Guiding Material with Variable Passline in Rolling and Finishing

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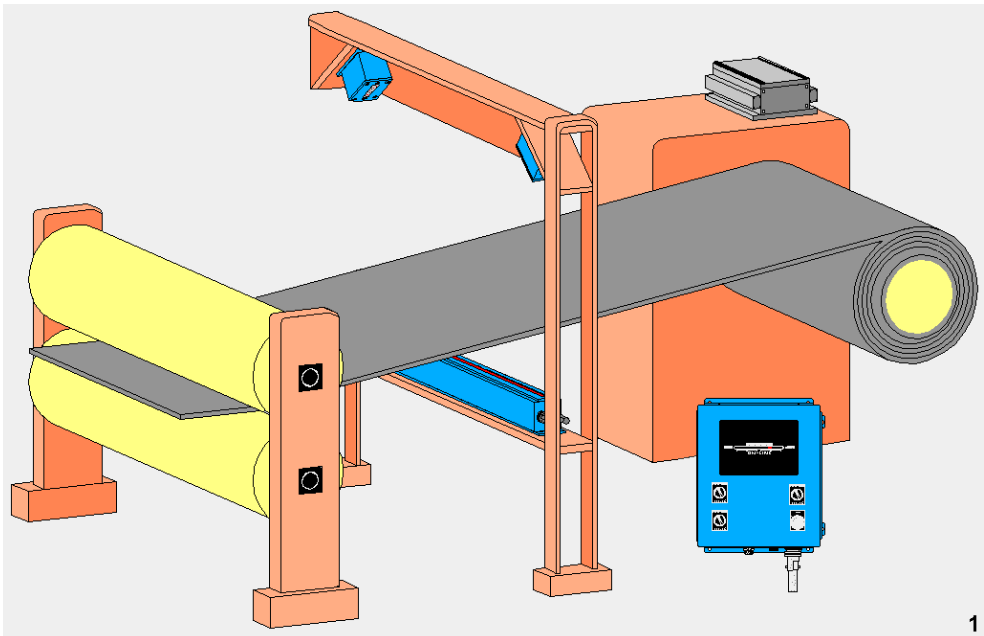
Presented to the
Association of Iron & Steel Engineers
11 September, 2000

INTRODUCTION

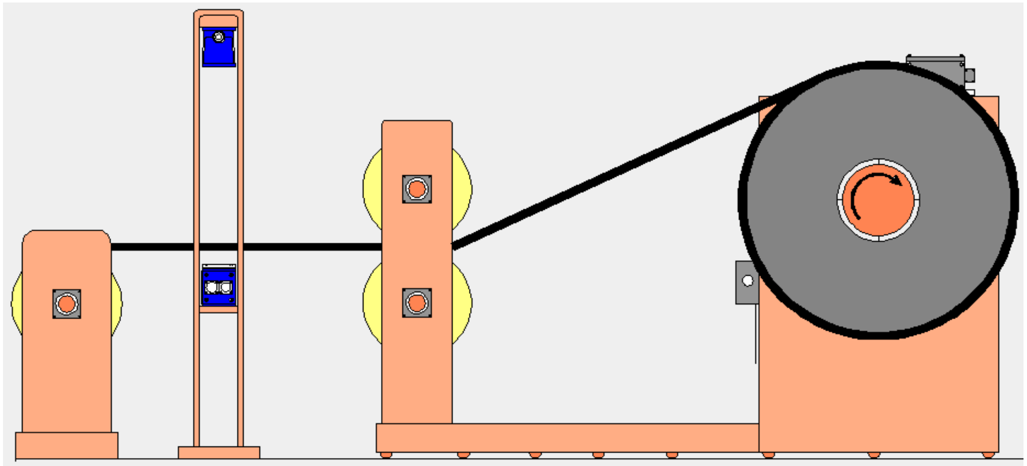
The intent of this paper is to provide a brief explanation of how the steadily increasing demand for quality products, high yield and minimum downtime drove the development of an accurate, passline independent optical sensor. Further, how this development has resulted in a rewind (recoiler) control system capable of high-speed passline independent operation.



