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Forming section monitoring

Scope

Instrumentation to measure, monitor, and troubleshoot the wet end of the paper machine is widely used to increase the knowledge of the papermaker. The objective of this technical publication is to provide the industry with a short description of the key parameter to be measured, its importance to the papermaker, and a listing of known commercial instruments used for these measurements. It should be noted that many of these instruments and methods have been developed or modified for the paper machine and that considerable practice and skill may be required to get reliable results.

Parameters discussed include:

1. Forming fabric thickness
2. Forming fabric air permeability
3. Forming fabric tension
4. Roll abrasiveness to a fabric
5. Foil angle and foil pitch
6. Surface finish of machine components
7. Surface speed of rolls or fabrics
8. Roll diameters
9. Sheet temperature
10. Motion Analysis
11. Wet end drainage
12. Sheet formation
13. Wet end dragload
14. Headbox jet velocity

Safety precautions

All applicable safety procedures for working around the wet end of a paper machine must be followed. These include standard safety precautions for working around moving equipment, and specific safety regulations required by the facility where the work is to be performed.

All measurement equipment instructions should be read and followed. It is highly recommended that a ground fault interrupter be used on the power cord when working with electrical power around the wet end of a paper machine to prevent electrical shock from short circuits caused by moisture.

Measurement parameters

Forming fabric thickness (caliper)

Residual fabric thickness is an indicator of the amount of wear and is one of the indicators used to decide when a fabric needs to be removed. Routine monitoring of caliper compared to historical data determines rate of wear and detects wear problems. Fabric thickness can be measured on machine a few inches in from the edges with C-frame calipers, or full width with a coatings thickness gauge. The full width caliper profile can also be done when the fabric is removed.

On-machine instruments most used are C-Frames with anvils attached and a dial indicator. The depth of the C-frame varies with the manufacturer, but normally ranges 150 – 380 mm (6 to 15 inches). This test is normally done with the machine down, but can be done on the run if the risk to fabric damage is taken into consideration.

A second method uses a sensor designed to measure coating thickness by measuring the distance from the top of the coating to some type of solid background material, usually a magnetic base such as steel. A full cross-direction profile can be made by placing a steel plate under the fabric on a foil or other fixed object, and taking a reading of thickness from the top side of the fabric to the plate. The plate can be moved across the machine, and readings taken at known intervals. DeFelsko and others manufacture instruments of this type.

A complete wear analysis in the cross-direction can be very informative once a fabric has been removed. Caliper profile can be measured by pulling a strip of fabric through a fixed-point caliper instrument, such as those used to measure paper caliper, and a profile of the fabric plotted. A second method involves use of a continuous profiler. Caliper analysis combined with microscopic analysis of the type of wear is a powerful tool in determining the main sources of wear and in extending fabric life. Visual examination of yarns with a low magnification lens is often used during the life of the fabric to monitor the type of wear being measured by caliper loss. An article by Pitt (1) provides a broad overview of fabric wear.

Forming fabric air permeability

The ability to measure fabric air permeability during the life of the fabric can be another useful tool in analyzing the effect of fabric wear. The analysis can be done both in the cross-direction and in the machine direction. On-machine analysis is done during a shutdown after careful drying of the area to be measured, using a portable air permeability tester that allows the measurement of airflow through a known area at a controlled pressure drop. This same instrument can be used on dryer fabrics. A commonly used measurement device for this type of work is the Metso Permtest Meter. A portable tester is also made by Textest.

In the laboratory, or at the fabric-manufacturing site, air permeability is commonly measured with a Frazier or Textest permeability tester.

Forming fabric tension

Forming fabric tension is controlled on the paper machine with the fabric stretch mechanism. The machine stretch mechanism may have an indicator of fabric tension, but it is standard practice in the industry to check tension with a portable tension meter. Fabric tension must be controlled within a range for traction on the machine, uniform drainage characteristics, and good sheet formation.

