Non-Contact, Laser-Based Technology for Accurately Measuring the Length and Speed of Product in Web Coating and Lamination

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ABSTRACT

The accurate control of product length and speed is becoming increasingly important as the web coating industry focuses on process optimization, quality control, and improving the bottom line.

As a long-time practice, length and speed measurements were obtained through tachometers and encoders attached to rollers or contact wheels. However, contact measurement methods are prone to calibration changes due to wear, and they often experience measurement errors caused by slippage between the roll and the material being measured.

Non-contact, laser-based gauges were developed more than 25 years ago. The first non-contact laser length and speed gauges were big, bulky, very expensive, and met with limited success in the market. Much technological advancement has occurred since then. The new generation of non-contact length and speed gauges are smaller, much less expensive than gauges previously available, and provide the high measurement accuracy and high performance offered by more expensive gauges.

Manufacturers across the globe are widely adopting non-contact, laser-based technology, such as the LaserSpeed gauge, for a variety of production applications including differential speed control, stretch and draw, and continuous length, cut control, to name a few. This technology can measure the length and speed of any moving product with an accuracy of ±0.05% and 0.02% repeatability without making contact. This gauge has no moving parts, it eliminates all slippage errors, and it is permanently calibrated.

This paper reveals how this proven technology works, how it is widely replacing error-prone, contact-type methods, and providing manufacturers with a highest degree of measurement accuracy as well as significant production savings.

OPERATION

The operating principle of this gauge is based on dual-beam Laser Doppler Velocimetry (DBLDV). When two laser beams intersect, an interference pattern of both light and dark fringes is created. This is called the measurement region and is illustrated in Figure 1. The distance \((d)\) between the fringes is a function of the wavelength \((\lambda)\) of light and the angle between the beams \((2 \sin K)\). It is represented in the following equation:

\[
d = \frac{\lambda}{2 \sin K}
\]  

(1)
Nearly all materials have light-scattering sites: that is, particles and minute facets that make up the surface microstructure. As a light-scattering site passes through the measurement region, light is scattered every time it passes through a light fringe. The scattered light is collected and converted to an electrical signal that has a frequency \( f \) proportional to the material velocity (Doppler frequency).

The material velocity \( v \) is Distance / Time where the Distance is the distance between light fringes and Time is the time required to move from one fringe to the next.

\[
v = \frac{d}{t}
\]  

(2)

Since the time is inversely proportional to the frequency of the signal, the material velocity can be obtained by multiplying the distance between fringes by the measured frequency.

\[
t = \frac{1}{f}
\]

(3)

Therefore, \( v = d \times f \)

Having measured the material velocity, the length can also be determined by integrating the velocity information over the total time.

\[
L = \int_{0}^{T} v \, dt
\]

(4)

Essentially, the gauge measures the speed of the surface and integrates the speed value over the total length of the material to obtain accurate length measurements. As material passes through the measurement region, the frequency of the scattered light is directly proportional to the speed of the material. The scattered light is then collected by receiving optics within the gauge and is converted to an electrical signal. Such electrical signals are then processed by digital signal processors (DSPs) to obtain frequency information, subsequently calculating speed and integrating it to determine the length.
A block diagram of the gauge is shown below in Figure 2.

![Block Diagram of a Laser Doppler Gauge](image)

Figure 2: Block Diagram of a Laser Doppler Gauge

There are many applications for length and speed measurements using this technique. This method is very accurate, very consistent, and works on virtually all surfaces. Examples on the benefits and savings produced, as compared to conventional methods, will be given below.

**APPLICATIONS**

**Coating and Lamination Control Application**

Manufacturers of paper, film, and foil products employing coating and lamination processes, require a measurement system that accurately measures the length and speed of product moving through the web. For example, a US label manufacturer depends on the accuracy of the line’s drive speed and contact encoders to accurately apply the correct amount of coating such as adhesive coatings on the face stock and special coatings on the release liner. Other coatings, such as varnishes, are applied to the face of the label to protect the printing and provide protection against environmental conditions. Other products require more protection such as lamination of a clear material to cover the printed face stock. For the lamination to be successful, the manufacturer needs to accurately synchronize the speed of two or more converging materials during the process. Speed inaccuracies in either of the above-mentioned processes create product quality issues and waste, and directly affect productivity. Length measurements are also important in both processes because the manufacturer wants to apply the exact quantity of coatings or lamination to cover the required surface area of the product based on production specifications.

Any contact-based method of length or speed measurement is subject to several types of error:

- Contact methods typically rely on measuring how fast a wheel of known circumference moves around. There will always be a certain amount of material slippage on the drive roller based on product texture, slick coatings, lubricants, and other factors. This makes it appear that the material is moving either faster or slower on the web than required. And, it could make it appear that more or less product is moving through the web than expected.