THE NEED

Internal or end user customers for finished coils of steel have generated a requirement for quality in the edge characteristics of wound coils. Profitable operation of the coil processing line also relies on the production of properly wound coils. The added cost of reprocessing (secondary rewinding) of prime coils or down grading of prime coils due to damage can be reduced significantly by producing coils with good wall build. Properly wound coils are less susceptible to damage during handling than poorly wound coils. Typically the finished coil is required to have one evenly wound edge. Occasionally coils are wound based upon the centerline of the strip when the coil has variable width and the user desires to distribute these width variations on both sides of the coil. In any case, a high degree of control can be difficult to achieve.

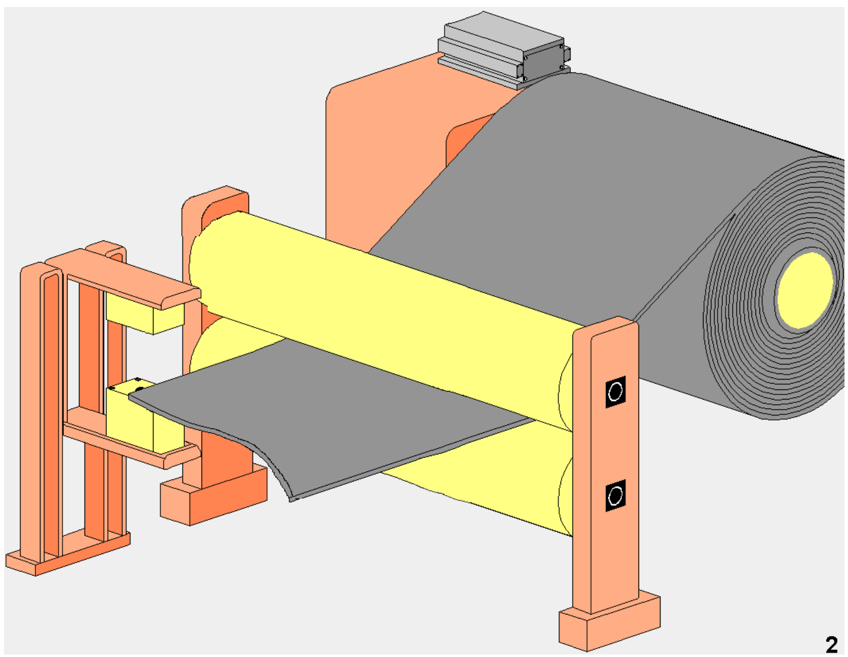
In reality the successful control of a rewind (recoiler) is not a matter of strip guiding at all. In fact with most applications the last point of actual strip guiding may be some distance "up stream" of the rewind equipment. Because of this, the control technique requires that the system in use knows the position of the strip and the position of the rewind mechanism at all times. As the strip moves laterally across the line, the system moves the rewind mechanism to follow the strip edge or centerline. It is, in essence, a "feed forward" control system that moves the recoiler to follow the strip's changing position. This is a well know technique that has been implemented by many companies using various sensors and configurations for years.



SOLUTIONS

The traditional solutions

Most systems employed for edge guiding use edge sensors comprised of a single point photo detector, a light source, and a process controller. The controller interprets the signals from the sensor to produce a control output to position the recoiler to follow the strip. Having a very limited range, these single point sensors must be mechanically aligned with the edge of the strip each time there is a change in the strip width. Then it must be linked to the recoiler by either a manually controlled mechanical linkage or automatic positioner. After being located at the strip edge at the start of the run the sensor detects any lateral edge position changes and commands the recoiler to move in the appropriate direction to keep the strip edge winding straight, Since the sensor is linked to the recoiler it is moved with the recoiler. Although this configuration is theoretically independent of strip passline changes it is typically labor intensive of set-up, calibration and frequently plagued by a long list of mechanical, electrical, or hydraulic maintenance problems. The result can be frequent unscheduled periods of downtime and a corresponding loss of yield. In addition, in many cases strip "edge wave" problems can produce a moving edge target that is lost to the limited range of the single spot detector, once again resulting in poorly wound coils.

