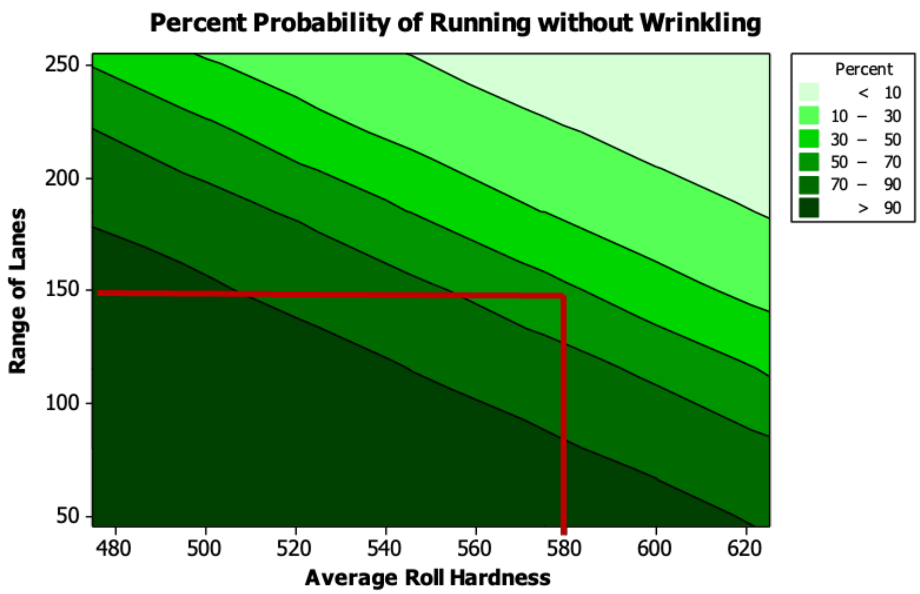
In any case, direct measurement of thickness (Web Test 102), either via online 'scanners' or even test labs is seldom good enough to resolve variations on the order of a few percent as described above. However, it has been found that wound roll hardness (Web Test 805) is a good proxy for thickness variations for many materials that are measured well with those instruments. While that excludes all tissue and foil, and some film, it is useful for many others.

However, mere hardness or mere hardness variation alone are not predictive. Instead, one must take into account both at the same time, as well as using the best roll hardness instruments and techniques. While gathering the needed data is as quick as hardness measurements can be made, analyzing the data to a priori determine your 'threshold of pain' takes some time. A detailed discussion and can be found on https://shareok.org/handle/11244/320247

1. Thuer, Amy (Avery Dennison). *Using Roll Hardness to Screen for Excessive Web Bagginess.* International Conference on Web Handling, Web Handling Research Center, Oklahoma State University, June 2013.

2. Roisum, David R. *Web201.07 Baggy Web Screening, Web201.45a-r Baggy Web Series. YouTube.*

The figure below redrawn from Amy Thuer's paper, summarizes the results for an example. The green shading indicates the probability of failure to run due to bagginess. Like many tests, the results are not a strictly determinative yes/no, but rather suggest risk. In this figure, a roll with a delta of wound roll hardness of 150 (on a ParoRoll Tester II) and an average roll hardness of 580, had about a 50/50 chance of running without complaint.



114 – Web Surface Roughness

V 2023.01.31 – Steve Lange

Purposes

This best practice gives guidance for measuring the surface roughness of a web.

Web surface roughness can have a significant effect on maintaining traction between a moving web and a rotating roller, or on the friction between a moving web and a stationary component, such as a turn bar or folding board. This is particularly true for non-permeable webs where entrained air between the web and contacting surface can create an air film that reduces the interaction of surface asperities of the roller and web, reducing the effective coefficient of friction.

In general, higher surface roughness of a web can increase friction and enhance traction between the web and roller, but the optimal roughness of web and roller depends on the application.

Figure 114.01 - Example of a Web with a Surface Texture

Equipment/Materials Required

There are several methods for measuring surface roughness, and the equipment for doing so varies with the method. Some of the methods include:

1. Contact profilometry: This method uses a stylus to physically contact the surface and measure variations in height. Note, this method may not be feasible for very fibrous substrates, as the stylus may snag on the fibers.

2. Non-contact profilometry: This method uses optical or laser technology to measure the surface profile without physical contact.
    a. Optical interferometry: This method uses the interference of light to measure surface roughness.
    b. White light interferometry: This method uses a white light source and a camera to measure surface roughness.
    c. Confocal microscopy: This method uses a laser to scan the surface and measure variations in height.

Method

1. Begin by selecting the appropriate profilometry method for measuring surface roughness, which depends on the substrate type, the measurement range and resolution required, etc.
2. Position the surface to be measured in the measurement field of the profilometry system.
3. Calibrate the system according to the manufacturer's instructions, ensuring that the correct parameters (such as measurement range and resolution) are set.
4. Capture a data set of the surface using the profilometry system.
5. Process the data using appropriate software to obtain a 3D representation of the surface.
6. Analyze the data to determine the surface roughness parameters, such as the RMS roughness and the maximum peak-to-valley height.
7. Record the results and compare them to any relevant standards or specifications.

References

- ANSI B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)
- Roughness of paper and paperboard, stylus (Emveco-type) method, TAPPI Test Method T 575 om-13
- ISO 21920-1 Geometrical product specifications (GPS)--Surface texture: Profile—Part 1: Indication of surface texture
- ISO 21920-2, Geometrical product specifications (GPS)--Surface texture: Profile—Part 2: Terms, definitions and surface texture parameters
- ISO 21920-3, Geometrical product specifications (GPS)--Surface texture: Profile—Part 3: Specification operators

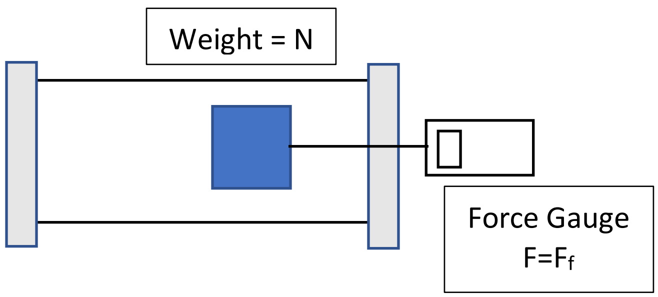
115 – Web to Web CoF

V 2023.02.16 – Andy Palmer

Purposes

1. Determining when inter-layer slip will happen in a wound roll
2. Determining torque capacity of a wound roll

Diagram



Equipment/Materials Required

3. Calibrated weight, approximately equal to the interlayer force in the wound roll of interest
4. Force gauge sized such that the maximum force expected in the test will be in the top third of its range
5. Material to be in the wound roll
6. Masking tape

Method

1. Tape one sample of the material on a firm surface. For a sided material, make sure to note which side is up.
2. Attach a segment of the same material to the calibrated weight (N). The side facing down should be the opposite side as the side facing up in step 1.
3. Zero the force gauge in a horizontal orientation.
4. Attach the force gauge to the calibrated weight.
5. Pull the force gauge slowly and steadily.
   a. Note the peak force before the web begins to slip and use that force as F_f to calculate the static friction coefficient.
6. Note the average force (F_f) while the web attached to the weight is slipping relative to the web attached to the table, used to calculate dynamic friction coefficient.
7. Calculate the CoF (μ) using the equation $\mu = \frac{F_f}{N}$

Alternatively, steps 5 and 6 may be modified such that the force gauge is attached to the top web, and the calibrated weight sits on top of the web. With this method, it is vital to make sure the weight and the top web do not slip relative to each other.

201 – Diametral Profile – Rollers

V 2024.03.16 Shane VanHorn

Purpose

This article provides guidance for measuring a rollers diametral profile and tolerancing methods for manufacturing of rollers.

A roller's diametral profile is the outer diameter variation range (highs and lows) across the entire roller face (cross direction). By recording diameter measurements in set distances across the roll, a diametral profile map can be created of the face. There are no perfect cylinders, but the amount of these imperfections can be specified with a diameter tolerance control feature. Large variations in a roller's diameter can affect the ability to level and tram the roller and potentially cause web conveyance issues. It is important to control and verify the amount of these variations to reduce the stresses being introduced into the web. Web tracking (guiding) difficulties, wrinkles, bagginess, and web scratching are some of the side effects that can be attributed to too much profile variation.

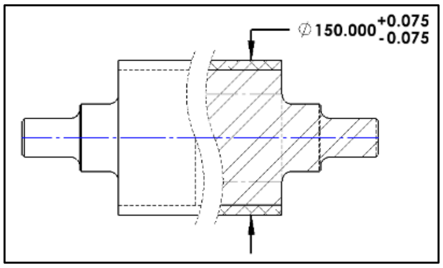
Testing Equipment/Materials Required

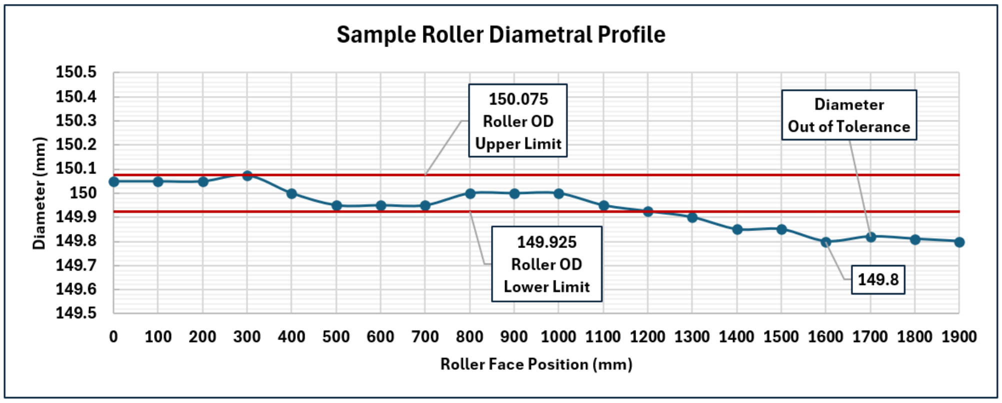
Designated roller(s)
Pi tape
** Micrometers or large diameter calipers can also be used but will require taking multiple reading in the same location to accurately measure the rollers outer diameter due to possible out of roundness cases.

