New Technology for measurement of Roll Hardness

By Micky Rowell Technidyne Corp. USA  AIMCAL 2016

Abstract:

Traditional methods for measurement of Roll hardness have many short comings. Some of the most common issues I've discussed with those responsible for roll condition; operator dependent operation, frequency of service or repair and most often, difficulties in obtaining a reliable CD profile of the roll under test. By utilizing sound physics practices and high speed electronics we can finally have operator independence and reliable profile capabilities with robust data collection to trouble shoot and optimize web product roll condition.

Background

Why measure Roll Hardness? Converting speeds (i.e. printers, die cutters, packaging etc.) are constantly pushing the envelope to increase their production output. Higher and higher demands are being put on roll product manufacturers.

Baggy edges, Gage bands, Telescoping, Blocking, Staring just to name a few are all issues that can be detected with proper roll hardness measurement systems.

The objective of any web product manufacturer is to build as many rolls with as few defects as possible. Your customers need to know they can count on you to ship them consistent product in order to keep their production running smoothly.

Reduce variation in roll quality hardness profile can be used to cull customers rolls or provide valuable information upstream to adjust process parameters and improve roll consistency.

Introduction

Several methods to measure Roll Hardness have been developed over the years. Many of which are operator dependent and require a well trained operator to use.

There are many factors which can influence, accurate and reproducible measurement of Roll Hardness.

- Orientation of the strike with relation to the core (direction of force should be radial)
- Striking force with which you contact the surface of the roll
- Measurement of the striking force (velocity) is extremely difficult due in part to the extremely brief moment of contact (approx. 2ms).
- Difficult to provide meaningful profile information, accurate distance between measurement points.

With the use modern day (high speed) electronics and age old physics, there is now a tool developed that will produce results with excellent repeatability and reproducibility, without the influence of the operator. This new tool also has the capability to easily export the test results (wired or wirelessly) to the appropriate data systems and personnel who can then make the necessary adjustments to your process, and either improve quality of your customer rolls or to tweak your converting process and keep your production lines moving.
Measurement methods

Traditional methods

The back-tender’s stick, has been and in some areas, continues to be the go-to tool for determining roll condition variation. This tool is nothing more than a miniature baseball bat (usually made of hardwood) (2). The operator traverses from one end of the roll to the other striking his "stick" on the surface of the roll listening to the sound generated by the strike. His free hand may also be used to hold against the roll surface to feel vibrations induced in the paper by the strike of the club (2). This tool requires a skilled operator with a trained ear to use properly. However, with that right operator a very good correlation exists between the operators perception (from the "stick") and what can be measured by more modern tools of today.

The major short coming with this tool is there is no way to quantify these results. The results are also short term, meaning there would never be a way to compare yesterday's or last week's results in a measureable way. (2)

More modern methods, began to develop in the 1950s-1960s introducing a method of measuring roll hardness with Rebound methodology. Most having similar designs that utilized a compression spring (to generate the force/velocity) connected to a plunger with significant mass (body) attached to generate what was meant to be a constant force. Rebound testers such as these measure the coefficient of restitution. (4)

\[ CoR = \sqrt{\frac{\text{bounce height}}{\text{drop height}}} \]

The rebound methodology short comings were, again operator dependence and were subject to variations in the products they were being used to measure. Measured materials have different elastic properties, which can then produce miss-leading or incorrect results (2). As an example, a material with high elastic properties (dense rubber) could generate a rebound reaction, similar to that of a very hard material (metal) with low elastic properties. In this case both measurements taken and calculated with the above formula, may produce similar "hardness" results, when truly the two materials are quite different in hardness. This makes comparing the results from this technique from one product to another difficult at best.
More sophistication:

The late 1960's and into the 1990s brought us new inventions continually striving for methods that would reduce operator influence and produce more consistent results.

The first (1969) of which introduced the use an electronic transducer to determine the peak force at which the striking body hits the surface of the roll and quickly produce the results on a digital display. The housing included a "shoe" to rest, the unit, on the roll surface and assist the operator in aligning the striking body in the radial direction of the roll.

A second device introduced in mid 1990 (Fig.1) took into account the force of the blow to "normalize" the hardness reading. This device incorporated a different design, which was more user friendly and designed to reduce the operator to operator variation. A hammer type tool with an accelerometer installed in the head is connected electronically to a keypad/data collector. Much like the back-tenders stick, the hammer is used to strike the roll surface. Two bits of data are collected, 1: the force with which the hammer (operator) strikes the surface and 2: the peak deceleration of the hammer as it comes in contact with the roll surface. The two pieces of data are combined in the computation to produce a "hardness" value independent of the force the operator generates for the strike. Thus reducing the variation of operator to operator (3).

One major pitfall with all of the devices mentioned above is in trying to strike the roll surface in such a way as to produce evenly spaced data points in the Cross Direction for a reliable profile evaluation. In addition to extra steps necessary to transfer the data to a device (PC or data historian) for analyzing.