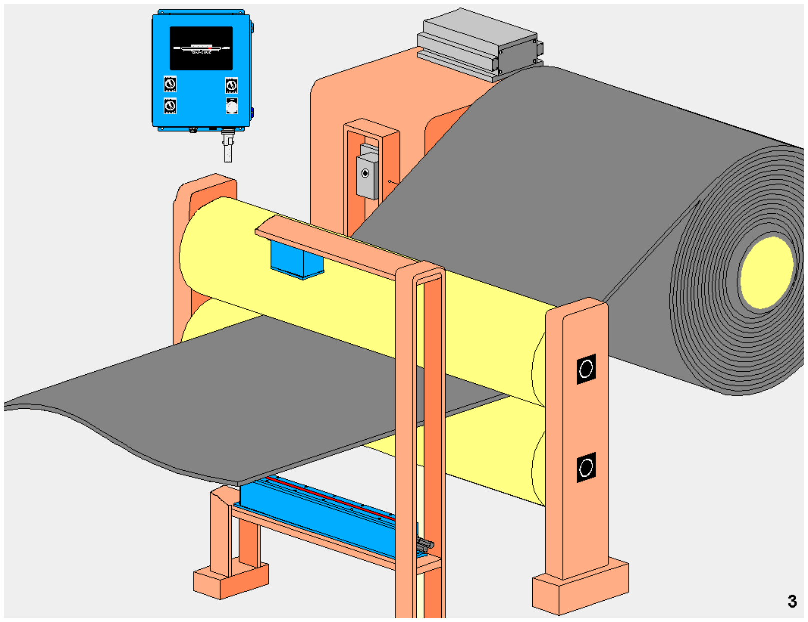


The scanned LED solution

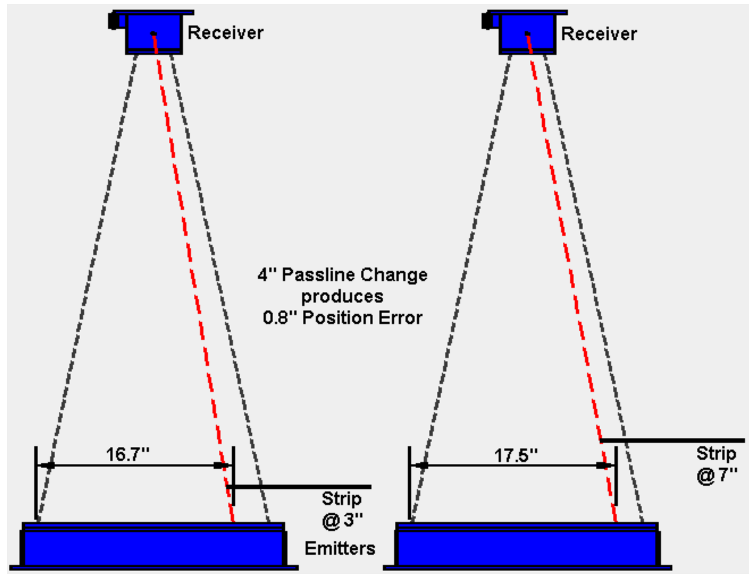
With the implementation of scanned light emitting diode (LED) array sensors for edge position detection, the nuisance of relocating the sensor to align it with the strip edge every time there is a strip width change has been eliminated. Since the LED sensor is manufactured in various lengths from ten to forty inches, it can be placed in a fixed position beneath the strip and will accommodate edge position changes throughout its range without being moved. In addition, since it is not linked to the recoiler mechanically, it is immune to the motion and the constant vibration imparted to other systems. Based on this sensor technology, a system was developed and marketed for automatic control of a rewind (recoiler) mandrel. This system requires that a linear position encoder be attached to the recoiler to permit tracking of the mandrel position.