Each one of these measurement tools has an approximate accuracy of +/- .0254 mm (+/- .001 in).

Method

The sample roller below has a nominal outer diameter of 150mm and a 1900mm wide roll face. The measurement data in the chart below, readings were taken every 100mm across the entire roller face width. Larger or shorter measurement intervals can be used depending on the desired accuracy of the profile data or roll face width.





The outer diameter tolerance of this roller is 150mm +/- 0.075mm giving an acceptable diameter tolerance range of 149.925 minimum to 150.075mm maximum. In the profile chart the rollers diameter starts to drop below the tolerance zone at the right side of the roller to a maximum of 0.125mm under tolerance.

When a roller has variations in its outer diameter, the surface speed at different locations across the width will vary, thus creating variation in the speed of the web that is contacting the roller.

Extensible and thinner webs may not be affected by such a tolerance/speed difference, but more rigid and thicker webs can show negative side effects from a roller that is out of tolerance. If these variances become too great, they can cause tracking issues, wrinkles, bagginess, or web scratching.

Some causes of poor roller diametral profiles are manufacturing errors, surface wear, uneven surface application and rubber surface breakdown. As a roller conveys web, the surface can wear and break down over time, whether from nipping forces or friction of the web over the surface. In these cases, roller reworking, recovering or replacement may be required to resolve.

There are rollers that intentionally have outer diameter variations such as crowned and reverse crowned rollers, which use these variations to manipulate the web by converging for spreading the web surface as it travels over these rolls. These types of rollers can also have a profile map created, but the results will need to match the intended variations of the design.

202 – TIR (Runout) – Rollers

V 2023.12.08 – Shane VanHorn

Purposes

The purpose of this article is to describe the method of measuring Total Indicator Reading (TIR).

TIR (Total Indicator Reading) of roller runout, measures the minimum to maximum amount of roller outer diameter misalignment to its rotating axis (bearing mounts/journals) across the entire roller face. There are no perfect cylinders, but we can specify and control how imperfect these roller cylinders can be with a TIR control feature. Runout can affect the ability to level and tram rollers due to the changing face position as the roller is rotated. You could be level and tram with the roller in one location but rotating it 180 degrees can change your level and tram to be out of tolerance. We need to control the amount of this value in order to help control level and tram as the machine is running web. Just like roller level and tram, runout is equally as important to control, to reduce excessive stresses being introduced into the web. Wrinkles, vibrations, web flutter, coating & printing errors are some of the side effects that can be attributed to excessive runout.

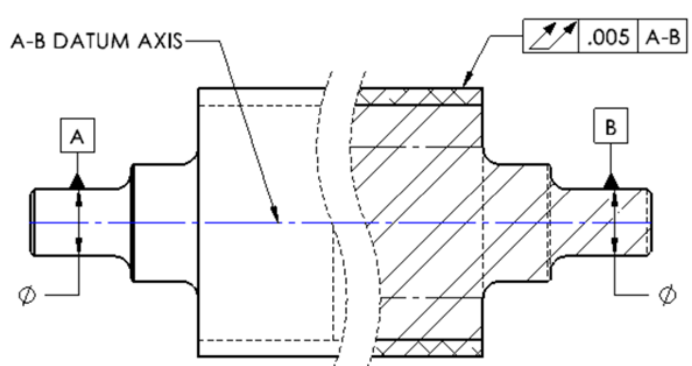
Equipment/Materials Required

Designated roller(s)

Dial indicator and magnetic or clamp-type mounting base having the ability to move across the entire face of the roller.

Method

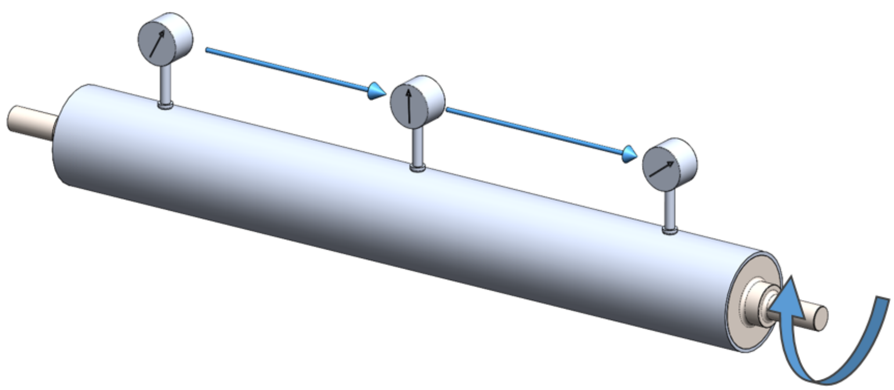
In this example roller drawing the two datums (A & B) are the roll journals and the roll face has a Total Indicator Runout tolerance of .005 inches to its central datum axis (A-B). This tolerance control feature specifies allowable radial and axial variations in the roller to its rotational axis datum.

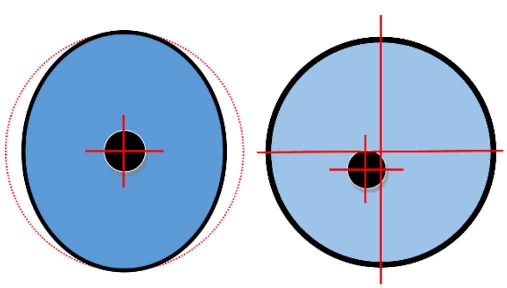


To measure runout TIR you will utilize a dial indicator and check the amount of movement of the indicator readings as the roll is rotated a full 360 degrees.

1. Securely mount a dial indicator using a magnetic base, clamp mechanism, or other technique that provides stability to the system.
2. Locate the dial indicator stylus touching the roller at one side of the roller face where the widest web edge will touch. (typically, 2 to 3" from the edge of the roll face end) and zero the dial indicator.
3. Rotate the roller a full 360 degrees.
4. Record the total amount of movement (minimum to maximum) of the indicator. This is your TIR reading for this location.
5. Relocate the dial indicator to the next desired position and repeat the process.

You will also move the indicator along the entire roller face surface (cross machine) and document these minimum and maximum readings throughout to determine the maximum TIR range. This will determine if the roller complies with the allowable amount of runout. It is recommended at minimum to take a measurement reading every 6" to 12" across the roll face (cross machine) to achieve a good sample range. The more samples taken, the more accurate profile range you will achieve.





These checks will determine the amount that the roller face is off-center to the bearings/journals about its rotational center axis and how out of round the roll OD is, which both affect the roller's TIR.

These images are an example of a rollers outer diameter being out of round and being off-center to its rotational axis (journals / bearings).

Reverse Crown/Negative Crown/Concave Rollers can also be checked for TIR Runout. The total indicator pointer movement can be checked even with roll outer diameter changes. Diametral profile readings are explained in section 201 of this document.

The allowable runout range for rollers will vary depending on roller type and material sensitivity and stiffness.

203.1 – Deflection – Simply Supported Rollers

V 2023.07.07 – Joe Kotwis

Purpose

To provide a technique for measuring roller deflection. *This document does not include deflection associated with nips.*

Diagram

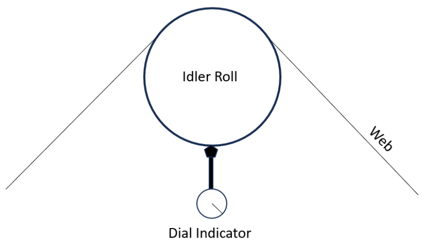


Diagram 1: Deflection at bisected angle example 1.

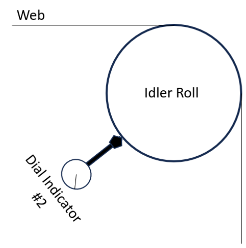


Diagram 2: Deflection at bisected angle – example 2.

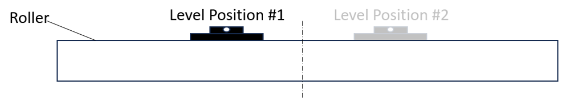


Diagram 3: Checking for roller deflection due to weight.

Equipment/Materials Required

- Web equipment, designated roller(s) and web (or rope).
- Dial indicator and magnetic or clamp-type mounting base.
- Precision (machinist) level

General

If a roller is deflecting excessively, it can create wrinkles in the web. Deflection can be affected by web tension, wrap angle, wrap orientation, roller shell construction, roller width, and roller weight. Ideally, during the design phase of new equipment, deflection calculations are completed, and acceptable tolerances are understood and defined. However, there are situations where this work was not completed, or a process is being used differently than its original intent. If roller deflection is suspected, it should be measured and resolved if found to be unacceptable.

According to The Mechanics of Rollers by David Roisum, there are rules of thumb around roller sizing such as the slenderness ratio (length/diameter), which should be between 10 and 20. This does not account for core material, wall thickness, or the sensitivity of a given web; however, it can provide useful information.

There are guidelines around acceptable deflection that state it should be better than <0.00015 x face width (for most rollers). There is more in-depth discussion around acceptable deflection and how to calculate it in The Mechanics of Rollers pages 30 – 33.

Roller Class	Description	Allowable Defection [in/in]
A	Precision Rollers	0.000080
B	Most Rollers	0.000150
A	Flexible Webs Thick Webs	0.000300
B	Coneyors Coreshafts	0.000600

Method

1. **Safety:** all site safety procedures should be followed including lock out tag out, not touching moving webs and equipment, and wearing gloves while working with equipment.
2. Identify the roller in question and determine the location of bisected wrap angle, which should be the point of maximum deflection. *See diagram 1 and 2.*
3. Safely mount a dial indicator using a magnetic base, clamp mechanism, or other technique that provides stability to the system.
4. Locate the dial indicator stylus touching the roller at the center of the web width.
5. Zero the dial indicator.
6. **Use the web as the load: If** the dial indicator can be mounted and still safely maintain the desired web path, then the tension can be set by selecting a value in the HMI. A range of tensions can be used to understand the magnitude of the effect at various tensions (and widths). Once the tension is stable at each condition, read the dial indicator for the total deflection at each given tension.