The most common unit for forming application is the Huyck unit sold by Weavexx. A similar unit is sold by A. Malo Ltee. The tension gauge has a bar contacting the fabric, and is attached to a spring-loaded plunger connected to a dial indicator or electronic readout. Honigsmann has two tension meters, one for speeds below, and another for speeds above 1000 mpm.

The unit is put on the fabric, normally on the return run, and readings taken while the machine is running. Readings should always be taken in the same location as tension does vary with position around the loop. The user must understand the proper use of this instrument to prevent damage to the fabric. Readings are normally in pli or N/m, but some are in tester units and a calibration graph is required to convert to force per unit of width. Calibration will be dependent on fabric style so care must be exercised when using absolute readings. Older machines may run as low as 2.6 to 3.5 kN/m (15 to 20 pli), while new machines may run as high as 7.9 to 8.8 kN/m (45 to 50 pli).

FelTest BV has introduced a digital tensometer called Tensio+ with readout options in N/mm, kg/cm, or pli. It can export data and can be used to record tension profiles. It is reported to be insensitive to operator technique which can influence the readings on previous types of sensors.

Roll abrasiveness to a fabric

When fabric wear is caused by an abrasive roll cover or corroded roll shell, it is useful to determine which rolls are most abrasive, so that priority for maintenance can be established. A test method that indicates relative abrasiveness of one roll to another is useful to determine which rolls need corrective action. Two tests are used; one is a direct measurement while the other is indirect or inferred.

The direct method involves a known caliper or weight sample of fabric mounted in a holder, and loaded against the roll for either a set time or lineal distance. The sample caliper or weight is remeasured, and the loss calculated. The test is repeated for all rolls in the fabric loop, and the relative abrasiveness of each roll ranked from the results. This test is limited to the front and back edges of the rolls unless the roll can be turned without the fabric on the machine. Some roll locations may not allow for testing with a hand held tester. Due to the safety concerns with this procedure, it is recommended that only trained personnel from the fabric suppliers perform this testing and therefore, no listing of test instruments is provided in the Appendix. Some fabric suppliers no longer offer this testing due to safety concerns.

A more commonly used method is to infer abrasiveness by measuring surface profile using a profilometer. The test instrument is discussed in the section on surface finish. No definitive study exists on roll cover roughness and fabric wear. Factors such as cover type, roughness, and speed differential between the roll and fabric have an influence on potential fabric wear. A rule of thumb is that roll cover roughness over 100 Ra is considered abnormal and the roll should be scheduled for grinding.

Foil angle and foil pitch

Foil angle is important as it affects drainage, retention, and stock activity. Foils wear with time. Misalignment can cause difference in angle in the cross-direction. Foil angle may change from the machine at rest to the running condition if the holder allows excessive movement of the blades. Angle measurement documents actual versus indicated angles and monitors foil wear.

Foil angles can measure differently with the machine down versus running. Plastic blades normally have some tendency to rotate on the tee bar. Plastic blade warp may cause the reading on the end of the blade to differ from readings inside the fabric run. The user should always note whether the machine is running or down with the readings.

Foil angles can be measured with any commercial inclinometer, either a bubble-type, or as most often used today, a digital indicator. The readout is the angle relative to horizontal, in degrees or radians. The same instruments can be used to check level of other stationary dewatering components.

Foil pitch, or distance between blades, is an important variable in drainage and stock activity management. Studies have shown that blades spaced closer can increase drainage and stock activity compared to the same set of foils used on wider spacing.

Foil pitch is commonly related to fabric speed and then referred to as foil frequency. Foil frequency is expressed as pulses per second, or Hertz. Foil frequencies above 60 Hz are normally beneficial on single wire forming. Turbulence is difficult to control above 100 Hz on fourdriniers.

The following formula is used to determine foil frequency:

$$F = \frac{S}{5 \times P}$$

where:

F	=	pulse frequency, Hz
S	=	fabric speed, ft/min
P	=	foil pitch, in.

Surface finish of components

Surface finish or roughness is an important factor in control of fabric wear. Surface finish of polished machine components, such as electropolished stainless steel in a headbox, has always been an important part of the control of buildup. The same instruments that are used to measure polished metal can also be used to measure wear surfaces such as foils and suction box covers.