Operation of the system is as follows: at the start of run the recoiler is centered and the head of the new coil is captured by the rewind mandrel. The operator pulls tension, defining the operating passline of the strip. The control processor is then commanded to read both the recoiler position, from the linear transducer, and the strip edge position, from the scanned LED array. Based upon these two signals the processor produces a voltage representing their relative positions. This voltage defines the edge target and is called the "reference edge position". As the line runs, any lateral change in the strips "real-time edge position" and the stored "reference edge position" will be detected by the scanned array. The processor then calculates the difference between the two position signals to produce the "error output". This control output signal is amplified and made available to drive a proportional hydraulic valve. The valve, in turn, controls the hydraulic pressure to drive the recoiler to a position where the "relative error" is once again zero. The "relative error signal" is a continuous Proportional, Integral & Derivative (PID) output whose individual control parameters are manually tunable. It is, therefore, continuously providing PID correction to keep the recoiler positioned to wind a straight edge.

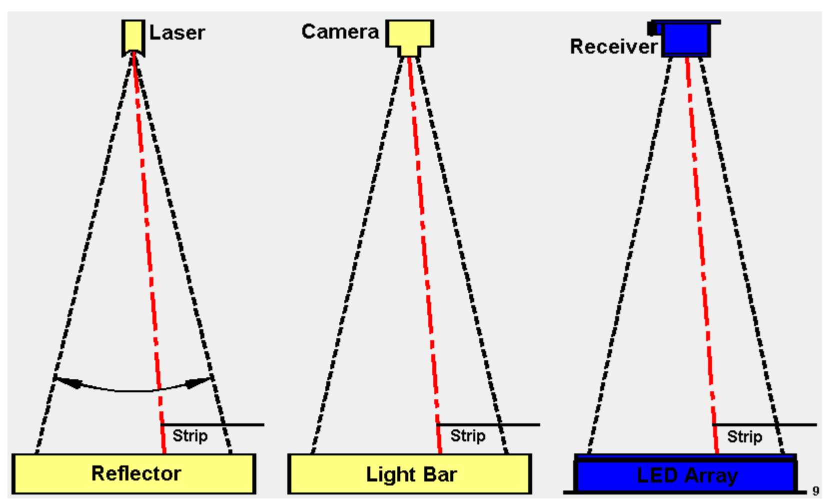
MORE CHALLENGES



The scanned LED system previously described was introduced to the steel industry in 1993 and has been employed successfully by many steel companies in the intervening years. The needs of the industry never remain static, however and soon new challenges and requirements were presented by our customers. Chief among these requirements was a rewind control system that used a sensor whose edge detection accuracy was independent of movements in the strip vertical position or "passline". These passline changes can result from the normal position change caused as the strip winds onto the recoil mandrel as well the position changes resulting from strip "edge wave". To fully understand the details of this problem, one must first examine how the scanned LED sensor locates edge position and the apparent error that is introduced by a changing passline.



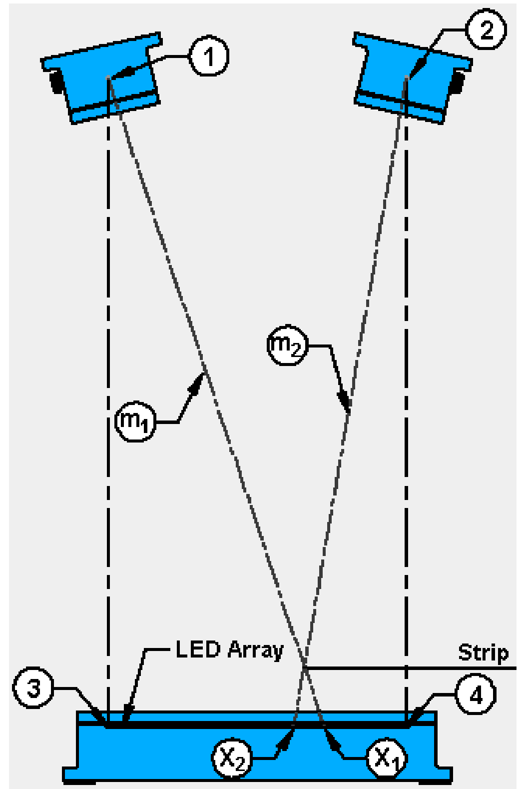
The basic concept in edge position determination used with the scanned LED array is described as a "timed light burst" technique. A linear array of LEDs (ten, twenty, thirty or forty inches in length) is scanned sequentially by a crystal controlled clock at a frequency of 20 kHz, thus producing a moving spot of light at precisely two thousand inches per second. The array is viewed by a receiver located some distance above the emitter. The receiver is a photosensitive detector and is simply viewing the array to detect the presence or absence of light at a given time during the array scan. The output from the receiver, when the array is unobstructed, is a simple 20kHz sine wave. This frequency signal is processed by the electronics in the array housing to produce a digital signal that is "duty cycle" modulated with the strip edge position within the array's scan. The time based edge position signal can be sent to a wide variety of processors for generating measured width, edge position, etc. This technology has been used for years in the measurement of edge position. It is accurate and repeatable and with no mechanical linkages or moving parts has a long history of reliability.