   -OR-

7. **Use a strap or rope with weight as the load: If** the mounting of the dial indicator interferes with the web, then the equipment should be locked out and a strap/rope threaded through the rollers to imitate the web path. This includes imitating the typical roller wrapping configuration and TD/CD location (i.e., web width centerline). The appropriate weight should be hung from the strap/rope to simulate web tension. *Keep in mind that a point load will have a different effect than a distributed load.*
8. **Roll deflection due to roll weight: It** is possible that the roller is deflecting under its own weight which could significantly contribute to tension created deflection. This can be verified by alignment techniques (optical and laser) or by placing a precision (machinist) level on top of the roller and comparing the level (direction of the bubble) on each half of the roller. *See diagram 3.*

References

The Mechanics of Rollers – David Roisum, TAPPI Press, 1996, p. 30 - 33.

203.2 – Deflection – Cantilevered Rollers

V 2023.07.07 – Joe Kotwis

Purpose

To provide a technique for measuring roller deflection. This document does not include deflection associated with nips.

Diagram

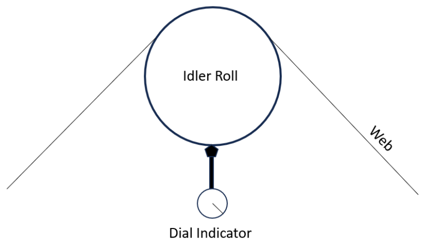


Diagram 1: Deflection at bisected angle example 1.

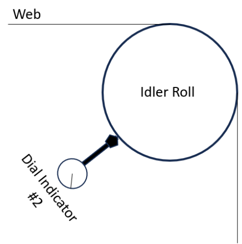


Diagram 2: Deflection at bisected angle – example 2.

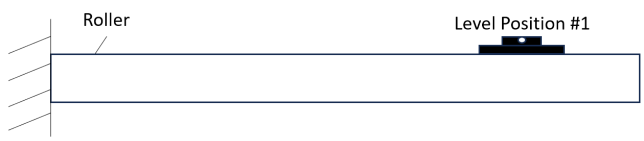


Diagram 3: Checking for roller deflection due to weight.

Equipment/Materials Required

- Web equipment, designated roller(s) and web (or rope).
- Dial indicator and magnetic or clamp-type mounting base.
- Precision (machinist) level

General

If a roller is deflecting excessively, it can create wrinkles in the web. Deflection can be affected by web tension, wrap angle, wrap orientation, roller shell construction, roller width, and roller weight. Ideally, during the design phase of new equipment, deflection calculations are completed, and acceptable tolerances are understood and defined. However, there are situations where this work was not completed, or a process is being used differently than its original intent. If roller deflection is suspected, it should be measured and resolved if found to be unacceptable.

According to The Mechanics of Rollers by David Roisum, there are rules of thumb around roller sizing such as the slenderness ratio (length/diameter), which should be between 10 and 20. This does not account for core material, wall thickness, or the sensitivity of a given web; however, it can provide useful information.

There are guidelines around acceptable deflection that state it should be better than <0.00015 x face width (for most rollers). There is more in-depth discussion around acceptable deflection and how to calculate it in The Mechanics of Rollers pages 30 – 33.

Roller Class	Description	Allowable Defection [in/in]
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B	Coneyors Coreshafts	0.000600

Method

1. **Safety:** all site safety procedures should be followed including lock out tag out, not touching moving webs and equipment, and wearing gloves while working with equipment.
2. Identify the roller in question and determine the location of bisected wrap angle, which should be the point of maximum deflection. *See diagram 1 and 2.*
3. Safely mount a dial indicator using a magnetic base, clamp mechanism, or other technique that provides stability to the system.
4. Locate the dial indicator stylus touching the roller at the unsupported end of the widest web edge (or the end of the cantilevered roller).
5. Zero the dial indicator.
6. **Use the web as the load: If** the dial indicator can be mounted and still safely maintain the desired web path, then the tension can be set by selecting a value in the HMI. A range of tensions can be used to understand the magnitude of the effect at various tensions (and widths). Once the tension is stable at each condition, read the dial indicator for the total deflection at each given tension.

   -OR-

7. **Use a strap or rope with weight as the load: If** the mounting of the dial indicator interferes with the web, then the equipment should be locked out and a strap/rope threaded through the rollers to imitate the web path. This includes imitating the typical roller wrapping configuration and TD/CD location (i.e., web width centerline). The appropriate weight should be hung from the strap/rope to simulate web tension. *Keep in mind that a point load will have a different effect than a distributed load and that hanging the weight closer to the unsupported edge will give you a more conservative value (greater deflection).*
8. **Roll deflection due to roll weight: It** is possible that the roller is deflecting under its own weight or bent, which could add to deflection related wrinkles. This can be verified by alignment techniques (optical and laser) or by placing a precision (machinist) level on top of the roller and measuring the 'out of level'. *See diagram 3.*

References

The Mechanics of Rollers – David Roisum, TAPPI Press, 1996, p. 30 - 33.

205 – Bearing Drag – Rollers

V 2024.03.09 Shane VanHorn

Purpose

The purpose of this article is to describe the measurement of bearing drag in a roller.

Bearing Drag

Bearing drag is the resistance encountered when starting or maintaining rotation, in this case, within a roller assembly. Many factors can contribute to this resistance, including friction, lubrication, and design to name a few.

Bearing drag can affect many elements of web handling and conveying. Each additional roller adds to the total amount of drag on the system. The tension force due to drag is defines as:

$$Tension\ Force\ Due\ to\ Drag = \frac{(drag\ torque\ \times\ 2\ bearing\ per\ roller)}{\left(\frac{Roller\ Diameter}{2}\right)} \times\ total\ number\ of\ rollers$$

For example, a bearing has a drag torque value of 50N·mm, and the roller has an outer diameter of 150mm. There are a total of 20 rollers in the tension zone path. The amount of drag force exerted onto the web and system is:

$$Tension\ Force\ = \frac{(50N \cdot mm\ \times\ 2)}{\left(\frac{150mm}{2}\right)} \times\ 20\ =\ 26.6\bar{6}\ N$$

As this example shows, this can have a negative impact on web conveyance, especially if this drag value approaches the operating web tension range. This value may not affect a system operating at a high-tension range and thicker web materials. However, if the web tension range for these 20 rollers were between 20 and 100 Newtons, then the drag could create problems when operating at the lower tensions. This is where lower bearing drag values are essential for good web control.

If one or more of these rollers had only a small amount of wrap on them, 30 degrees or less, the traction of the web to the roller could be less than the drag of the bearing. This would cause the roller to slow down or even stop and web scratching can occur (capstan equation). Higher drag values can also cause machine inefficiency, drawing more horsepower and consuming more energy to operate. The optimum condition is to properly match the bearing drag to the tensions, speeds and materials being conveyed. To verify and measure these drag values, we can perform a spin down test to determine what the actual drag values are.

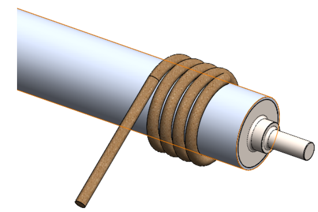
Testing Equipment/Materials Required

Method to speed up roller depending on method used (one of either):

- Drill with non-damaging friction speed up wheel.
- Length of rope to spiral wrap the roller.
- Hand acceleration (This method is only for low-speed acceleration testing)

Method to measure roller speed:

Non-Contact Tachometer with reflective tape or,
Contact tachometer.



Rope acceleration method

Method to record time:

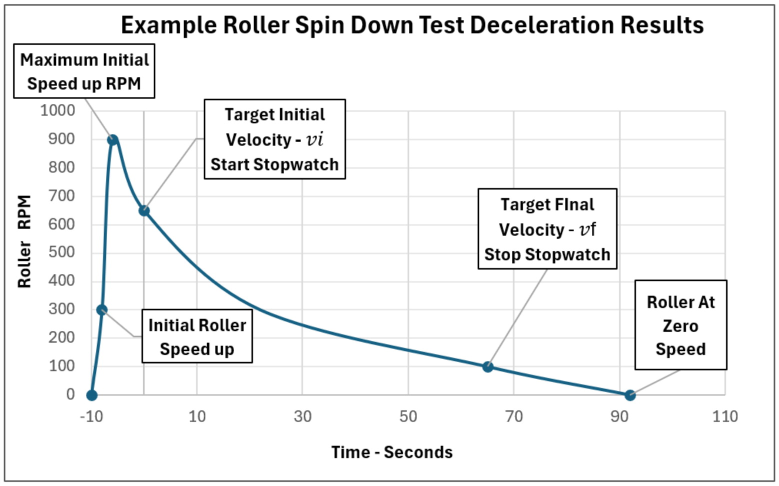
Stopwatch

Testing method

1. High Speed Spin Down Test

   (Non-contact tachometer, reflective tape, stopwatch, drill with friction speed up wheel that will not damage the roller surface)

   a. When using a non-contact tachometer, place a small piece of reflective tape at the edge of the roller face where you can easily access. The non-contact tachometer will utilize this tape to track the roller rpm.
      * You can use a contact tachometer, but you will need to remove the tachometer after the top target speed has been reached to receive accurate results and then record when the roller comes to a complete.
   b. Using the drill, start the roll spinning up to a speed higher than your target initial roller rpm.
      ** This can also be performed by spiral wrapping the roller several times with a length of rope and then pulling off the roll quickly to speed up the roller spin.
   c. Place the tachometer where it can monitor the roller rpm.
   d. Once the roller has slowed to the target start rpm, start the stopwatch to begin the countdown.
      *** the target start rpm should be close to the actual web speed rpm for the most accurate results.
   e. If using a contact tachometer, remove it from the roll and set aside
   f. If using a non-contact tachometer using the reflective tape, continue to monitor the rpm until you have slowed to the target final rpm or until the roller has fully stopped if your target is zero speed.
   g. Stop the countdown and record the time in second that it took to reach this final speed.