- A contact encoder attached to the drive roller or riding on the product has the same problem. The circumference of the measurement wheel can increase because of dirt buildup or decrease because of wear. This requires the system to be recalibrated often to minimize error.

Length and speed inaccuracies during coating and lamination processes may be as much as 2%. A 2% inaccuracy on a 20,000 foot roll of material means 400 feet of uncertainty. If this inaccuracy...
is in excess of the desired amount, each roll is costing the manufacturer a significant amount of money in unnecessary expense. If the roll product is 400 feet short because of improper coating or lamination, it can cost the manufacturer significantly in customer bill-backs or product waste.

To solve this problem, the manufacturer installed a LaserSpeed gauge at specific measurement points on the line enabling it to accurately control the length and speed of the lamination line and coating application (see Figures 3 and 4). The +/-0.05% measurement accuracy offers a fast payback in savings. Instead of an uncertainty of 400 foot per every 20,000 feet with the contact method, the non-contact laser gauge lowers the possible error to a maximum of 10 feet on a 20,000 foot roll.

Continuous Length Application

A common application with manufacturers is ability to accurately measure the continuous length of product. For example, a US manufacturer of adult diapers, pads, liners, and pull-on style disposable underwear had problems with inconsistent length measurements at the slitter/rewind station. The installed mechanical encoder wheel would have slippage errors caused by lubricants on the product. The lubricants caused slippage between the encoder wheel and product, creating a slippage error of up to 2.5%. Slippage errors always make the product length longer than the target length.

If the target length of the product was 1000 feet and the encoder wheel had 2.5% slippage, then the actual length produced would be 1025 feet. This means that the manufacturer was giving away an extra 25 feet for every 1000 feet produced.

A LaserSpeed gauge was installed on the infeed side of the parent roll. The measurement area was stabilized by using two idler rollers to minimize product movement. Slitter blades were located downstream after a series of idler rollers.

By installing the LaserSpeed gauge, the customer was able to eliminate the slippage errors and save a significant amount of money. Since the manufacturer produces $2M to $4M of product on this line per year, the LaserSpeed gauge reduced the length error by about 2.0%, thereby saving the manufacturer approximately $40,000/year.

The LaserSpeed gauge provided the following direct benefits to the manufacturer:

- Eliminates product give-away by 2%, representing a $40,000/year savings
- Realized ROI in 3 months
- Higher accuracy measurements minimize waste, product give-away, and bill-backs from customers
- Permanent calibration and no moving parts eliminates routine recalibration and mechanical maintenance
- Critical personnel are freed and can be utilized for other valuable jobs in the plant, rather than monitoring and servicing the measurement system
**Stretch and Draw Application**

Manufacturers needing to control the stretch or draw of product during production may require one of the following conditions:

1) **Draw down the product as thin as possible without breaking**
2) **Make sure there is no draw and that all drive rollers are pulling the product down the line at the same speed**
3) **Draw down the product to a very specific and accurate thickness**

Most manufacturers currently measure this by either trusting the speed that their drives are reporting or using a contact encoder in some way. While drives are becoming more sophisticated and more accurate every year, the simulated encoder output from the drive cannot compensate for slippage. Similar to lamination processes, every product has some amount of slipping on the drive roller. The amount that the product slips can change based on texture, product composition, or even tension at other points on the production line. Drive encoders experience similar issues.

A mechanical wheel encoder contacting the web’s surface also falls short of providing the accuracy necessary to measure the product length and speed. The wheel can either wear down or have dirt build up, both of which change the calibration. This, along with the same types of slippage problems, makes any sort of contact measurement a poor choice when high accuracy is desired.

Since non-contact laser length and speed gauges measure the product itself and not a roller, slippage is not a problem. With a measurement accuracy of better than ±0.05%, the manufacturer can be confident that the stretch or draw measurement will be reliable and correct.

By placing a LaserSpeed gauge at each critical measurement point along the line, a manufacturer can accurately determine the amount of stretch or draw down of the product, eliminating any guessing or uncertainty.

**SUMMARY**

This paper describes the use of a non-contact laser gauge to accurately measure the length and speed of products in coating and lamination processes. This proven technology is steadily becoming the standard measurement technology for many common manufacturing applications, and is quickly replacing mechanical contact-type measurement techniques. The benefits of length and speed measurement accuracy offer manufacturers a real competitive advantage. The three different cases presented in this paper show how each application enables manufacturers to achieve significant savings through the use of a non-contact laser gauge. Those companies that adopt this high-precision measurement technology will quickly realize dividends in improved product quality and increased productivity with substantial cost savings.