Fig. 1

![Fig. 1](image)

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More modern design

Utilizing the excitation of an electronic solenoid to accelerate the striking body towards the surface of the roll. The housing, "shoe" is designed with a radius which will nest with the roll surface, thus ensuring alignment of the striking body in the radial direction each time a measurement is taken.

We can very precisely and repeatedly accelerate the striking body towards the roll surface with a known velocity. As soon as the body comes in contact with the surface of the roll, it begins to "decelerate". Once the velocity of the striking body reaches 0, the results are calculated and displayed on a high definition touch screen built into the housing. The results are reported in g-force or $1g = 9.81\text{m/s}$. The rate of deceleration, as established with earlier designs, has a direct relationship to surface Hardness.

Ergonomic considerations have been incorporated into the newest designs to eliminate operator influence from the measurement process. Overall size and shape have been designed to fit the average hand size. The weight of the unit is approximately 3lbs, so even the smallest operator should be comfortable using them for extended periods of time. Robust packaging to withstand normal handling. A break-away safety strap is also included to prevent dropping on the operations floor.
The test cycle

The striking body (known mass) is attached to a solenoid which when energized, produces the movement which drives the body towards the surface under test (Acceleration curve) Fig. 2. At the point of contact the body immediately begins to decelerate (Deceleration curve) Fig. 2. The acceleration curve is analyzed to calculate the maximum velocity produced at the time of collision. The body will strike the surface at a frequency of approximately 30Hz. One strike cycle time is approximately 20 ms. The time of contact between the body and roll surface is in the order of 2 ms. The Striking body motion is dampened in between strikes to reduce any residual effects on the next strike cycle.

Fig. 2
Measurement accuracy considerations

We have been able to determine, thru experimentation, that it is nearly impossible to reproduce the exact same striking force without taking extra measures to accurately measure each strike. We have to employ these extra measures to develop our target velocity.

Plunger Position is monitored 100,000/s
  • High precision distance measurement
Travel Time determined with a 48MHz clock
  • High precision time piece
Calibrated mass determination
  • Total mass of plunger mechanism measured on high precision scale
Position of the device at the time of contact is determined with distance encoder
  • Encoder calibrated to 0.1mm

Transport speeds (Cross Direction movement) of approximately 30cm / sec. (recommended by the manufacturers) mean very short test times to develop the roll profile and download data to your mill information system. A parent roll of 200 in can be completely evaluated and data downloaded in less than 20sec. Fig. 3 shows the typical application of one of these devices.

Fig. 3
Presentation of Results

Graphic and numeric (data) representation of the roll under test is generated immediately following the completion of each test. Automated data transfer capabilities further expedite data movement to the mill data collection systems and personnel, who can then act on disposition of, future optimization of or maintaining the condition of each roll coming off of their machines. (See Fig.4)

**Fig. 4**

- Measurement date
- Measurement time
- Barcode

On Y-axis is the hardness value, the unit is g (gravity)

X-axis shows distance in desired unit:
- Meter, inch or dimensionless number (it can be defined by actuator spacing for example)

Key values of the average profile are shown above the graph.

The average profile is white line and individual profiles are coloured lines (red, green and blue)
Comparing results

Although there are similarities in the profiles developed with traditional and this modern technique, the difficulty comes with comparing their respective absolute values and the resolution of results. Where older technologies can measure at approximately, 1/2 - 1.0" resolution, the newer devices, resolution is 1mm. Fig.5 compares the results of one older design to that of the newest design. Showing the difference in defining a "Buckle" known to be in a customer roll.

The newest approach measures deceleration of the striking head from the point of collision to the point of 0 velocity. By doing so, we eliminate any effects of material elasticity (no rebound measurement used in the calculation), similar to "normalizing" the hardness description/result. (2)

1g = 9.81m/s.

Fig. 5  Deceleration and Hardness profiles (1 roll 5 operators) similar profiles, very different absolute numbers and more definition with new measurement technique.
Benefits of the new method

Data generated is extremely reliable. Data integrity is extremely high by automating the data storage, data transfer and analytical steps.

Operator independent. The operator has to work extremely hard to place the device on the roll in such a way that the plunger is not perpendicular to the surface and roll core, thus reducing the chance of data error.

Summary:
Roll condition is the evaluation of many characteristics of which Roll hardness is one of them. Utilizing modern electronics and high speed computing power, and proven scientific formulas, we have designed a tool to better define the hardness profile of rolled materials. Removing operator error, improving reliability, ease of data transfer / analysis / utilization of the data,........all contribute to improved roll quality and customer satisfaction.

Always remember:
Winding can't make the roll quality better, but it can make is worse (5)

Literature cited:
4. ParoTester2 Literature
6. Manufactures manuals (ACA Systems)