The most straightforward method to identify trouble areas is to compare one roller spin down time to adjacent rollers. If you receive high variations in a particular location, that would be the roller of focus to work on correcting. The spin down time data can be calculated and converted into a numerical bearing drag value.

$$Bearing\ Drag\ \ (T_b) = Roller\ Moment\ of\ Inertia\ \times Angular\ \text{Deceleration}\ \ =\ \ J_r \times \alpha_d$$

First, calculate the rollers moment of inertia:

$$J_r\ = \frac{\pi\ \times \mathrm{m} \times\ \mathrm{L}_r \left(R_o^4 - r_i^4\right)}{2}$$

The inertias of the roller heads and journals can be added into the equation to get an even more accurate drag value, but with diminishing returns due to the small impact it will have on the overall calculated values, except for very low tensions and low inertia rollers.

Next, calculate the angular deceleration of the rollers spin down test result values:

$$\alpha_d = \frac{\omega_f - \omega_i}{\Delta t} \quad where \quad \omega_i = \frac{v_i\ \times\ (2\pi)}{60} \qquad \omega_f = \frac{v_f\ \times\ (2\pi)}{60}$$

Multiply the two variables to obtain the bearing drag for the example roller.

$$T_b\ = J_r \times \alpha_d$$

Dividing the bearing drag value by the rollers outer radius will show the drag force in Newtons (N) on the web.

$$Roller\ tension\ force = \frac{T_b\ \times 1000}{R_o}$$

T_b = Bearing drag (N-m)
J_r = Roller shell rotational moment of inertia (kg/m^2)
α_d = Angular deceleration (rad/sec^2)
m = Roller shell material density (kg/m^3)
L_r = Roller face width (m)
ω_i = Initial Angular Velocity (rad/sec^2)
ω_f = Final Angular Velocity (rad/sec^2)
R_o = Roller outer radius (m)
r_i = Roller inner radius (m)
Δt = Time slow down to final velocity (sec)
v_i = Initial velocity - highest speed (rpm)
v_f = Final velocity - lowest speed (rpm)

The following is an example bearing drag calculation based on the chart test data in the figure from above. The subject machine line operates at 300 mpm web. The example roller has a 150mm outer diameter x 135mm inner diameter roller with a 1900mm wide roll face. The roller material is aluminum, which has a material density of = 2700 kg/m^3 . At 300 mpm this roller will be spinning at 636.6 rpm. From the spin down test example above, it took 65 seconds for the roller to slow from the initial target speed of 650 rpm down to 100 rpm.
* Zero speed can also be used as a value and record the time it takes for the roller a completely stop.

$$Roller\ rpm = \frac{web\ speed\ (mpm)}{Roller\ od\ (mm) \times \pi} \times 1000 = \frac{300}{150 \times 3.14159} \times 1000 = 636.6\ rpm$$

$$Roller\ Inertia\ (J_r) = \frac{\pi \times m \times L_r\ (R_o^4 - r_i^4)}{2} = \frac{3.14159 \text{ x } 2700 \text{ x } 1.9\ (.075^4 - .0675^4)}{2} = \frac{.175365}{2} = .08768 \text{ kg/m}^2$$

$$\omega_i = \frac{v_i \times (2\pi)}{60} = \frac{650 \times (2\pi)}{60} = 68.0678 \qquad \omega_f = \frac{v_f \times (2\pi)}{60} = \frac{100 \times (2\pi)}{60} = 10.4719$$

$$Angular\ Velocity\ (\alpha_d) = \frac{\omega_f - \omega_i}{\Delta t} = \frac{68.0678 - 10.47197}{65} = 0.8861 \text{ rad/sec}^2$$

$$Bearing\ drag\ (T_b) = J_r \times \alpha_d = .08768 \times .8861 = 0.0777 \text{ N} \cdot \text{m} \equiv 77.7 \text{ N} \cdot \text{mm}$$

$$Roller\ tension\ Force = \frac{T_b}{R_o} = \frac{0.0777}{.075} = 1.036 \text{ N}$$

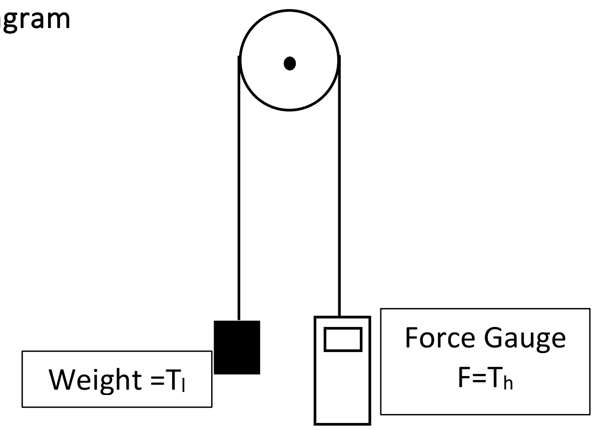
206 – Web to Roller Coefficient of Friction (CoF) Measurement

V 2022.09.15 – Andy Palmer

Purposes

1. Determining when slip occurs between a given web and a given roller
2. Determining tension ratio across a fixed element, such as a turn bar

Diagram



Equipment/Materials Required

1. Calibrated weight
2. Force gauge, sized such that the maximum force expected in the test will be in the top third of its range.
3. Material and roller that are the same as those used in the process
4. Masking tape

Method

1. Set up the roller in a way that it will not spin
2. Attach a known weight (T_l) to one end of a length of material.
3. Zero the force gauge in the orientation it will be when pulling on the web
4. Drape the material over the roller such that the weight hangs down vertically
5. Attach the force gauge to the free end of the web.
    a. If attaching via a hook, it is recommended to reinforce a section of the web with tape, then poke a hole in that section and thread the hook through.
    b. If using a spring clamp to connect the force gauge to the web, make sure it is strong enough that it will not slip when force is applied.
6. Pull the force gauge slowly and steadily in the direction in which it was calibrated. If possible, it is recommended that a pull be done such that the wrap angle is 180 and or 90 degrees, as these are the easiest to keep consistent.

   a. Note the peak force before the web begins to slip and use that force as T_h to calculate the static friction coefficient.
   b. Note the average force (T_h) while the web is slipping over the roller, used to calculate dynamic friction coefficient.
7. Optionally, an additional test could be done where the weight is allowed to drop, and it becomes T_h , while the force read on the gauge becomes T_l .
8. Calculate the CoF (μ) using the equation, where θ is the wrap angle of the web around the roller, in radians.

$$\mu = \frac{ln\left(\frac{T_h}{T_l}\right)}{\theta}$$

9. Repeat the procedure for the other side of the web, in case the web is sided.

Alternatively, steps 6 and 7 may be modified such that the force gauge is anchored, and the roller turned slowly in one or both directions.

References

Roisum, David R., Timothy J. Walker, and Dilwyn P. Jones. *The Web Handling Handbook.* Lancaster, PA: DEStech Publications, Inc., 2021, pp 156-160

209 – Driven Roller Angular Velocity

V2023.08.28 – Steve Lange

Overview

The angular velocity of rollers in a web path, often given in units of revolutions per minute or RPM, is critical in determining the speed and the tension of a web being pulled through a converting machine by rollers. The speed and tension of the web can affect the machine direction and cross-machine direction web position and wrinkling of a web. Knowing the precise rotational speed of rollers is then key in controlling a web and preventing damage to it.

Apparatus

There are several devices available for measuring the RPM of a driven roller:

Shaft encoders: the roller with bearings may be installed on a rotating shaft connected through pulleys and belts to a motor. A shaft encoder, or rotary pulse generator, sends out a high number of pulses per revolution of the shaft (e.g., up to 5000), providing a high-resolution measurement of the shaft speed.

Proximity sensors provide low to medium resolution RPM measurement, where a proximity sensor senses the teeth on a gear, or a bolt head mounted on a shaft.

Contact Tachometers use a rolling wheel or other attachment in contact with the roller surface to measure the RPMs of the roller. These devices usually require a person to directly hold the device against a rotating roller, so following safety procedures for this measurement method are critical. Also, the reading may be affected by how well the rolling wheel is held flush against the roller surface, so there is some inherent person-to-person variability using this method.

Non-Contact Optical Tachometers sense a reflective target, like reflective tape, on the shaft or roller. This method is usually lower resolution due to the low number of pulses per revolution. The method does not require an operator to directly contact a rotating roller, but aim the tachometer at the reflective target, often placed on the side of the roller, enabling measurement outside of machine guarding.

Measurement Method

1. Determine the required resolution for measurement of RPM, low versus high, in order to select the appropriate measurement device.
2. Determine if this is a one-time measurement, or an on-going measurement. If one-time, a handheld device may be appropriate. If on-going, installation of a permanent measuring device may be appropriate.
3. Read and follow the manufacturer’s procedures for calibration and use of the measurement device. Follow safety procedures for the converting machine when making measurements.

4. Make at least three measurements of the roller/shaft RPM and record the values. Calculate an average of the measurements and report that as the RPM of the roller.

210.1 – Web Speed Using Roller Angular Velocity

V2023.08.28 – Steve Lange

Overview

The speed (velocity) of a web in a web path affects aerodynamics of the web and related phenomena like flutter, traction of the web due to air entrainment, and tension from aerodynamic drag.

The mass flowrate of a web in a web path may be calculated from the velocity of a web in a span relative to a theoretical relaxed web speed. From this flow rate and knowing tension, strain, or speed in enough spans allows mathematical modeling of various web conditions.

Having accurate web speed measurements is essential to understanding and predicting web behavior.

Using the angular velocity of a roller, e.g., measured using Best Practice 209, the average radius of a roller, and the average thickness of a web crossing a roller, the velocity of a web on the roller may be calculated.