This technology, however, does require a consistently stable passline. Since the receiver views the array through a triangular view path, any change in the strip passline will appear as a change in the location of the edge. The drawing above illustrates this "parallax error" on scanned LED sensors that result from a changing strip passline. The drawing also demonstrates that this induced parallax error is inherent in any optical measurement sensor that views the edge through a triangular optical path. This includes CCD array cameras, scanning laser sensors, as well as the scanned LED technology (drawing to the right).

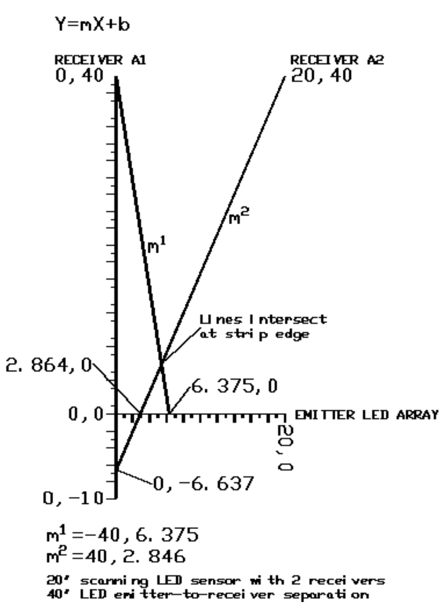
NEW DEVELOPMENTS

A new sensor

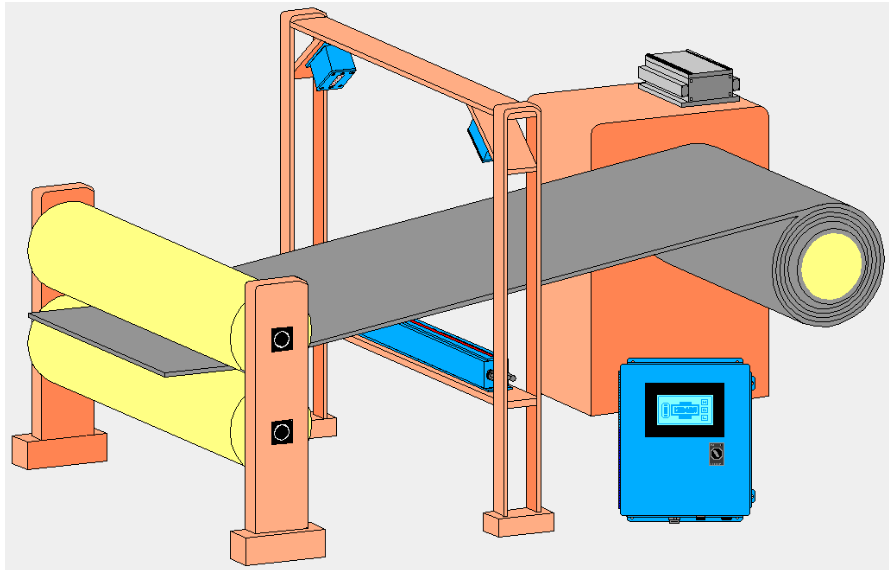


Due in large part to the ever increasing demand for high quality products and maximum "throughput" from the mills the market requirements for a sensor that could provide accurate edge position data that was independent of the vertical position of the strip continued to grow in the mid nineties. This requirement was particularly important in strip width measurement. In many applications it was difficult, if not impossible, to provide a predictably stable passline. Yet the need for accurate strip width measurement was critical to the process.

