Accuracy, Precision, Linearity, and Resolution in Web Guiding: Understanding the Terminology

Article

As we search for the most appropriate equipment for our operation, we are faced with the task of selecting from myriad options based on technical data and specs. Through these data, manufacturers are trying to present the benefits of their products based on the device's performance profile. However, sometimes what appears to be the best offer, based on what looks to be the best technical data, might not really be the best. The technical data can even be irrelevant information when considering performance. That is the issue with accuracy, precision, linearity and resolution in the web guiding world…

First, we need to be clear of what these terms really mean.Typically, these terms are thrown around as indicators of performance. However, in many instances, these indicators are incorrectly applied or interpreted.

Accuracy

Accuracy is an indicator of a measurement that is true. Simply put, we are looking at how close is the average of all measurements to the real value of what is measured. So, in average, we are really measuring what we say we are measuring. If we were to use shooting as an example, high accuracy would mean that the average of all shots taken is right at the target, or very close to it. In the case of web guiding, accurate sensing and guiding of material means the average sensing and placement of the material is very close to the true and desired position. However, the spread of individual occasions of the positioning of the material might be so wide that it makes the accuracy useless. In the shooting example, we would have a wide pattern with the average on the target.

Precision

Precision is an indicator of the consistency of our measurements. In the shooting example, high precision would mean we are constantly hitting the same target. Some would say the grouping is very tight. However, the target we are hitting consistently might be the wrong one! This is a problem faced with sensors that employ a blocking principle in detecting the web. The sensor needs to be calibrated every time there is a material change, otherwise, the sensor will infer the position of the web based on a calibration for a different material characteristic. The measurement will be consistent, but it will not be accurate.

The following images illustrate how accuracy and precision would be represented in the case of hitting a target for the different situations discussed above.

Example illustrating the concept of accuracy and precision

As we can see, a combination of high accuracy and precision is required to guarantee the proper positioning of the material by web guiding systems. Accuracy would allow for the average of all measurements of the web location to be at the true location, and after actuating the guide, the average of all positioning at the desired location. Precision would have each individual measurement very close to the average of the all measurements, and after actuating the guide, each individual positioning of the web very close to the average positioning of the web.

Linearity

Another term used and presented in technical sheets regarding sensors for web guides is linearity. Linearity is an indicator of the consistency of measurements over the entire range of measurements. In general, it is a good indicator of performance quality of a sensor, but on its own, it can be a misleading indicator. In simple terms, linearity tells us how well the instrument measurement corresponds to reality. In this case we want a linearity as close to 1.0 as possible. A linearity of 1.0 means that if the real position of the material is 1.0 mm to the right, then the measurement instrument reports a displacement of 1.0 mm to the right. If the real position is 2.0 mm to the right, then the measurement instrument should indicate a displacement of 2.0 mm to the right, and so forth. If we traced this relationship in a two-axis graph we should get a straight line with a slope of 1.0.

Sensors with a blocking principle present an interesting case regarding linearity. The sensor can have a linearity very close to 1.0. However, these types of sensors require calibration in order to maintain its 1.0 linearity when the material characteristics change. As you might have noticed in the paragraph above, there is no reference to the true position of the material, only to how much the material is displaced and how well this displacement is recorded or detected. When material properties change, such as in the case of a material change, the linearity of the sensor is affected.

A problem with sensors that employ a blocking principle is they rely on detecting a percentage of the blocked signal to infer the position of the material. When material properties change the percentage of signal blockage by the web also changes. For example, material “A” might be at a desired position when the sensor records a 30% signal blockage. Material “B” might be at that same position when the sensor records a 40% signal blockage. If the sensor has been originally calibrated for material “A” with a 30% blockage, the sensor has to be recalibrated when running material “B” that has a 40% blockage, otherwise the sensor will erroneously consider that the material is at its correct position when it detects a 30% blockage. The linearity may still remain the same and the displacement might be perceived, but the true position of the material will be in the wrong place and the magnitude of displacement measured by the sensor would be incorrect. The way to counter for this error in existing sensors is to recalibrate the sensor to compensate for the change in the material as the only means to support the accuracy.

Resolution

Resolution is the smallest measurement an instrument can detect or measure. This technical specification is usually included in technical sheets and is sometimes mistaken for an indicator of precision and accuracy. The higher the resolution, the smaller the measurement it can record. In the case of web edge sensors, it would be the smallest measurement the web position sensor can observe or measure. While high resolution is very desirable, it does not guarantee accuracy and precision. Again, resolution on sensors can be material dependent so it might vary with material property changes. For existing sensors with blocking principle, a material that blocks less (light or sound signal) will have a lower resolution than a material that blocks more. Hence porosity and opacity are known to affect the resolution of the sensors, and therefore, its performance. Again, resolution on its own has no meaning when working with material changes if the sensors are not calibrated each time to compensate for the changes in material characteristics.

The Status Quo

Even though factual precision and accuracy is not typically reported in technical sheets of most web positioning sensors and web guide systems available, these two measurement indicators should be the ones used to determine the efficacy of sensors. As of now, the industry has relied on implied accuracy indicators based on the product of calibrated gains of the components that make up a web guide system. Still, it is an inferred accuracy and precision as it is not based on real physical measurements of the web position and of the sensor readings. Furthermore, the accuracy is dependent on the calibration of the sensor. In second part of this article we will show how accuracy, precision, resolution and linearity can be quantified for web position sensors as well as web guiding system.

Conclusion

The question that must be asked is, does my operation require high performance web sensor and guiding capacity? For operations running at lower speeds and with wider tolerances in their web positioning, the answer is probably no. These operations can get by with not having to worry about calibration of their sensors when running different materials. However, operations that run at faster speeds requiring precise placement of the material, calibration will be a must if they are using sensors that operate under a blocking principle. Of course the trade off is lost production time in calibrating sensors, but it is the only way that an adequate accuracy and precision can be achieved. Certainly, misplacement at higher speed will turn into greater amount of wasted materials, and important losses in uptime. There is definitely a need for systems that are not only accurate and precise, but also that eliminate the need for calibration of the web guiding systems to reduce downtime.