Web Speed Calculation

A web's neutral bending axis is also its pitch line as it crosses a roller. The velocity of the web entering a roller is determined by its pitch line velocity. *Assuming the pitch line is in the center of the web*, the pitch line velocity, V , is[1]

$$\boldsymbol{V = \omega\left(r_0 + \frac{h_w}{2}\right)}$$

Where

ω Is the angular velocity of the roller

r_0 is the radius of the roller

h_w is the web thickness

Reference

1. Lynch, R. (2017, June). Optimizing idler diameter. Paper presented at the Fourteenth International Conference on Web Handling (IWEB), Stillwater, OK, https://hdl.handle.net/11244/322054

300 – Web Tension Measurement

Overview

Web tension is one of the most important variables for web handling and quality control. Of foremost importance is to choose the units most appropriate for your application as either force, force per unit width (the most common) or force per unit width per unit thickness (stress). In the most common units, force per unit width, the units could be in metric (N/m) or US (lb/in or PLI). Units should accompany the test value.

Web Tension Measurement Tests

301 Calibrating Load Cells
302 Calibrating Dancers
303 Dancer Friction

301 – Calibrating Load Cells

V 2023.8.23 – Aravind Seshadri

Overview

Web tension is often measured and controlled using a load cell transducer. It is important to calibrate the load cells periodically to get the best tension control performance. To calibrate the load cells the following should be checked:

- Check and ensure that the load cell(s) is (are) installed properly according to the manufacturer's recommendations.
- Check and ensure that the load limit on the load cell is within the designed tension limits for the machine.
- Check and ensure that the load direction on the load cell bisects the wrap around the load cell roller.
- Check and ensure that one or two load cells are connected to the amplifier and wired accordingly.
- Check output type of the load cell amplifier and the corresponding range. For example, 0 - 10 V or 4 - 20 mA.

Needed Material

- A long rope or a cord or wire or strap that is inelastic.
- Known weight that can be hung at the end of the rope. The weight should be at least 25% of the desired full scale tension range and never more than the maximum load cell tension limit.
- A multimeter with voltage and current measurement and display option.

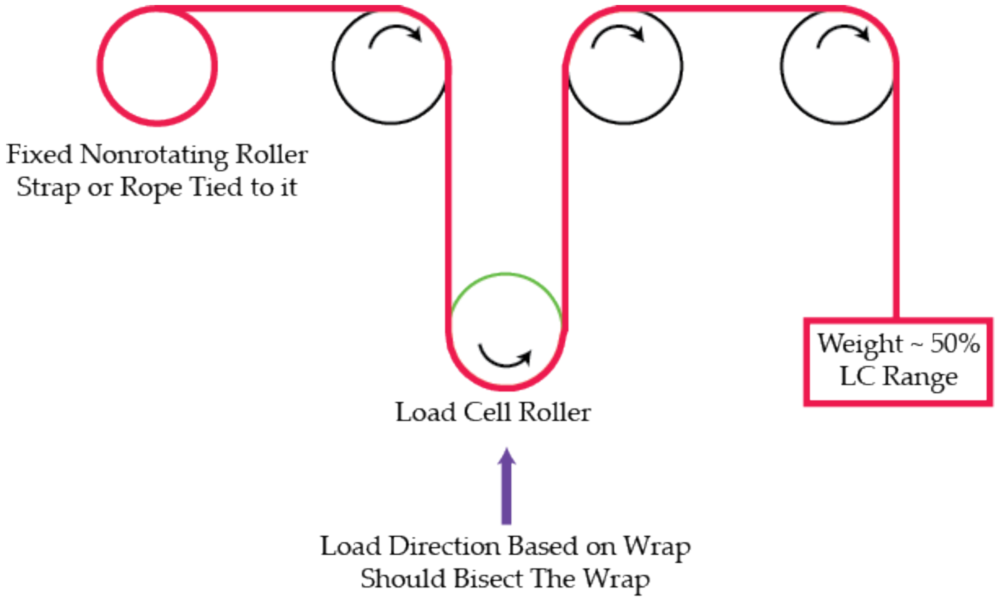
Calibration Procedure

There are two main steps to the calibration process. Zero adjustment (bias) and gain (slope) adjustment. The calibration procedure is essentially done to adjust for the bias and gain so that a linear relationship can be obtained from the zero to the full-scale value. Both zero and gain adjustment must be repeated multiple times to get the best fit.

Zero Adjustment

- With no weight around the load cell roller measure the output voltage or current from the load cell amplifier.
- If the output is non-zero, then adjust the "zero" (most likely by turning the zero-potentiometer screw) until the output voltage or current is at the zero-scale value. Please note that for 4 - 20 mA amplifier output the zero-scale value would be 4 mA so do the adjustment accordingly.

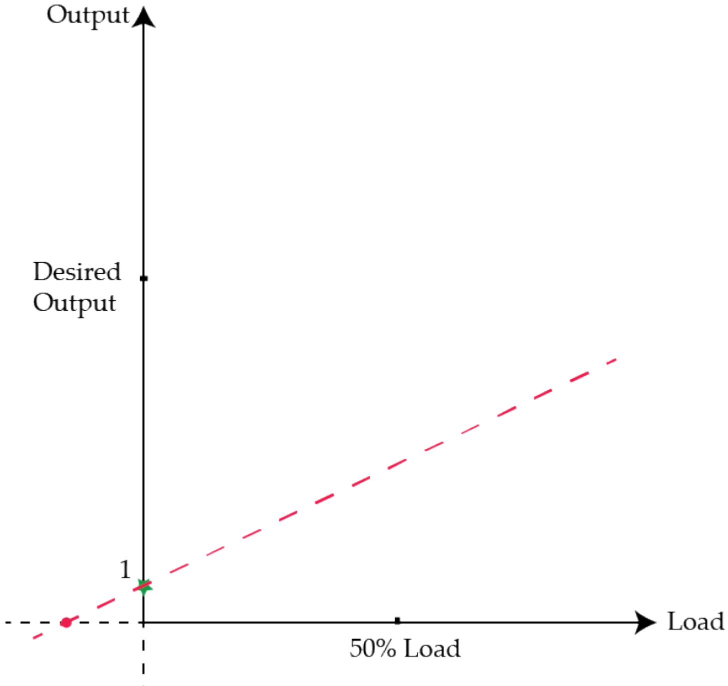
Gain Adjustment



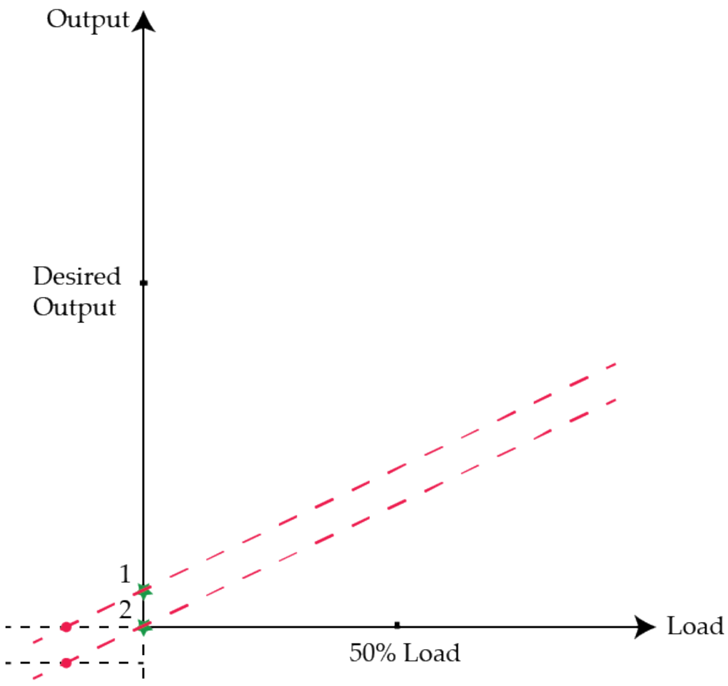
- Thread the rope or strap around the load cell roller following the same path that the web would take around the rollers near the load cell roller.
- Ensure that the wrap around the load cell roller is the same as when the web is wrapped around it during normal operation.
- Tie one end of the rope or strap to a roller and prevent that roller from spinning.
- Tie the weight to the other end of the rope or strap and let it hang.
- Rotate all the rollers several revolutions, in the direction of the weight, to remove any static friction between the rollers and the strap. This will tension the strap properly and avoid any inaccurate calibration.
- Now adjust the “calibration” (most likely by turning a potentiometer labeled for calibration) until the output matches the desired value. The desired value is computed based on the following formula:
  DO = (CW/DFTR)*(ORLA) where, DO is the desired output in appropriate units of measure, CW is the weight used for calibration, DFTR is the desired full scale tension range and ORLA is the Output Range of the Load Cell Amplifier in the corresponding unit.
- Remove the strap around the load cell and measure the output. This output would most likely be non-zero and we need to repeat zero adjustment followed by gain adjustment steps until both the zero scale and calibrated weight outputs match their desired value.

The last step is critical for proper calibration and sometimes it is ignored. To understand why it is important, let's visualize the calibration procedure.

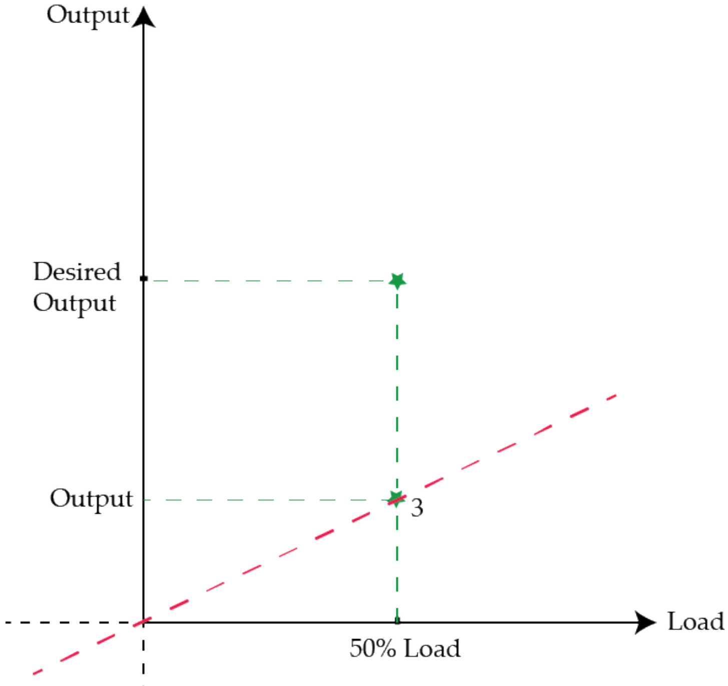
- An uncalibrated load cell might have the following linear relationship between the load and the output. Since at zero load the output is non-zero, the whole line is moved down using the zero adjustment (or the bias adjustment).