The development of a system to overcome this problem began by designing a sensor that is equipped with two receivers rather than the standard single receiver. By viewing the strip edge with two receivers, one positioned above each end of the emitter LED array, two independent views of the edge are produced. It can be seen in the attached drawing that these two views of the strip edge result in a geometric relationship that can be used to determine the height of the strip above the face of the LED array. Since the position of the receivers is known and the two positions of the edge as viewed on the LED array are known then the actual edge position can be calculated using the formula for the intercept of two lines, Y=mX + B, for each line (where 'm' = slope of the line, 'B' = 'Y' intercept where 'X' = 0). When the X and Y coordinates are equal, the edge position is defined. This derived "height factor" is used by the program in the microprocessor to calculate the true position of the strip edge after every scan of the array. This corrected edge position is now independent of its vertical position above the emitter LED array.

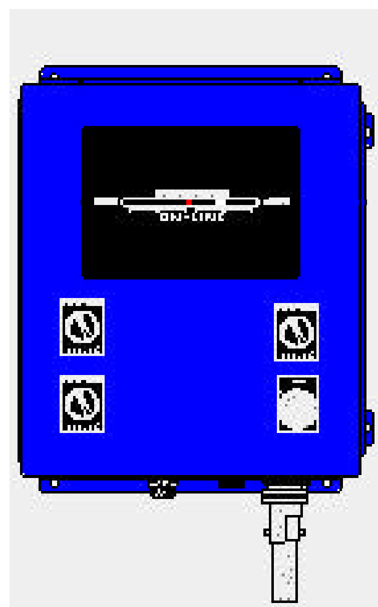


A new measurement processor



It soon became apparent that the demand for "real-time" measurement data with the existing width measurement processor was far too great for the hardware being used at that time. In order to read the position data and apply the height correction factor at a rate of up two hundred times per second and continue to perform all the other functions required of the measurement processing unit, a faster processor had to be developed. A "crash program" to come up with new hardware and operating software were undertaken and a new system was ready for "beta test" in less than six months. The first customer requirements for this passline independent technology were in the application of absolute width measurement so it was natural that the first processor developed was configured to meet this requirement.

A new control processor



Subsequent to the successful introduction and initial sales of the passline independent width measurement system", we realized that all the elements necessary to develop a strip guiding system that was truly independent of strip passline were now at hand. The same microprocessor and much of the software were used to produce this new controller. With minor changes in the existing hardware and software a new system was born. The advantage of a digital based control processor is that the functions of the controller are under software control and easily tailored to the individual applications. The hardware has been designed to fully accommodate virtually any guiding or steering application. It provides for selection of "auto/manual" operation, selection of "right-center-left edges" for the guide point, and even has front panel switch for manual "left/right jog". It has analog inputs for position transducers that track the recoiler position or the angular position of a guide roll when controlling an intermediate guide. An added bonus with this control system is the capability of providing the customer measured width. Since the system can, in many applications, monitor both edges of the strip the software in this new controller goes a step further and produces a measured width via a serial RS-232 port.

Now the same controller can be configured for use as a center-guide at a payoff, an edge or center-guide for intermediate steering rolls or, as in our first application, a rewind control system. The first system capable of passline independent control was sold to a Pennsylvania stainless steel producer. The primary requirement was passline independent control resulting from the need to accurately wind coils with severe edge wave. This customer has reported a significant increase in the efficiency of this line that he attributes to the accuracy of the rewind control and the high reliability of this system. This success has prompted the purchase of additional passline independent systems in this plant.

IN CONCLUSION

The message we hope to convey by telling the story of this product development is the story of the continuing synergy between our customers, you the steel producers, and us the designers and manufactures of process instrumentation. Your never ending quest to produce higher quality products in greater quantities and at lower cost drive our industry to produce the tools necessary to measure and control your processes.