The two most common portable instruments used are the Mahr Federal Pocket Surf and Taylor Hobson Surftronic. Both use a diamond stylus attached to a motor-driven arm that traverses the stylus over the measuring surface. Measurement results can be expressed in different units, so the user must be aware when comparing results from different

sources. The most common unit of expression is Ra, the average roughness value of the measurement, either in micrometers or micro-inches. Other units of expression can include Rtm (Rz DIN), which is the root mean square average, or other various maximum measured values.

Surface roughness of ceramic elements on the wet end should be monitored for roughening compared to the original factory polished finish to reduce the possibility of excessive fabric wear. It is particularly important that edges of holes or slots on ceramic covers be well polished and have a radius, as these can be far more abrasive to fabrics than flat surfaces. A rule of thumb is that early forming table elements should be 16 Ra or less and high vacuum box covers should be 10 Ra or less (lower is smoother).

Surface speed of fabric or rolls

Surface speed is measured to determine actual speeds versus indicated for both the fabrics and rotating machine components, and for troubleshooting slippage between components. The measurement is made by a contact tachometer with a small wheel attached to a digital counter that reads revolutions as feet or meters per minute. Special versions of these counters with large diameter wheels are used for determination of running length of the fabric. Accuracy of the tachometer varies with the manufacturer and should be known by the user. Slippage of the measuring wheel or misalignment of the wheel to the moving surface can also affect accuracy. Standard tachometers are readily available from numerous manufacturers. Fabric-length wheels are less common.

An alternate method that is used more for special diagnostics is to mount a reflective tape on the end of a roll or on the journal and to measure rpm with an optical tachometer. This method usually requires that tape be mounted during a down day. Since this is not a routine method, it is not discussed further in this document.

Roll diameters

Roll diameters can be measured on the machine using a steel pi tape. The units on a pi tape are made to indicate diameter when the circumference of the roll is measured. The measurement must be taken with care to ensure that the taped length is the shortest distance around the circumference to provide an accurate diameter reading.

Sheet temperature

Average stock temperature is most accurately determined in the early forming section by use of a calibrated thermometer at the headbox or white water pans. Sheet temperature begins to cool once air is drawn through the sheet over vacuum assisted dewatering elements. Non-uniform CD sheet temperature entering the dryer section can cause moisture profile variation at the reel. An infrared (IR) pyrometer is the best method to measure wet sheet temperature. Numerous brands of IR pyrometers are available. The emissivity of a sheet has been determined to vary with moisture content. A study by Trepanier (2) showed that emissivity is dependent on the fiber-water-air surface interface condition, which varies down the paper machine. The minimum emissivity of 0.65 is reached at 40-60% solids. In practice, measurements are typically made using an emissivity of 0.92–0.95 from the wet end to the dry end.

The path between the instrument and the sheet should be free from significant amounts of steam or water vapor when taking a measurement, or the temperature reading will be in error. An IR pyrometer can be used to measure temperature changes resulting from the use of a steam shower.

To evaluate the variation in cross-direction temperature, an infrared thermography system is more informative than a pyrometer. A thermography system uses a video screen to provide the user with a thermal image of the object.

Thermography systems give a real time picture that shows variations in temperature as they occur. When linked to video or digital recorders, further analysis of the data is possible. At the wet end, evaluation of steam boxes, basis weight variation, or plugged suction boxes or couch rolls can sometimes be done with these systems.

Motion analysis

Motion analysis at the wet end generally falls into two categories, examination of stock activity on the forming fabric or random event capture. Stock activity is typically performed using strobe light illumination, still photography with flash exposure, or video recording with strobe light illumination. Random event recording can be done using special high speed video tape recording or with digital recording technology.

Examination of free surface activity or flow disturbances on a moving fabric is one method used by the papermaker to correlate operating variables and final sheet properties. Strobe light illumination can be very useful for short-term observations while still photography and video allow documentation for future use.