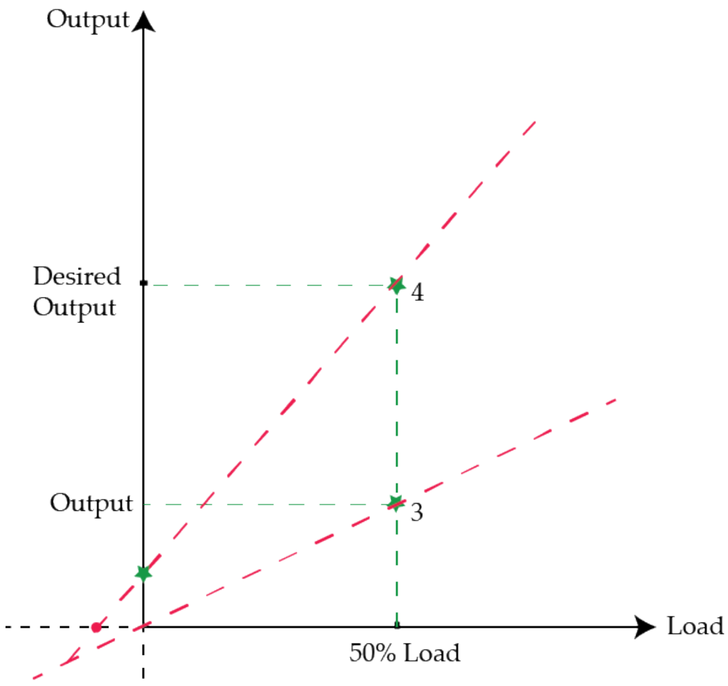
- Once the zero is adjusted now the input output relationship looks like the following image.



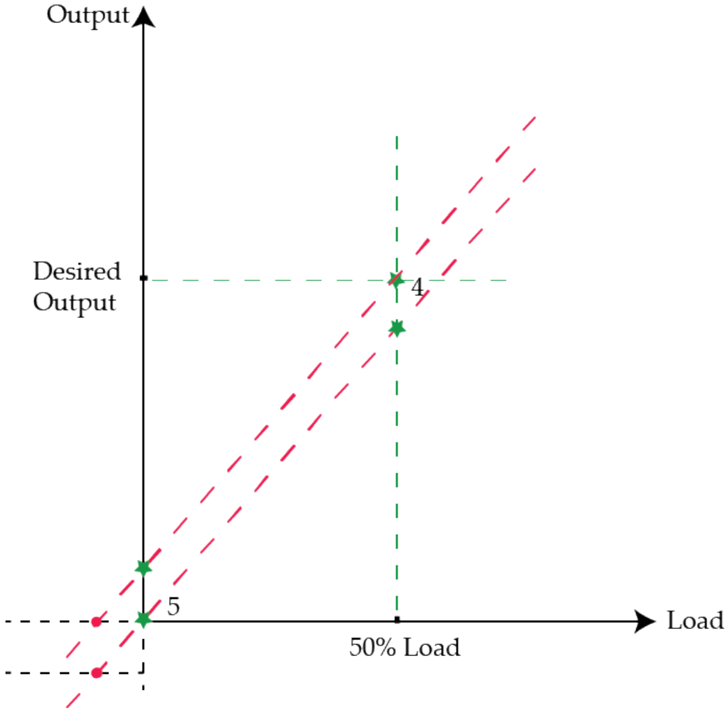
- Now when the load is added the output will be well below the desired output hence the slope of the linear fit needs to be adjusted.



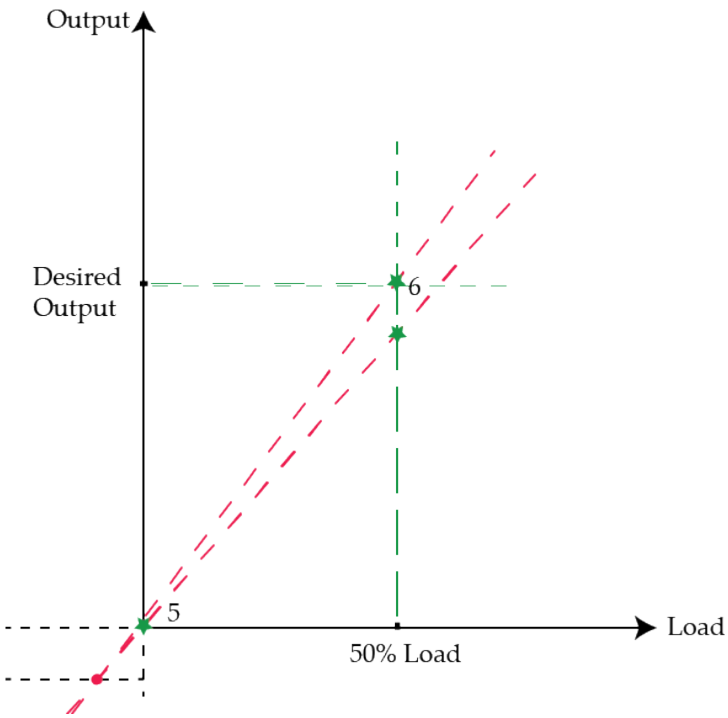
- Now when the gain is adjusted so that the output matches the desired output, this creates another bias error as shown below.



- Now when the bias is subsequently adjusted to zero then the output also moves lower than the desired output.



- The gain should now be adjusted to make sure that the output matches the desired output. And the process is repeated until zero and calibrated output matches the desired values.



302 – Calibrating Dancers

V 2021.11.15 – DR Roisum

Overview

Dancers can and should be calibrated just as are load cells. Here, a linear fit of tension (in appropriate units, see 300 Web Tension) as a function of dancer cylinder pressure or counterweight. As seen in these YouTube videos, the calibration graph should be first constructed by calculation by the designer and then checked by the service engineer or quality control technician by a simple test. Note that dancer friction (a measure of control design quality) and dancer calibration should be measured simultaneously. Finally, due to the very wide range of dancer arrangements and designs, you may need to adapt these ideas to your own specific dancer.

Web201.16a - Dancer Friction - http://www.youtube.com/watch?v=yV_JAZA3Ro8

Web201.16b - Dancer Calibration - http://www.youtube.com/watch?v=4isc_BYxitQ

500 – Wrinkle Overview

V 2024.01.06 – David Roisum

Motivation and Definition

Few webs and few web machines are immune from wrinkles. As such, wrinkles and associated problems could be the top cause of waste, delay, and customer complaint in the collective web industries. Associated problems are many and include poor customer acceptance, degraded printer registration, non-uniform coating, excessive web breaks and many others.

An inclusive definition of wrinkles is wherever and whenever the web is not adequately or observably flat. Quality Assurance and the customer may each have their own 'threshold of pain' where the threshold is 'adequately'. However, process troubleshooters would do better to be able to observe or measure **wrinkle severity** at a lower value than rejection for two reasons. The first is that by the time the severity reaches rejection, economic loss has already occurred. It would be helpful to observe or measure severity *approaching* rejection so that preventative action might be taken. The second reason is that the value of the measurements increases as the sample size increases. Thus, if you can measure flatness (or lack thereof) on every roll because your *analog* measurement is sensitive, you would have much more information than if you only record *binary* observational go/no go for the 10% of rolls that are rejected as an example. Thus, the motivation for developing and using web flatness measurements.

Wrinkle Types

While wrinkling is such an important topic for web handling, this text is not the place for treating that subject in any detail. The references below are a better resource for details. Nonetheless, it is imperative to have a wrinkling vocabulary and a wrinkling taxonomy. Words such as hard wrinkle, soft wrinkle, puckers, layflat and others are seldom suitable for any purpose due to their vagueness.

We first need to note *where* the web was observed to be not flat. We will use a roller oriented language for that purpose because rollers may either be the root cause or they are the trigger for another problem, such as bagginess, to manifest as a rejectable wrinkle. If the web is not flat in the open web span, we will call that a *trough*. While troughs are seldom rejectable, they can be if the web is not dead flat in a forming zone. More importantly, the open web span is where the troubleshooter will get more information more quickly than waiting for it to fail by creasing on a roller, for example. If the web is not flat going over a roller, we will call that a ridge. This is the rejection threshold for many webs because permanent damage has been incurred. Finally, if the ridge on the roller gets large enough, it may fold over into a *crease*.

Second, we need to develop a *taxonomy* that groups wrinkles into major types and subtypes. Subtypes within a single major type share similar or the same mechanics and often a similar appearance. Subtypes are the root cause in common language. While there are several taxonomies, we will use the one that has been in widest use for the longest time. First appearing in 1996, it is the basis of chapters in two books, one training course and one AbbottApp listed in references below. Almost all cases of less than perfect flatness fall into one of the types listed below.

MD Wrinkle – troughs, ridges or creases oriented close to the MD – mechanics are related to width – severity measured with Test 501 and 502

Tension too high (only low modulus materials)

Tension drop in a span or with time (only low modulus materials)

Temperature (e.g. film, film) or Moisture (e.g. paper, nylon) increase

Slender roller deflection

Excesssive roller grooving width

Roller groove or bump

Improper spreading

A 'lane' in the profile of the web

Diagonal Shear – wrinkle at a small angle – mechanics are that something, either web or roller, are crooked in some way - severity measured as the angle

Crooked web (such as bagginess measured with Tests 110.1, 110.2 and 110.3)

Crooked roller (inplane roller misalignment, uneven nip, etc)

CD Wrinkles – mechanics are MD compression – measured with Tests 501 and 502

Tunnel wrinkles (delamination)

Buckles in a wound roll (air escape, starring, core collapse etc)

Baggy Web – mechanics are a MD residual tension profile, often caused by a web with a thickness profile variation upon winding - measured with Tests 110.1, 110.2 and 110.3

Manufactured or converted baggy

Gage bands stretched into baggy lanes upon winding

Brutish handling (very uncommon)

Corrugation – after winding a web with a high-low or high-low-medium profile

Curl – mechanics are a variation of MD tension across the thickness of the web – measured with Test 113

'Sidedeness' in forming

Coating on one side

Lamination

Rollset

Chiral (diagonal)

References

You can find more than 200 wrinkling articles, columns and books in the Roisum Library database either as an MS Excel file or as an AbbottApp https://www.stevenabbott.co.uk/abbottapps/RL/index.html. However, the following are the most influential, with [5] being clearly the most modern and complete treatment.

1. Roisum, David R. *The Mechanics of Wrinkling.* Tappi J, vol 79, no 10, pp 63-70, Oct 1996 and Tappi J, vol 79, no 10, pp 217-226, Oct 1996

2 Walker, Timothy J. The Taxonomy of Wrinkles 10th Int'l Conf. on Web Handling Proc., Web Handling Research Center, Oklahoma State Univ, June 7-10, 2009

3. Smith, Duane. *The Ultimate Roll and Web Troubleshooting Guide, chapter 4.* TAPPI PRESS, 2013.

4 Roisum and Abbott. Wrinkle Troubleshooter, 2013 https://www.stevenabbott.co.uk/abbottapps/WT/index.html

5. Roisum, Walker and Jones. *The Web Handling Handbook, chapter 9*, Destech, 2020.

601 – Amount of Bow

V 2024.08.08 – Neal Michal

Background

Bow rolls are used to spread the web laterally in the cross-machine direction (CD). Bow rolls are known by several names such as curved axis rollers, banana rollers, or simply spreaders. Some bow rolls are adjustable as the one shown below in Figure 1. Others have a fixed bow as shown in Figure 2. For most web processes a fixed bow roll with 0.5% to 1% is all that is required. Adjustable bow rolls can be twice as expensive as a fixed bow roll. Adjustable bow rolls will also have a lower natural frequency which will cause them to vibrate at a lower speed than a fixed bow roll.

Figure 1 Adjustable Bow Roll (Courtesy of Converting Accessories)

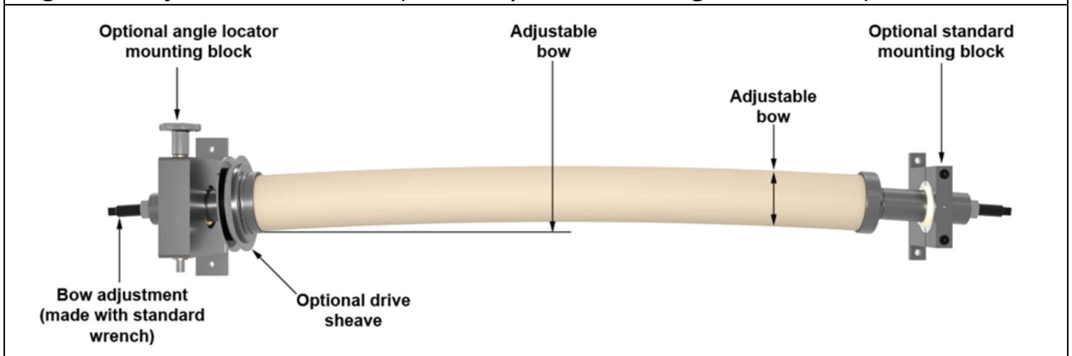
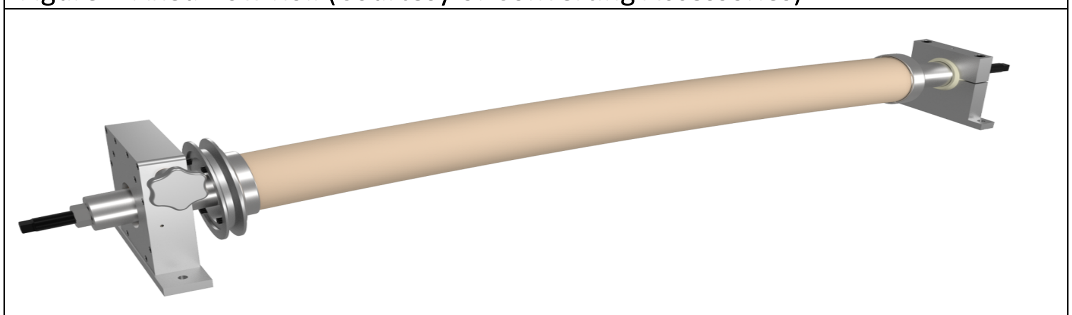


Figure 2 Fixed Bow Roll (Courtesy of Converting Accessories)



Purpose

Measure % Bow for a Spreader Roller

Definition

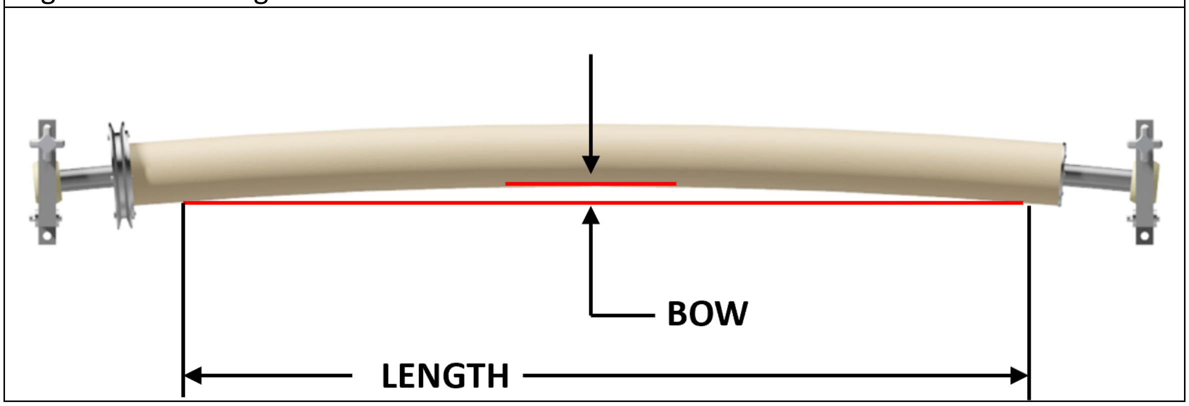
% Bow is the maximum amount of bow in the middle of the roller divided by the width of the bow roll times 100.

Process

1. Lock out the machine according to your mill's safety guidelines.
2. Measure the nominal face width of the bow roll.

3. Look closely at the bow roll to find the inside arc of the curvature.
4. Mark the center of the bow roll with a sharpie or a piece of tape.
5. Place a straight edge along the inside of the curvature. Make sure it is centered on the bow roll.
6. While holding the straight edge with the two corners touching the inside of the bow roll, measure the gap from the center of the bow roll to the inside edge of the straight edge. See Figure 3 for details.
7. It is best for two people to take this measurement. One holds the straight edge. The second measures the amount of bow.
8. Remove mark on the bow roll or the tape
9. Remove lock out
10. Divide the amount of bow by the length of the straight edge.

Figure 3 Measuring the Amount of Bow



Sample Calculation
Roll Face = 110”
Length of Straight Edge = 100 in
Amount of Bow = 0.75 in
% Bow = (Bow / Length)*100
% Bow = (0.75 in/100in)*100
<u>% Bow = 0.75%</u>

800 – Wound Roll Testing

Overview

Wound roll testing can be used to troubleshoot certain web and certain winder problems. It can also be used as a quality assurance tool to downgrade or quarantine or cull rolls that do not conform to product specifications or would otherwise be risky to send to the customer.

Preparation

Many tests could be done on every roll set between the winder and the warehouse or shipping, if there were the time and need. Some tests, such as diagnosing returned rolls, are better done in a quiet aisleway. Ideally, the packing and outer several layers of a roll should be removed prior to testing. Documentation would include the usual time/date of testing, time/date of roll manufacture, web grade (SKU, part number etc) and roll ID# [801, 802].

Wound Roll Tests

800 – Wound Rolls
801 Roll Diameter
802 Roll Width
803 Roll Length
804 Roll Edge Roughness
805 Roll Hardness (hard rolls)
806 Roll Density (for soft rolls)

References

801 Web401.21c -Traceability - Roll ID. AllWebHandling channel of YouTube.
802 Web401.21d - Traceability - Lane Mapping. AllWebHandling channel of YouTube.

801 – Wound Roll Diameter

V 2021.10.25 – DR Roisum

Overview

Wound roll diameter, along with roll width and length, are common commercial specifications. It can also be used to troubleshoot certain web problems (such as poor profile) and certain winding problems (such as not stopping at the correct wound roll diameter).

801.1 – Automated Roll Diameter Measurement on the Winder

Many modern winders include roll diameter readouts for any number of purposes such as the basis for tension taper, automatic roll stop-to-diameter, safety shutdowns, drive motor inertia compensation to name just a few. Three common continuous measurements include the dual tach (one on a roller in traction and the other on the core chuck or core shaft, also in traction), nip roller position (such as via absolute encoder) or ultrasonic. Accuracies vary (the dual tach being the best) from less than 100 micron to perhaps 1 centimeter.

801.2 - Roll Diameter as a Circumference

The most accurate offline measurement is a circumference using a flat tape measure. Unfortunately, this requires a roll be stored on end or suspended and is much more time consuming. Accuracy can be improved, and some profile checks can be made by measuring the circumference in 3-5 equally spaced intervals.

801.3 - Roll Diameter on the Roll Face

The fastest offline measure is using a ruler or tape measure on the roll face. On all but the hardest rolls, it is best to take the measure at 45 degrees on both sides of vertical and average the two. Measuring both ends of a single roll increases measurement resolution even a bit more. Avoid making the measurement horizontally and especially vertically to reduce the effect of roll distortion sitting on the floor. See Figure 801.31. Note, this method does not work well for webs whose thickness drops off at the ends, such as coated products where the coating does not extend all the way to the ends.

Figure 801.31 – XXX to be added

802 – Wound Roll Width

V 2022.01.22 – DR Roisum

Overview

Wound roll width, along with roll diameter and length, are common commercial specifications. The width of the roll can be more complicated that merely setting the correct or consistent slitter-to-slitter distance, especially for low moduli webs and thus looser tolerances can be expected for those products. Tighter width tolerances are more common with stiff materials such as paper and especially metals.

802.0 – Roll Width Varies with Respect to Radial Position

Because (MD and ZD) stresses vary with respect to radial position, so also must the wound roll width as shown in Figure 802.1. While roll width is usually specified at the OD of the roll, the bulging of the interior locations may cause at least two issues, particularly for low moduli materials such as nonwovens and tissue. The first is that the width variations will not entirely recover when unwound so that the product width as seen by the customer will vary. The second is that the rolls will not stack on end as well. Winding looser, to the extent practicable, and not over specifying width beyond product/process capabilities, will be helpful.

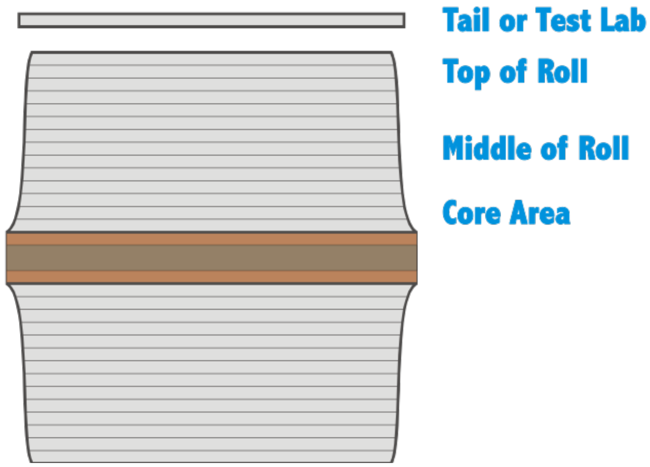
802.1 – Using a Carpenter’s Tape Measure

The most common way to measure roll width, by far, is using a common carpenter’s tape measure by hooking the hook on one roll edge (usually the left side as you face it), extending the tape and reading the width on the other edge. This could be a certified tape measure or merely one that might be found in any hardware store. Accuracy and repeatability of the measurement is usually better or much better than 1 mm or 1/8” for rolls whose cut is clean and roll edges are straight. This is also a common commercial tolerance for slit width, though some products are notably tighter. Low modulus webs or webs which will be slit again in the next process may have a bit looser tolerances.

802.2 – Using a (Digital) Caliper

For roll width for narrower than say 10 mm, 2.5”, it is often better to use a digital caliper whose accuracy and repeatability of measurement is often better than 0.1 mm or 0.004 or the thickness of a human hair.

Figure 802.1 – Roll Width as a Function of Radial Position


Tail or Test Lab
Top of Roll
Middle of Roll
Core Area

803 – Wound Roll Length

V 2022.01.22 – DR Roisum

Overview

Wound roll length, along with roll diameter and width, are common commercial specifications. Length tolerances are often even tighter for synchronized unwinds where two or more supply rolls will desirably finish unwinding at nearly the same time.

803.0 – Roll Length Complications

There are many sources of roll length variation that can contribute to discrepancies and complaints from customers who may get different measurements for length. Measurement issues include OD slabbing or leftover material on the core, timing of footage enable/disable, slippage on wheel/roller, the ‘real’ diameter of wheel/roller and the ‘effective’ diameter of wheel (nip) and roller (web thickness). Material behavior issues include differences in tension at two different measurements, temperature (most materials) and moisture (paper and some polymers) changes, creep, crystallization shrinkage of newly extruded polymers and more. When faced with measurement discrepancies, the sizes of these sources should be estimated so that specifications will be within product/process capabilities.

803.1 – Roll Length Using Tachometer

The most common way to measure roll lengths is via counting revolutions of a roller, motor or wheel. Length is calculated ‘simply’ the number of revolutions times the roller (or wheel) circumference. ‘Simple’ is in quotes because of the complications listed above.

803.2 – Roll Length Using LDA

Roll length can be measured by LDA (Laser Doppler Anemometry). Several commercial devices are available. Though roll diameter and slippage can’t not occur with this method, LDA is not immune to some of the other complications listed above.

803.3 – Roll Length Using A Tape Measure

Roll length for short rolls can be measured directly by unwinding onto the floor and measuring length with a long tape measure such as might be used for landscaping. If necessary, the slightly longer roll can be cut into manageable lengths, each of which is measured and summed. This method becomes impractical when roll lengths exceed a few hundred yards or meters.

805 – Wound Roll Hardness (for Hard Rolls)

V 2022.01.25 – DR Roisum

Overview

Wound roll hardness is a very common test used by QA, manufacturing, and winder troubleshooters alike. 'Hardness' is a common synonym for tightness and is an indication of the magnitude of (MD and ZD) stresses at the top of the wound roll. Test 805, described here, is for harder, denser rolls such as paper and many films. However, extremely dense materials such as linerboard and certainly metals may be off scale for commercial instruments. Test 806, described next, is for softer, looser and fluffier wound rolls such as many nonwovens, textiles and tissue where the readings may be 'in the mud' low for commercial test instruments and thus lack resolution.

How to Measure

Test 805 has two applications that inform sampling, though the instrument chosen may be the same. At this time, the known commercial roll hardness measurement instruments include those of Table 805.1 and are listed in approximate order of invention/commercialization. If readers are aware of other instruments, please contact the authors. The first task of the engineer is to select the device among the options based on some combination of sensitivity (resolution), ease of use, data recording, prior history and so on [1]. Sensitivity is evaluated by comparing variation of readings of devices on the same wound roll [2]. Note that repeat measurements should always be in in the same CD location but a slightly difference circumferential position.

Table 805.1 – List of Known Roll Hardness Measurements

Billy club - a hard wood stick about 5 cm in diameter and 50 cm long
Schmidt (Concrete) Hammer
(Beloit) Rhometer – mechanical or CPU based.
Parotester II
TAPIO Roll Quality (hardness) Profiler
ACA Systems RoQ roll quality analyzer.
Technidyne

The first of two applications that informs sampling is **if one suspects that manufacturing may not be uniform**, i.e. the caliper/thickness/weight 'profile' is not level. In that case one samples across the top of the roll at evenly spaced intervals such that at least 3 measurements are made at the front, center and back. Avoid measurements within about 5 cms of the edge of the roll to avoid edge effects that would result in artificially lower values of hardness. Repeats may be done to increase resolution. However, they must be in the same CD location, but always moving to a slightly different circumferential location. A plot of roll hardness versus CD position is the result that is to be interpreted to either cull rolls (if hardness variation across a single roll is excessive) or to make level corrections at an appropriate upstream process step.

An interesting somewhat recent application for roll hardness profile variation is to cull rolls that may not be runnable, due to **web bagginess**, due to a combination of high average roll hardness and the maximum delta of hardness, both across the top of the same wound roll [3,4].

The second of two applications that informs sampling is **if one suspects that the winder TNT programming, e.g. 'curves' or 'taper' may not be ideal.** In that case, one samples as above, but *average* of the samples taken across the width is recorded. More importantly, sampling is done at various radii by either winding or unwinding and stopping periodically to make the measurement. A plot of average roll hardness versus radial position is the result that is to be interpreted for TNT changes.

References

1. Roisum, David R. *Roll Quality Measurements.* Module 27 of Web101 shortcourse.
2. Roisum, David R. *How to Measure Roll Quality.* Tappi J., vol 71, no 10, pp 91-103, October 1988.
3. Thuer, Amy. *Using Roll Hardness to Screen for Excessive Web Baginess.* 12th Int'l Conf. on Web Handling Proc., Web Handling Research Center, Oklahoma State Univ, June 2-5, 2013
4. Roisum, David R. *New methods to screen wound rolls for bagginess*. Converting Quarterly, qtr 4, 2013.

806 – Wound Roll Density (for Soft Rolls)

V 2022.01.25 – DR Roisum

Overview

Wound roll hardness is a very common test used by QA, manufacturing and winder troubleshooters alike. ‘Hardness’ is a common synonym for tightness and is an indication of the magnitude of (MD and ZD) stresses and density at the top of the wound roll. Test 805, described previously, is for harder, denser rolls such as paper and many films. Test 806, described here, is for softer, looser and fluffier wound rolls such as many nonwovens, textiles and tissue where the readings may be ‘in the mud’ low for commercial test instruments and thus lack resolution.

806.1 – Bulk Density

The bulk density of the wound roll is very responsive to even small changes in the winding TNT’s as well as hardness, stress or tightness. Density is most easily calculated as

Equation 806.1

The weight of the roll and core are measured using scales of appropriate size and sensitivity so that the resolution is well better than 1% for the smallest roll. For shipping rolls, the easiest may be a scale at the end of the winder or near the loading docks. Roll diameter is measured using one of the methods described in Test 801. Roll length/width is measured using one of the methods described in Test 802.

806.2 – Density Profile

Density profile information is possible if one can cut a single roll up into narrower rolls and using the method of Test 806.1. If the widths and diameters are similar, you may be able to do the calculation based on the measured weights of the daughter rolls and using an average single measurement for the other parameters. Obviously, the profile information that results is quite ‘chunky’ for three daughter rolls across the width and merely chunky for a dozen rolls across.

806.3 – Roll Structure via Density vs Radius

It is either time consuming or difficult to get ‘roll structure’ type information using density. However, there are two methods. The first is to unwind or slab down say ten times from the OD to the ID. The calculation of Equation 806.1 uses the *delta* of roll weights and *delta* of roll diameter between two consecutive roll diameters during the periodic unwinding/slabbing.

The other method is extremely sensitive and that is to use automated roll density computer using the dual tach method. Figure 806.1 shows a schematic and a complete description every aspect of design for this instrument is given in the references [1,2].

Figure 806.1 – Roll Density Analyzer Schematic

References

1. Eriksson, Leif G and Lydig C and Viglund JA and Komulainen, Pekka. *Measurement of Paper Roll Density During Winding.* Tappi J., vol 66, no 1, pp 63-66, Jan 1983.
2. Roisum, David R. *The Mechanics of Winding*, chapter 3. TAPPI PRESS, 1996.